NASA Completes Spacecraft to Transport, Support Roman Space Telescope

5 min read

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing.

Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the telescope itself.

“They call it a spacecraft bus for a reason — it gets the telescope to where it needs to be in space,” said Jackie Townsend, the Roman deputy project manager at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “But it’s really more like an RV because it has a whole assortment of functions that enable Roman to accomplish its scientific goals while out there too.”

Those goals include surveying wide swaths of the universe to study things like: dark energy, a mysterious cosmic pressure thought to accelerate the universe’s expansion; dark matter, invisible matter seen only via its gravitational influence; and exoplanets, worlds beyond our solar system.

The mission’s science wouldn’t be possible without a spacecraft to transport the telescope, point the observatory toward different cosmic targets, provide power, communicate with Earth, control and store instrument data, and regulate Roman’s temperature. Nearly 50 miles of electrical cabling are laced throughout the assembly to enable different parts of the observatory to communicate with each other.

The spacecraft will also deploy several major elements that will be stowed for launch, including the solar panels, deployable aperture cover, lower instrument Sun shade, and high-gain antenna. It’s also responsible for collecting and beaming down data, which is no small task for a space observatory that will survey the cosmos like Roman will.

“Roman will send back 1.4 terabytes of data per day, compared to about 50 to 60 gigabytes from the James Webb Space Telescope and three gigabytes from the Hubble Space Telescope,” said Jason Hylan, the Roman observatory manager at NASA Goddard. “Webb’s daily downlink is roughly comparable to 13 hours of YouTube video at the highest quality while Roman’s would amount to about 2 weeks.”

This milestone is the culmination of eight years of spacecraft design work, building, and testing by hundreds of people at Goddard.

“Goddard employees were the brains, designers, and executors. And they worked with vendors who supplied all the right parts,” Townsend said. “We leaned on generations of expertise in the spacecraft arena to work around cost and schedule challenges that arose from supply chain issues and the pandemic.”

One time- and money-saving technique the team came up with was building a spacecraft mockup, called the structural verification unit. That allowed them to do two things at once: complete strength testing on the mockup, designed specifically for that purpose, while also assembling the actual spacecraft.

The spacecraft’s clever layout also allowed the team to adapt to changing schedules. It’s designed to be modular, “more like Trivial Pursuit pie pieces than a nesting egg, where interior components are buried inside,” Townsend said. “That’s been a game-changer because you can’t always count on things arriving in the order you planned or working perfectly right away with no tweaks.” It also increased efficiency because people could work on different portions of the bus at the same time without interfering with each other.

The slightly asymmetrical and hexagonal spacecraft bus is about 13 feet (4 meters) wide by 6.5 feet (2 meters) tall and weighs in at 8,400 pounds (3,800 kilograms).

One reason it doesn't weigh more is that some components have been partially hollowed out. If you could peel back some of the spacecraft's panels, you'd find superthin metallic honeycomb sandwiched between two slim layers of metal. And many of the components, such as the antenna dish, are made of strong yet lightweight composite materials.

When the spacecraft bus was fully assembled, engineers conducted a comprehensive performance test. Prior to this, each component had been tested individually, but just like with a sports team, the whole unit has to perform well together.

"The spacecraft passed the test, and now we're getting ready to install the payload — Roman's instruments and the telescope itself," said Missie Vess, a spacecraft systems engineer for Roman at NASA Goddard. "Next year, we'll test these systems together and begin integrating the final components of the observatory, including the deployable aperture cover, outer barrel assembly, and solar panels. Then we'll finally have ourselves a complete observatory, on track for launch by May 2027."

To virtually tour an interactive version of the telescope, visit:

https://roman.gsfc.nasa.gov/interactive

The Nancy Grace Roman Space Telescope is managed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are BAE Systems, Inc in Boulder, Colorado; L3Harris Technologies in Rochester, New York; and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Ashley BalzerNASA's Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire Andreoliclaire.andreoli@nasa.govNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940

Talented Teams Tackle Toasty Planet

NASA Science Editorial Team

Exoplanets, look out! Two NASA-funded teams of amateur astronomers are tracking you with their backyard telescopes.

These two teams, called UNITE (UNISTELLAR Network Investigating TESS Exoplanets) and Exoplanet Watch, have combined forces to confirm a new planetary discovery—a toasty "warm Jupiter".

"I pinch myself every day when I recall that I have made a meaningful scientific contribution to astronomy by helping professional astronomers confirm and characterize a new exoplanet," said Darren Rivett, a volunteer from Australia who contributed to the effort.

Planets around other stars, called exoplanets, sometimes block the light from the stars they orbit. When this happens, it's called a "transit". Amateur astronomers can observe exoplanet transits with their own telescopes by watching for the light from a nearby star to dim.

NASA's Transiting Exoplanet Survey Satellite (TESS) sees these dimming events, too—many thousands of them. But just seeing a star dim once is not enough. You need to catch multiple dimming events (and perform various other checks) to know that you've found a new exoplanet.

That's where volunteers from the UNITE and Exoplanet Watch projects come in.

These two teams of amateur astronomers have collaborated with the SETI Institute to detect the transit of an object called TIC 393818343 b (aka TOI 6883 b)---proving to the world that this object does indeed contain a planet orbiting a star.

First, the UNISTELLAR and SETI Institute team saw a single transit signal detected by the TESS space telescope. They gathered data to predict when the planet would transit again. They then alerted the UNITE and Exoplanet Watch amateurs to help observe the host star for signs of a transiting planet during the predicted time. The observations from the two networks showed two new transit detections, confirming the predictions, and demonstrating that a planet indeed causes the signals.

This newly discovered giant planet falls into the "warm Jupiter" category of exoplanets, meaning it orbits closer to its host star than Jupiter, or even the Earth does. Astronomers have even predicted that it might, under certain circumstances, migrate still further inward toward its star to become a "hot Jupiter." Hot or not, thanks to some terrific teamwork, we are now one step closer to understanding the population of planets that lies outside our own Solar System. The news is now published in the Astronomical Journal, and all the citizen scientists involved, including a high school student, are co-authors on this scientific publication, "Confirmation and Characterization of the Eccentric, Warm Jupiter TIC 393818343 b with a Network of Citizen Scientists".

UNITE (UNISTELLAR Network Investigating TESS Exoplanets) uses the global network of observers with UNISTELLAR telescopes to gather data on TESS exoplanet candidates and long-duration exoplanet transits. To get involved, no matter what kind of telescope you have, visit https://science.unistellar.com/exoplanets/unite/ or reach out to citizenscience@unistellaroptics.com.

Participation is open to everyone, regardless of citizenship. "What I find amazing about the NASA citizen science project is that they involve people from all around the world contributing meaningful observation data that leads to incredible discoveries!" Sophie Saibi, a high school student from California who participated. "Researching as a citizen scientist is something I highly recommend to anyone who gazes at the night sky with awe and wonder," said Rivett.

Congratulations to everyone on the team! The amateur astronomers who coauthored this paper are listed below.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s EXCITE Mission Prepared for Scientific Balloon Flight

5 min read

Jeanette Kazmierczak

Editor's note: EXCITE successfully launched at 9:22 a.m. EDT (7:22 a.m. MDT) Saturday, Aug. 31. The balloon and payload reached a float altitude of 130,000 feet. The flight was safely terminated after a total flight time of 10 hours, 13 minutes, 31 seconds.

Scientists and engineers are ready to fly an infrared mission called EXCITE (EXoplanet Climate Infrared TElescope) to the edge of space.

EXCITE is designed to study atmospheres around exoplanets, or worlds beyond our solar system, during circumpolar long-duration scientific balloon flights. But first, it must complete a test flight during NASA’s fall 2024 scientific ballooning campaign from Fort Sumner, New Mexico.

“EXCITE can give us a three-dimensional picture of a planet’s atmosphere and temperature by collecting data the whole time the world orbits its star,” said Peter Nagler, the mission’s principal investigator at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Only a handful of these types of measurements have been done before. They require a very stable telescope in a position to track a planet for several days at a time.”

EXCITE will study hot Jupiters, giant gas exoplanets that complete an orbit once every one to two days and have temperatures in the thousands of degrees. The worlds are tidally locked, which means the same side always faces the star.

The telescope will observe how heat is distributed across the planet, from the scalding hemisphere facing the star to the relatively cooler nightside.

It will also determine how molecules in a world’s atmosphere absorb and emit light over the entire orbit, a process called phase-resolved spectroscopy. Not only can this data reveal the presence of compounds — like water, methane, carbon dioxide, and others — but also how they circulate globally as the planet orbits its star.

NASA’s Hubble, James Webb, and retired Spitzer space telescopes have collected a handful of these measurements between them.

In 2014, for example, Hubble and Spitzer observed an exoplanet called WASP-43 b. To collect data over the world’s 22-hour day, scientists needed 60 hours of Hubble time and 46 hours from Spitzer. Resource-intensive studies like this on space-based observatories are difficult. Time is a limited resource, and studies must compete with hundreds of other requests for that time.

“During its first science flight, EXCITE aims to fly for over a dozen days from the Columbia Scientific Balloon Facility’s site in Antarctica,” said Kyle Helson, an EXCITE team member and a research scientist at the University of Maryland, Baltimore County and NASA Goddard. “And at the pole, the stars we’ll study don’t set, so our observations won’t be interrupted. We hope that the mission will effectively double the number of phase-resolved spectra available to the science community.”

EXCITE will fly to about 132,000 feet (40 kilometers) via a scientific balloon filled with helium. That takes it above 99.5% of Earth’s atmosphere. At that altitude, the telescope will be able to observe multiple infrared wavelengths with little interference.

“The telescope collects the infrared light and beams it into the spectrometer, where it kind of goes through a little obstacle course,” said Lee Bernard, an EXCITE team member and a graduate research assistant at Arizona State University in Tempe. “It bounces off mirrors and through a prism before reaching the detector. Everything must be aligned very precisely — just a few millimeters off center and the light won’t make it.”

The spectrometer rests inside a vessel called a cryostat situated behind the telescope. The cryostat cools the spectrometer’s detector — once a flight candidate from Webb'sNIRSpec (Near InfraRed Spectrograph)— to about 350 degrees below zero Fahrenheit (minus 210 degrees Celsius) so it can measure tiny intensity changes in the infrared light.

The entire telescope and cryostat assembly rests in a rowboat-shaped base where it can rotate along three axes to maintain stable pointing down to 50 milliarcseconds. That’s like holding a steady gaze on a U.S. quarter coin from 65 miles away.

“Several different institutions contributed to EXCITE’s subsystems,” said Tim Rehm, an EXCITE team member and a graduate research assistant at Brown University in Providence, Rhode Island. “It’s great to see them all assembled and working together. We’re excited to do this test flight, and we’re looking forward to all the future science flights we hope to have.”

The EXCITE instrument was primarily built by NASA Goddard, Brown, Arizona State University, and StarSpec Technologies in Ontario, with additional support from collaborators in the U.S., Canada, Italy, and the United Kingdom.

NASA’s scientific balloons offer frequent, low-cost access to near-space to conduct scientific investigations and technology maturation in fields such as astrophysics, heliophysics, and atmospheric research, as well as training for the next generation of leaders in engineering and science. To follow the missions in the 2024 Fort Sumner fall campaign, visit NASA’s CSBF (Columbia Scientific Balloon Facility) website for real-time updates of a balloon’s altitude and GPS location during flight.

NASA’s Wallops Flight Facility in Virginia manages the agency’s scientific balloon flight program with 10 to 15 flights each year from launch sites worldwide. Peraton, which operates CSBF in Texas, provides mission planning, engineering services, and field operations for NASA’s scientific balloon program. The CSBF team has launched more than 1,700 scientific balloons over some 40 years of operations. NASA’s balloons are fabricated by Aerostar. The NASA Scientific Balloon Program is funded by the NASA Headquarters Science Mission Directorate Astrophysics Division.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire Andreoli301-286-1940claire.andreoli@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA Completes Spacecraft to Transport, Support Roman Space Telescope

5 min read

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing.

Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the telescope itself.

“They call it a spacecraft bus for a reason — it gets the telescope to where it needs to be in space,” said Jackie Townsend, the Roman deputy project manager at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “But it’s really more like an RV because it has a whole assortment of functions that enable Roman to accomplish its scientific goals while out there too.”

Those goals include surveying wide swaths of the universe to study things like: dark energy, a mysterious cosmic pressure thought to accelerate the universe’s expansion; dark matter, invisible matter seen only via its gravitational influence; and exoplanets, worlds beyond our solar system.

The mission’s science wouldn’t be possible without a spacecraft to transport the telescope, point the observatory toward different cosmic targets, provide power, communicate with Earth, control and store instrument data, and regulate Roman’s temperature. Nearly 50 miles of electrical cabling are laced throughout the assembly to enable different parts of the observatory to communicate with each other.

The spacecraft will also deploy several major elements that will be stowed for launch, including the solar panels, deployable aperture cover, lower instrument Sun shade, and high-gain antenna. It’s also responsible for collecting and beaming down data, which is no small task for a space observatory that will survey the cosmos like Roman will.

“Roman will send back 1.4 terabytes of data per day, compared to about 50 to 60 gigabytes from the James Webb Space Telescope and three gigabytes from the Hubble Space Telescope,” said Jason Hylan, the Roman observatory manager at NASA Goddard. “Webb’s daily downlink is roughly comparable to 13 hours of YouTube video at the highest quality while Roman’s would amount to about 2 weeks.”

This milestone is the culmination of eight years of spacecraft design work, building, and testing by hundreds of people at Goddard.

“Goddard employees were the brains, designers, and executors. And they worked with vendors who supplied all the right parts,” Townsend said. “We leaned on generations of expertise in the spacecraft arena to work around cost and schedule challenges that arose from supply chain issues and the pandemic.”

One time- and money-saving technique the team came up with was building a spacecraft mockup, called the structural verification unit. That allowed them to do two things at once: complete strength testing on the mockup, designed specifically for that purpose, while also assembling the actual spacecraft.

The spacecraft’s clever layout also allowed the team to adapt to changing schedules. It’s designed to be modular, “more like Trivial Pursuit pie pieces than a nesting egg, where interior components are buried inside,” Townsend said. “That’s been a game-changer because you can’t always count on things arriving in the order you planned or working perfectly right away with no tweaks.” It also increased efficiency because people could work on different portions of the bus at the same time without interfering with each other.

The slightly asymmetrical and hexagonal spacecraft bus is about 13 feet (4 meters) wide by 6.5 feet (2 meters) tall and weighs in at 8,400 pounds (3,800 kilograms).

One reason it doesn’t weigh more is that some components have been partially hollowed out. If you could peel back some of the spacecraft’s panels, you’d find superthin metallic honeycomb sandwiched between two slim layers of metal. And many of the components, such as the antenna dish, are made of strong yet lightweight composite materials.

When the spacecraft bus was fully assembled, engineers conducted a comprehensive performance test. Prior to this, each component had been tested individually, but just like with a sports team, the whole unit has to perform well together.

“The spacecraft passed the test, and now we’re getting ready to install the payload — Roman’s instruments and the telescope itself,” said Missie Vess, a spacecraft systems engineer for Roman at NASA Goddard. “Next year, we’ll test these systems together and begin integrating the final components of the observatory, including the deployable aperture cover, outer barrel assembly, and solar panels. Then we’ll finally have ourselves a complete observatory, on track for launch by May 2027.”

To virtually tour an interactive version of the telescope, visit:

https://roman.gsfc.nasa.gov/interactive

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are BAE Systems, Inc in Boulder, Colorado; L3Harris Technologies in Rochester, New York; and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire Andreoliclaire.andreoli@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Talented Teams Tackle Toasty Planet

NASA Science Editorial Team

Exoplanets, look out! Two NASA-funded teams of amateur astronomers are tracking you with their backyard telescopes.

These two teams, called UNITE (UNISTELLAR Network Investigating TESS Exoplanets) and Exoplanet Watch, have combined forces to confirm a new planetary discovery—a toasty "warm Jupiter".

"I pinch myself every day when I recall that I have made a meaningful scientific contribution to astronomy by helping professional astronomers confirm and characterize a new exoplanet," said Darren Rivett, a volunteer from Australia who contributed to the effort.

Planets around other stars, called exoplanets, sometimes block the light from the stars they orbit. When this happens, it's called a "transit". Amateur astronomers can observe exoplanet transits with their own telescopes by watching for the light from a nearby star to dim.

NASA's Transiting Exoplanet Survey Satellite (TESS) sees these dimming events, too—many thousands of them. But just seeing a star dim once is not enough. You need to catch multiple dimming events (and perform various other checks) to know that you've found a new exoplanet.

That's where volunteers from the UNITE and Exoplanet Watch projects come in.

These two teams of amateur astronomers have collaborated with the SETI Institute to detect the transit of an object called TIC 393818343 b (aka TOI 6883 b)---proving to the world that this object does indeed contain a planet orbiting a star.

First, the UNISTELLAR and SETI Institute team saw a single transit signal detected by the TESS space telescope. They gathered data to predict when the planet would transit again. They then alerted the UNITE and Exoplanet Watch amateurs to help observe the host star for signs of a transiting planet during the predicted time. The observations from the two networks showed two new transit detections, confirming the predictions, and demonstrating that a planet indeed causes the signals.

This newly discovered giant planet falls into the "warm Jupiter" category of exoplanets, meaning it orbits closer to its host star than Jupiter, or even the Earth does. Astronomers have even predicted that it might, under certain circumstances, migrate still further inward toward its star to become a "hot Jupiter." Hot or not, thanks to some terrific teamwork, we are now one step closer to understanding the population of planets that lies outside our own Solar System. The news is now published in the Astronomical Journal, and all the citizen scientists involved, including a high school student, are co-authors on this scientific publication, "Confirmation and Characterization of the Eccentric, Warm Jupiter TIC 393818343 b with a Network of Citizen Scientists".

UNITE (UNISTELLAR Network Investigating TESS Exoplanets) uses the global network of observers with UNISTELLAR telescopes to gather data on TESS exoplanet candidates and long-duration exoplanet transits. To get involved, no matter what kind of telescope you have, visit https://science.unistellar.com/exoplanets/unite/ or reach out to citizenscience@unistellaroptics.com.

Participation is open to everyone, regardless of citizenship. "What I find amazing about the NASA citizen science project is that they involve people from all around the world contributing meaningful observation data that leads to incredible discoveries!" Sophie Saibi, a high school student from California who participated. "Researching as a citizen scientist is something I highly recommend to anyone who gazes at the night sky with awe and wonder," said Rivett.

Congratulations to everyone on the team! The amateur astronomers who coauthored this paper are listed below.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s EXCITE Mission Prepared for Scientific Balloon Flight

5 min read

Jeanette Kazmierczak

Editor's note: EXCITE successfully launched at 9:22 a.m. EDT (7:22 a.m. MDT) Saturday, Aug. 31. The balloon and payload reached a float altitude of 130,000 feet. The flight was safely terminated after a total flight time of 10 hours, 13 minutes, 31 seconds.

Scientists and engineers are ready to fly an infrared mission called EXCITE (EXoplanet Climate Infrared TElescope) to the edge of space.

EXCITE is designed to study atmospheres around exoplanets, or worlds beyond our solar system, during circumpolar long-duration scientific balloon flights. But first, it must complete a test flight during NASA’s fall 2024 scientific ballooning campaign from Fort Sumner, New Mexico.

“EXCITE can give us a three-dimensional picture of a planet’s atmosphere and temperature by collecting data the whole time the world orbits its star,” said Peter Nagler, the mission’s principal investigator at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Only a handful of these types of measurements have been done before. They require a very stable telescope in a position to track a planet for several days at a time.”

EXCITE will study hot Jupiters, giant gas exoplanets that complete an orbit once every one to two days and have temperatures in the thousands of degrees. The worlds are tidally locked, which means the same side always faces the star.

The telescope will observe how heat is distributed across the planet, from the scalding hemisphere facing the star to the relatively cooler nightside.

It will also determine how molecules in a world’s atmosphere absorb and emit light over the entire orbit, a process called phase-resolved spectroscopy. Not only can this data reveal the presence of compounds — like water, methane, carbon dioxide, and others — but also how they circulate globally as the planet orbits its star.

NASA’s Hubble, James Webb, and retired Spitzer space telescopes have collected a handful of these measurements between them.

In 2014, for example, Hubble and Spitzer observed an exoplanet called WASP-43 b. To collect data over the world’s 22-hour day, scientists needed 60 hours of Hubble time and 46 hours from Spitzer. Resource-intensive studies like this on space-based observatories are difficult. Time is a limited resource, and studies must compete with hundreds of other requests for that time.

“During its first science flight, EXCITE aims to fly for over a dozen days from the Columbia Scientific Balloon Facility’s site in Antarctica,” said Kyle Helson, an EXCITE team member and a research scientist at the University of Maryland, Baltimore County and NASA Goddard. “And at the pole, the stars we’ll study don’t set, so our observations won’t be interrupted. We hope that the mission will effectively double the number of phase-resolved spectra available to the science community.”

EXCITE will fly to about 132,000 feet (40 kilometers) via a scientific balloon filled with helium. That takes it above 99.5% of Earth’s atmosphere. At that altitude, the telescope will be able to observe multiple infrared wavelengths with little interference.

“The telescope collects the infrared light and beams it into the spectrometer, where it kind of goes through a little obstacle course,” said Lee Bernard, an EXCITE team member and a graduate research assistant at Arizona State University in Tempe. “It bounces off mirrors and through a prism before reaching the detector. Everything must be aligned very precisely — just a few millimeters off center and the light won’t make it.”

The spectrometer rests inside a vessel called a cryostat situated behind the telescope. The cryostat cools the spectrometer’s detector — once a flight candidate from Webb'sNIRSpec (Near InfraRed Spectrograph)— to about 350 degrees below zero Fahrenheit (minus 210 degrees Celsius) so it can measure tiny intensity changes in the infrared light.

The entire telescope and cryostat assembly rests in a rowboat-shaped base where it can rotate along three axes to maintain stable pointing down to 50 milliarcseconds. That’s like holding a steady gaze on a U.S. quarter coin from 65 miles away.

“Several different institutions contributed to EXCITE’s subsystems,” said Tim Rehm, an EXCITE team member and a graduate research assistant at Brown University in Providence, Rhode Island. “It’s great to see them all assembled and working together. We’re excited to do this test flight, and we’re looking forward to all the future science flights we hope to have.”

The EXCITE instrument was primarily built by NASA Goddard, Brown, Arizona State University, and StarSpec Technologies in Ontario, with additional support from collaborators in the U.S., Canada, Italy, and the United Kingdom.

NASA’s scientific balloons offer frequent, low-cost access to near-space to conduct scientific investigations and technology maturation in fields such as astrophysics, heliophysics, and atmospheric research, as well as training for the next generation of leaders in engineering and science. To follow the missions in the 2024 Fort Sumner fall campaign, visit NASA’s CSBF (Columbia Scientific Balloon Facility) website for real-time updates of a balloon’s altitude and GPS location during flight.

NASA’s Wallops Flight Facility in Virginia manages the agency’s scientific balloon flight program with 10 to 15 flights each year from launch sites worldwide. Peraton, which operates CSBF in Texas, provides mission planning, engineering services, and field operations for NASA’s scientific balloon program. The CSBF team has launched more than 1,700 scientific balloons over some 40 years of operations. NASA’s balloons are fabricated by Aerostar. The NASA Scientific Balloon Program is funded by the NASA Headquarters Science Mission Directorate Astrophysics Division.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire Andreoli301-286-1940claire.andreoli@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

Primary Instrument for Roman Space Telescope Arrives at NASA Goddard

6 min read

The primary instrument for NASA’s Nancy Grace Roman Space Telescope is a sophisticated camera that will survey the cosmos from the outskirts of our solar system all the way out to the edge of the observable universe. Called the Wide Field Instrument, it was recently delivered to the agency’s Goddard Space Flight Center in Greenbelt, Maryland.

The camera’s large field of view, sharp resolution, and sensitivity from visible to near-infrared wavelengths will give Roman a deep, panoramic view of the universe. Scanning much larger portions of the sky than astronomers can with NASA’s Hubble or James Webb space telescopes will open new avenues of cosmic exploration. Roman is designed to study dark energy (a mysterious cosmic pressure thought to accelerate the universe’s expansion), dark matter (invisible matter seen only via its gravitational influence), and exoplanets (worlds beyond our solar system).

“This instrument will turn signals from space into a new understanding of how our universe works,” said Julie McEnery, the Roman senior project scientist at Goddard. “To achieve its main goals, the mission will precisely measure hundreds of millions of galaxies. That’s quite a dataset for all kinds of researchers to pull from, so there will be a flood of results on a vast array of science.”

About 1,000 people contributed to the Wide Field Instrument’s development, from the initial design phase to assembling it from around a million individual components. The WFI’s design was a collaborative effort between Goddard and BAE Systems in Boulder, Colorado. Teledyne Imaging Sensors, Hawaii Aerospace Corporation, Applied Aerospace Structures Corporation, Northrop Grumman, Honeybee Robotics, CDA Intercorp, Alluxa, and JenOptik provided critical components. Those parts and many more, made by other vendors, were delivered to Goddard and BAE Systems, where they were assembled and tested prior to the instrument’s delivery to Goddard this month.

“I am so happy to be delivering this amazing instrument,” said Mary Walker, Roman’s Wide Field Instrument manager at Goddard. “All the years of hard work and the team’s dedication have brought us to this exciting moment.”

After Roman launches by May 2027, each of the Wide Field Instrument’s 300-million-pixel images will capture a patch of the sky bigger than the apparent size of a full moon. The instrument’s large field of view will enable sweeping celestial surveys, revealing billions of cosmic objects across vast stretches of time and space. Astronomers will conduct research that could take hundreds of years using other telescopes.

And by observing from space, Roman’s camera will be very sensitive to infrared light — light with longer wavelengths than our eyes can see — from far across the cosmos. This ancient cosmic light will help scientists address some of the biggest cosmic mysteries, one of which is how the universe evolved to its present state.

From the telescope, light’s path through the instrument begins by passing through one of several optical elements in a large wheel. These elements include filters, which allow specific wavelengths of light to pass through, and a grism and prism, which split light into all of its individual colors. These detailed patterns, called spectra, reveal information about the object that emitted the light.

Then, the light travels on toward the camera’s set of 18 detectors, which each contain 16 million pixels. The large number of detectors and pixels gives Roman its large field of view. The instrument is designed for accurate, stable images and exquisite precision in measuring the exact amount of light in every pixel of every image, giving Roman unprecedented power to study dark energy. The detectors will be held at about minus 300 degrees Fahrenheit (minus 184 degrees Celsius) to increase sensitivity to the infrared universe.

“When the light reaches the detectors, that marks the end of what may have been a 10-billion-year journey through space,” said Art Whipple, an aerospace engineer at Goddard who has contributed to the Wide Field Instrument’s design and construction for more than a decade.

Once Roman begins observing, its rapid data delivery will require new analysis techniques.

“If we had every astronomer on Earth working on Roman data, there still wouldn’t be nearly enough people to go through it all,” McEnery said. “We’re looking at modern techniques like machine learning and artificial intelligence to help sift through Roman’s observations and find where the most exciting things are.”

Now that the Wide Field Instrument is at Goddard, it will be tested to ensure everything is operating as expected. It will be integrated onto the instrument carrier and mated to the telescope this fall, bringing scientists one step closer to making groundbreaking discoveries for decades to come.

To virtually tour an interactive version of the telescope, visit:

https://roman.gsfc.nasa.gov/interactive

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are BAE Systems, Inc. in Boulder, Colorado; L3Harris Technologies in Rochester, New York; and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire Andreoliclaire.andreoli@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

How NASA Citizen Science Fuels Future Exoplanet Research

5 min read

Lauren Leese

NASA's upcoming flagship astrophysics missions, the Nancy Grace Roman Space Telescope and the Habitable Worlds Observatory, will study planets outside our solar system, known as exoplanets. Over 5,000 exoplanets have been confirmed to date — and given that scientists estimate at least one exoplanet exists for every star in the sky, the hunt has just begun. Exoplanet discoveries from Roman and the Habitable Worlds Observatory may not be made only by professional researchers, but also by interested members of the public, known as citizen scientists.

Exoplanet research has a long involvement with citizen science. NASA's TESS (Transiting Exoplanet Survey Satellite) mission and now-retired Kepler mission, which are responsible for the vast majority of exoplanet discoveries to date, both made observations freely available to the public immediately after processing. This open science policy paved the way for the public to get involved with NASA's exoplanet science.

NASA's Planet Hunters TESS project invites the public to classify exoplanet light curves from TESS online. Another project, Exoplanet Watch, allows citizen scientists to gather data about known exoplanets, submit their observations to NASA's public data archive, and receive credit if their observation is used in a scientific paper. Participants don't even need their own telescope — Exoplanet Watch also curates data from robotic telescopes for users to process.

“Anyone across the world who has access to a smartphone or a laptop can fully participate in a lot of these citizen science efforts to help us learn more about the cosmos,” said Rob Zellem, the project lead and project scientist for Exoplanet Watch and astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

NASA's citizen science projects have discovered several new planets from Kepler and TESS data. They have also helped scientists refine the best time to observe important targets, saving hours of precious observation time on current flagship missions like NASA's James Webb Space Telescope.

Roman and the Habitable Worlds Observatory provide even more possibilities for citizen science. Expected to launch by May 2027, Roman will discover exoplanets through direct imaging, transits, and gravitational microlensing. Following that, the Habitable Worlds Observatory will take direct images of stars in our solar neighborhood to find potentially habitable planets and study their atmospheres.

Rob Zellem

Exoplanet Watch Project Lead and Project Scientist; Nancy Grace Roman Space Telescope Deputy Project Scientist for Communications

Like Kepler and TESS before them, data from Roman and the Habitable Worlds Observatory will be available to both the scientific community and the public immediately after processing. With Roman's surveys expected to deliver a terabyte of data to Earth every day — over 17 times as much as Webb — there is a huge opportunity for the public to help sift through the information.

“The general public can get Roman data as quickly as I can as a scientist working on the mission,” said Zellem, who also serves as Roman's deputy project scientist for communications at NASA

Goddard. “It truly makes Roman a mission for everyone and anyone.”

Although the Habitable Worlds Observatory’s full capabilities and instrumentation have yet to be finalized, the inclusion of citizen science is expected to continue. The team behind the mission is embracing a community-oriented planning approach by opening up working groups to volunteers who want to contribute.

“It’s already setting the tone for open science with the Habitable Worlds Observatory,” said Megan Ansdell, the program scientist for the mission at NASA Headquarters in Washington. “The process is as open as possible, and these working groups are open to anybody in the world who wants to join.” There are already over 1,000 community working group members participating, some of whom are citizen scientists.

Future citizen science initiatives may be combined with cutting-edge tools such as artificial intelligence (AI) for greater efficacy. “AI can be exceptionally powerful in terms of classification and identifying anomalous things,” said Joshua Pepper, the deputy program scientist for the Habitable Worlds Observatory at NASA Headquarters. “But the evaluation of what those anomalous things are often requires human insight, intervention, and review, and I think that could be a really fantastic area for citizen scientists to participate.”

Before Roman and the Habitable Worlds Observatory launch, exoplanet citizen scientists still have plenty of data to analyze from the Kepler and TESS satellites, but the contributions of the community will become even more important when data begin pouring in from the new missions. As Zellem said, “We’re in a golden age of exoplanet science right now.”

NASA's citizen science projects are collaborations between scientists and interested members of the public and do not require U.S. citizenship. Through these collaborations, volunteers (known as citizen scientists) have helped make thousands of important scientific discoveries. To get involved with a project, visit NASA’s Citizen Science page.

By Lauren Leese Web Content Strategist for the Office of the Chief Science Data Officer

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Selects 5 New Roman Technology Fellows in Astrophysics

9 min read

NASA Science Editorial Team

NASA has awarded Nancy Grace Roman Technology Fellowships (RTF) to five early-career researchers in astrophysics for the class of 2023. The program will support the advancement of their ideas for new technologies to further the exploration of the universe.

This annual fellowship gives researchers the opportunity to develop the skills necessary to become principal investigators of future astrophysics missions, and fosters new talent by putting early-career instrument builders on track towards long-term positions. Specifically, the fellowship facilitates the development of skills necessary to lead astrophysics flight instrumentation development projects, as well as the development of innovative technologies that have the potential to enable major scientific breakthroughs.

“We saw higher numbers of strong applications for this class than in recent years, so we are especially honored to welcome this new group of five fellows,” says Mario Perez, RTF program scientist and chief technologist for NASA's Astrophysics Division, based at the agency’s headquarters in Washington. “These new fellows advance important areas of technological interest to NASA astrophysics, and we expect them to become leaders in their fields and principal investigators of supporting technologies and space missions.”

Since the RTF program was established in 2011, all 31 researchers who have previously been awarded the fellowship are still active in careers within the fields of astrophysics or planetary mission development. In 2024, five additional fellows were competitively selected, making the total 36 researchers who have been awarded this fellowship since the program began.

The program’s name honors Dr. Nancy Grace Roman, the first female executive at NASA who created the agency’s first astronomical program. She is known as the “Mother of Hubble” for her foundational role in planning NASA’s Hubble Space Telescope. NASA’s forthcoming Nancy Grace Roman Space Telescope is also named for her.

The five newly selected fellows are:

Position: Instrument engineer, Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, Boulder

Hometown: Orchard Park, New York (“Go Bills!”)

Education: B.A. in Physics, Drexel University; Ph.D. in Astrophysical and Planetary Science, University of Colorado, Boulder

What is the focus of your research? Ultraviolet (UV) instrumentation and sounding rockets, with a focus on diffraction grating development.

What does this fellowship mean to you? At LASP, we’ve assembled a team that’s knowledgeable and passionate about sounding rockets and developing novel UV technologies. Having this environment provides a strong platform for mentoring undergraduate and graduate students. This fellowship provides much needed support to keep that team together and maintain our mission of the training the next generation of UV principal investigators and Roman fellows.

What inspired you to pursue your career in astrophysics? I've always been fascinated by the physics of light and its interaction with optics. Astrophysical instrumentation provided an outlet to channel that passion into a career. It gives me the opportunity to study optical phenomena in detail, but in the context of gaining a deeper understanding of the physical processes governing our universe.

Name: Drew Miles

Position: Research assistant professor, California Institute of Technology

Hometown: Marshalltown, Iowa

Education: B.B.A in Accounting and B.S. in Physics and Astronomy, University of Iowa; M.S. and Ph.D. in Astronomy and Astrophysics, Penn State University

What is the focus of your research? My research is focused on developing and demonstrating technologies for space-based grating spectrographs. In this work we develop the full life cycle of the technology: conceiving new spectrograph designs and applications, using nanofabrication techniques to manufacture next-generation diffraction gratings, implementing the gratings into astronomy instruments, and verifying their performance in applications representative of their applicability to large NASA missions.

What does this fellowship mean to you? This fellowship will help allow me to further develop my research program and implement the lab support and characterization capabilities needed to advance our technologies. Further, the Nancy Grace Roman Technology Fellowship program continues to be an excellent investment in the careers of early-career researchers, and I am appreciative at being awarded a fellowship and having the opportunity to advance impactful instrumentation for the future.

What inspired you to pursue your career in astrophysics? After not having exposure to physics and astronomy prior to college, I became interested in further exploring astronomy while taking a few elective physics and astronomy courses during my business degree. The idea of working to better understand the nature and evolution of our universe is extremely compelling. Later, I was fortunate to become involved in a research lab for experimental astrophysics and was hooked by the hands-on nature of the research and the need to maintain a long-term vision for the technology while ensuring the smallest details are well understood. Throughout my time as a student and postdoctoral researcher, the positive mentorship from my dissertation advisor (and former Roman Technology Fellow), Dr. Randall McEntaffer, and other members of the field have been critical in teaching me and allowing me to grow into the field.

Position: Warren E. Rupp Assistant Professor of Physics at Case Western Reserve University

Hometown: Lompoc, California

Education: B.S. in Physics, Stanford University; Ph.D. in Physics, Case Western Reserve University

What is the focus of your research? My research group focuses on cosmology, studying the evolution and composition of the universe through increasingly precise measurements of the Cosmic Microwave Background. We build instruments to measure its polarization and analyze the resulting data. Several of our current projects use NASA's stratospheric balloons to access signals that are difficult to see from the ground.

What does this fellowship mean to you?

This fellowship will allow me to continue to grow my research group and expand our lab's capabilities. I am most excited about being able to work with more undergraduate and graduate students and to help them pursue their own career paths.

What inspired you to pursue your career in astrophysics?

I became deeply interested in space when I was in middle school, but in college I learned how much I enjoy experimental work. It still amazes me that instruments we build by hand in the lab can help us answer fundamental questions about the universe. I have also been fortunate to have many fantastic mentors throughout my career and hope to pay it forward.

Name: Dustin Swarm

Position: Postdoctoral Research Scholar in the Department of Physics & Astronomy at University of Iowa

Hometown: Greenville, Illinois

Education: B.S. in Spanish Education, B.A. in Physics and Mathematics, Greenville University; Ph.D. in Physics, University of Iowa

What is the focus of your research? My research involves the design and fabrication of focusing optics for high-energy astrophysics investigations. Constructing telescopes with focusing optics that operate in the hard X-ray to soft gamma-ray regime (100-600 keV) is unfeasible with current technologies. Developing high-performance focusing optics for this regime would enable deeper investigations of, for instance, accreting compact objects or sources of electron-positron annihilation.

What does this fellowship mean to you? The Roman Technology Fellowship is impactful for my early career in a number of ways. It is a major source of encouragement that my work is interesting and meaningful to people beyond myself. It is a validation that I have a place in the broader astrophysics community. It offers a chance of stability and a solid foundation on which to build my nascent career. I am also grateful for the opportunity it provides me to mentor and train future astrophysicists, following in the footsteps of the mentors who have poured into me along this journey. I am honored to be selected as a Roman Technology Fellow.

What inspired you to pursue your career in astrophysics? I grew up with a love of science. From my mother burying chicken bones in my sandbox to inspire my play as a paleontologist to my grandfather purchasing a telescope so we could look at the Moon in his backyard, my ambition was to become a scientist. I began college on an aerospace engineering path, but along the way I switched majors to Spanish education. I spent six years as a high school Spanish teacher, but during that time I followed the physics and astronomy world through documentaries, news articles, and books. I missed engaging with mathematics and science, and I eventually decided it was time to go back to school to become an astrophysicist. It was in this time that NASA’s Juno spacecraft was transmitting high quality photographs of Jupiter, and the ground-based LIGO, the Laser Interferometer Gravitational-wave Observatory, was detecting black hole mergers. I was wrapping up my second undergraduate degree when news broke of the simultaneous detection of gravitational waves and electromagnetic radiation from the neutron star merger GW170817. I was fascinated by the papers published on this event, and it cemented my desire to become a high-energy astrophysicist.

Name: Kyle Van Gorkom

Position: Assistant research professor at Steward Observatory, University of Arizona

Hometown: Tucson, Arizona

Education: B.S. in Physics and Philosophy, Brandeis University; Ph.D. in Optical Sciences, University of Arizona

What is the focus of your research: My research focuses on the use of high-contrast imaging techniques and wavefront control to directly image exoplanets (planets around other stars) with space- and ground-based observatories.

What does this fellowship mean to you: This fellowship will enable me to start building an independent research program, to set up a laboratory for technology development in coronagraphy, and to begin mentoring the next generation of instrument builders.

What inspired you to pursue a career in astrophysics: I first became interested in astrophysics after taking a philosophy of science course during college, which led me to realize that if I wanted to be able to think carefully about the world, I needed a deeper understanding of physics. I joined a research group doing radio astronomy and then, following graduation, worked several years at the Space Telescope Science Institute in Baltimore, which introduced me to astronomical instrumentation and motivated me to pursue a PhD in optics. Over the years, I’ve had several supportive mentors whose guidance set me on my current career trajectory.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Investigates Eternal Sunrises, Sunsets on Distant World

NASA Webb Mission Team

Goddard Space Flight Center

Near-infrared spectral analysis of terminator confirms differences in morning and evening atmosphere

Researchers using NASA’s James Webb Space Telescope have finally confirmed what models have previously predicted: An exoplanet has differences between its eternal morning and eternal evening atmosphere. WASP-39 b, a giant planet with a diameter 1.3 times greater than Jupiter, but similar mass to Saturn that orbits a star about 700 light-years away from Earth, is tidally locked to its parent star. This means it has a constant dayside and a constant nightside—one side of the planet is always exposed to its star, while the other is always shrouded in darkness.

Using Webb’s NIRSpec (Near-Infrared Spectrograph), astronomers confirmed a temperature difference between the eternal morning and eternal evening on WASP-39 b, with the evening appearing hotter by roughly 300 Fahrenheit degrees (about 200 Celsius degrees). They also found evidence for different cloud cover, with the forever morning portion of the planet being likely cloudier than the evening.

Astronomers analyzed the 2- to 5-micron transmission spectrum of WASP-39 b, a technique that studies the exoplanet’s terminator, the boundary that separates the planet’s dayside and nightside. A transmission spectrum is made by comparing starlight filtered through a planet’s atmosphere as it moves in front of the star, to the unfiltered starlight detected when the planet is beside the star. When making that comparison, researchers can get information about the temperature, composition, and other properties of the planet’s atmosphere.

“WASP-39 b has become a sort of benchmark planet in studying the atmosphere of exoplanets with Webb,” said Néstor Espinoza, an exoplanet researcher at the Space Telescope Science Institute and lead author on the study. “It has an inflated, puffy atmosphere, so the signal coming from starlight filtered through the planet’s atmosphere is quite strong.”

Previously published Webb spectra of WASP-39b’s atmosphere, which revealed the presence of carbon dioxide, sulfur dioxide, water vapor, and sodium, represent the entire day/night boundary – there was no detailed attempt to differentiate between one side and the other.

Now, the new analysis builds two different spectra from the terminator region, essentially splitting the day/night boundary into two semicircles, one from the evening, and the other from the morning. Data reveals the evening as significantly hotter, a searing 1,450 degrees Fahrenheit (800 degrees Celsius), and the morning a relatively cooler 1,150 degrees Fahrenheit (600 degrees Celsius).

“It’s really stunning that we are able to parse this small difference out, and it’s only possible due Webb’s sensitivity across near-infrared wavelengths and its extremely stable photometric sensors,” said Espinoza. “Any tiny movement in the instrument or with the observatory while collecting data would have severely limited our ability to make this detection. It must be extraordinarily precise, and Webb is just that.”

Extensive modeling of the data obtained also allows researchers to investigate the structure of WASP-39 b’s atmosphere, the cloud cover, and why the evening is hotter. While future work by the team will study how the cloud cover may affect temperature, and vice versa, astronomers confirmed gas circulation around the planet as the main culprit of the temperature difference on WASP-39 b.

On a highly irradiated exoplanet like WASP-39 b that orbits relatively close to its star, researchers generally expect the gas to be moving as the planet rotates around its star: Hotter gas from the dayside should move through the evening to the nightside via a powerful equatorial jet stream. Since the temperature difference is so extreme, the air pressure difference would also be significant, which in turn would cause high wind speeds.

Using General Circulation Models, 3-dimensional models similar to the ones used to predict weather patterns on Earth, researchers found that on WASP-39 b the prevailing winds are likely moving from the night side across the morning terminator, around the dayside, across the evening terminator and then around the nightside. As a result, the morning side of the terminator is cooler than the evening side. In other words, the morning side gets slammed with winds of air that have been cooled on the nightside, while the evening is hit by winds of air heated on the dayside. Research suggests the wind speeds on WASP-39 b can reach thousands of miles an hour!

“This analysis is also particularly interesting because you’re getting 3D information on the planet that you weren’t getting before,” added Espinoza. “Because we can tell that the evening edge is hotter, that means it’s a little puffier. So, theoretically, there is a small swell at the terminator approaching the nightside of the planet.”

The team’s results have been published in Nature.

The researchers will now look to use the same method of analysis to study atmospheric differences of other tidally locked hot Jupiters, as part of Webb Cycle 2 General Observers Program 3969.

WASP-39 b was among the first targets analyzed by Webb as it began regular science operations in 2022. The data in this study was collected under Early Release Science program 1366, designed to help scientists quickly learn how to use the telescope’s instruments and realize its full science potential.

The James Webb Space Telescope is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

Right click any image to save it or open a larger version in a new tab/window via the browser's popup menu.

View/Download all image products at all resolutions for this article from the Space Telescope Science Institute.

The research results have been published in Nature.

Rob Gutro - rob.gutro@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

Hannah Braun hbraun@stsci.edu Christine Pulliam - cpulliam@stsci.eduSpace Telescope Science Institute, Baltimore, Md.

ARTICLE: What is an Exoplanet?

VIDEO: How do we learn about a planet's Atmosphere?

VIDEO: Reading the Rainbow of Light from an Exoplanet's Atmosphere

VIDEO: Science Snippets - Exoplanets

BLOG: Reconnaissance of Potentially Habitable Worlds with NASA’s Webb

More Webb News - https://science.nasa.gov/mission/webb/latestnews/

More Webb Images - https://science.nasa.gov/mission/webb/multimedia/images/

Webb Mission Page - https://science.nasa.gov/mission/webb/

What is a exoplanet?

What is the Webb Telescope?

SpacePlace for Kids

Para Niños : Qué es una exoplaneta?

Ciencia de la NASA

NASA en español

Space Place para niños

James Webb Space Telescope

Exoplanets

Exoplanet Stories

Universe

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Images Cold Exoplanet 12 Light-Years Away

NASA Webb Mission Team

Goddard Space Flight Center

An international team of astronomers using NASA’s James Webb Space Telescope has directly imaged an exoplanet roughly 12 light-years from Earth. The planet, Epsilon Indi Ab, is one of the coldest exoplanets observed to date.

The planet is several times the mass of Jupiter and orbits the K-type star Epsilon Indi A (Eps Ind A), which is around the age of our Sun, but slightly cooler. The team observed Epsilon Indi Ab using the coronagraph on Webb’s MIRI (Mid-Infrared Instrument). Only a few tens of exoplanets have been directly imaged previously by space- and ground-based observatories.

“Our prior observations of this system have been more indirect measurements of the star, which actually allowed us to see ahead of time that there was likely a giant planet in this system tugging on the star,” said team member Caroline Morley of the University of Texas at Austin. “That's why our team chose this system to observe first with Webb.”

“This discovery is exciting because the planet is quite similar to Jupiter — it is a little warmer and is more massive, but is more similar to Jupiter than any other planet that has been imaged so far,” added lead author Elisabeth Matthews of the Max Planck Institute for Astronomy in Germany.

Previously imaged exoplanets tend to be the youngest, hottest exoplanets that are still radiating much of the energy from when they first formed. As planets cool and contract over their lifetime, they become significantly fainter and therefore harder to image.

“Cold planets are very faint, and most of their emission is in the mid-infrared,” explained Matthews. “Webb is ideally suited to conduct mid-infrared imaging, which is extremely hard to do from the ground. We also needed good spatial resolution to separate the planet and the star in our images, and the large Webb mirror is extremely helpful in this aspect.”

Epsilon Indi Ab is one of the coldest exoplanets to be directly detected, with an estimated temperature of 35 degrees Fahrenheit (2 degrees Celsius) — colder than any other imaged planet beyond our solar system, and colder than all but one free-floating brown dwarf. The planet is only around 180 degrees Fahrenheit (100 degrees Celsius) warmer than gas giants in our solar system. This provides a rare opportunity for astronomers to study the atmospheric composition of true solar system analogs.

“Astronomers have been imagining planets in this system for decades; fictional planets orbiting Epsilon Indi have been the sites of Star Trek episodes, novels, and video games like Halo,” added Morley. “It's exciting to actually see a planet there ourselves, and begin to measure its properties.”

Epsilon Indi Ab is the twelfth closest exoplanet to Earth known to date and the closest planet more massive than Jupiter. The science team chose to study Eps Ind A because the system showed hints of a possible planetary body using a technique called radial velocity, which measures the back-and-forth wobbles of the host star along our line of sight.

“While we expected to image a planet in this system, because there were radial velocity indications of its presence, the planet we found isn’t what we had predicted,” shared Matthews. “It’s about twice as massive, a little farther from its star, and has a different orbit than we expected. The cause of this discrepancy remains an open question. The atmosphere of the planet also appears to be a little different than the model predictions. So far we only have a few photometric measurements of the atmosphere, meaning that it is hard to draw conclusions, but the planet is fainter than expected at shorter wavelengths."

The team believes this may mean there is significant methane, carbon monoxide, and carbon dioxide in the planet's atmosphere that are absorbing the shorter wavelengths of light. It might also suggest a very cloudy atmosphere.

The direct imaging of exoplanets is particularly valuable for characterization. Scientists can directly collect light from the observed planet and compare its brightness at different wavelengths. So far, the science team has only detected Epsilon Indi Ab at a few wavelengths, but they hope to revisit the planet with Webb to conduct both photometric and spectroscopic observations in the future. They also hope to detect other similar planets with Webb to find possible trends about their atmospheres and how these objects form.

NASA's upcoming Nancy Grace Roman Space Telescope will use a coronagraph to demonstrate direct imaging technology by photographing Jupiter-like worlds orbiting Sun-like stars – something that has never been done before. These results will pave the way for future missions to study worlds that are even more Earth-like.

These results were taken with Webb's Cycle 1 General Observer program 2243 and have been published in the journal Nature.

The James Webb Space Telescope is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

Right click any image to save it or open a larger version in a new tab/window via the browser's popup menu.

View/Download all image products at all resolutions for this article from the Space Telescope Science Institute.

Laura Betz - laura.e.betz@nasa.gov, Rob Gutro - rob.gutro@nasa.govNASA's Goddard Space Flight Center, Greenbelt, Md.

Christine Pulliam - cpulliam@stsci.edu , Hannah Braun hbraun@stsci.eduSpace Telescope Science Institute, Baltimore, Md.

Animation: Eclipse/Coronagraph Animation

Webb Blog: NASA's Webb Takes Its First-Ever Direct Image of Distant World

Webb Blog: How Webb's Coronagraphs Reveal Exoplanets in the Infrared

Article: Webb's Impact on Exoplanet Research

NASA's Exoplanet Website

More Webb News

More Webb Images

Webb Mission Page

What is a exoplanet?

What is the Webb Telescope?

SpacePlace for Kids

Para Niños : Qué es una exoplaneta?

Ciencia de la NASA

NASA en español

Space Place para niños

James Webb Space Telescope

Exoplanets

Exoplanet Stories

Universe

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: With Six New Worlds, 5,500 Discovery Milestone Passed!

4 min read

Chelsea Gohd

On Aug. 24, 2023, more than three decades after the first confirmation of planets beyond our own solar system, scientists announced the discovery of six new exoplanets, stretching that number to 5,502. From zero exoplanet confirmations to over 5,500 in just a few decades, this new milestone marks another major step in the journey to understand the worlds beyond our solar system.

With the discovery of six new exoplanets, scientists have tipped the scales and surpassed 5,500 exoplanets found (there are now 5,502 known exoplanets, to be exact).

Just about 31 years ago, in 1992, the first exoplanets were confirmed when scientists detected twin planets Poltergeist and Phobetor orbiting the pulsar PSR B1257+12. In March 2022, just last year, scientists celebrated passing 5,000 exoplanets discovered.

Scientists have discovered six new exoplanets — HD 36384 b, TOI-198 b, TOI-2095 b, TOI-2095 c, TOI-4860 b, and MWC 758 c — this has pushed the total number of confirmed exoplanets discovered to 5,502.

HD 36384 b is a super-Jupiter that orbits an enormous M giant star.

TOI-198 b is a potentially rocky planet that orbits on the innermost edge of the habitable zone around its star, an M dwarf.

TOI-2095 b and TOI-2095 c are both large, hot super-Earths that orbit in the same system around a shared star, an M dwarf.

TOI-4860 b is a Jupiter-sized gas giant, or a “hot Jupiter,” that orbits an M dwarf star.

MWC 758 c is a giant protoplanet that orbits a very young star. This star still has its protoplanetary disk, which is a rotating disc of gas and dust that can surround a young star.

The field of exoplanet science has exploded since the first exoplanet confirmation in 1992, and with evolving technology, the future for this field looks brighter than ever.

There are a number of both space and ground-based instruments and observatories that scientists have used to detect and study exoplanets.

NASA's Transiting Exoplanet Survey Satellite (TESS) launched in 2018 and has identified thousands of exoplanet candidates and confirmed over 320 planets.

NASA's flagship space telescopes Spitzer, Hubble, and most recently the James Webb Space Telescope have also been used to discover and study exoplanets.

NASA's Nancy Grace Roman Space Telescope is set to launch in May 2027. Roman will be carrying a technology demonstration called the Roman Coronagraph Instrument. This coronagraph will work by using a series of complex masks and mirrors to distort the light coming from far-away stars. By distorting this starlight, the instrument will reveal and directly-image hidden exoplanets.

With the success of the Roman Coronagraph Instrument, NASA could push the envelope even further with is a concept for the mission the Habitable Worlds Observatory, which would search for "signatures of life on planets outside of our solar system," according to the 2020 Decadal Survey on Astronomy and Astrophysics.

These six exoplanets were discovered by different teams as part of five separate studies:

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Exoplanets

Universe

Roman

Exoplanet Catalog

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Webb Finds Plethora of Carbon Molecules Around Young Star

NASA Webb Mission Team

Goddard Space Flight Center

An international team of astronomers has used NASA's James Webb Space Telescope to study the disk of gas and dust around a young, very low-mass star. The results reveal the largest number of carbon-containing molecules seen to date in such a disk. These findings have implications for the potential composition of any planets that might form around this star.

Rocky planets are more likely than gas giants to form around low-mass stars, making them the most common planets around the most common stars in our galaxy. Little is known about the chemistry of such worlds, which may be similar to or very different from Earth. By studying the disks from which such planets form, astronomers hope to better understand the planet formation process and the compositions of the resulting planets.

Planet-forming disks around very low-mass stars are difficult to study because they are smaller and fainter than disks around high-mass stars. A program called the MIRI (Mid-Infrared Instrument) Mid-INfrared Disk Survey (MINDS) aims to use Webb's unique capabilities to build a bridge between the chemical inventory of disks and the properties of exoplanets.

"Webb has better sensitivity and spectral resolution than previous infrared space telescopes," explained lead author Aditya Arabhavi of the University of Groningen in the Netherlands. "These observations are not possible from Earth, because the emissions from the disk are blocked by our atmosphere."

In a new study, this team explored the region around a very low-mass star known as ISO-ChaI 147, a 1 to 2 million-year-old star that weighs just 0.11 times as much as the Sun. The spectrum revealed by Webb's MIRI shows the richest hydrocarbon chemistry seen to date in a protoplanetary disk – a total of 13 different carbon-bearing molecules. The team's findings include the first detection of ethane (C_2H_6) outside of our solar system, as well as ethylene (C_2H_4), propyne (C_3H_4), and the methyl radical CH_3.

"These molecules have already been detected in our solar system, like in comets such as 67P/Churyumov–Gerasimenko and C/2014 Q2 (Lovejoy)," added Arabhavi. "Webb allowed us to understand that these hydrocarbon molecules are not just diverse but also abundant. It is amazing that we can now see the dance of these molecules in the planetary cradles. It is a very different planet-forming environment than we usually think of."

The team indicates that these results have large implications for the chemistry of the inner disk and the planets that might form there. Since Webb revealed the gas in the disk is so rich in carbon, there is likely little carbon left in the solid materials that planets would form from. As a result, the planets that might form there may ultimately be carbon-poor. (Earth itself is considered carbon-poor.)

"This is profoundly different from the composition we see in disks around solar-type stars, where oxygen bearing molecules like water and carbon dioxide dominate," added team member Inga Kamp, also of the University of Groningen. "This object establishes that these are a unique class of objects."

"It's incredible that we can detect and quantify the amount of molecules that we know well on Earth, such as benzene, in an object that is more than 600 light-years away," added team member Agnés

Perrin of Centre National de la Recherche Scientifique in France.

Next, the science team intends to expand their study to a larger sample of such disks around very low-mass stars to develop their understanding of how common or exotic such carbon-rich terrestrial planet-forming regions are. “The expansion of our study will also allow us to better understand how these molecules can form,” explained team member and principal investigator of the MINDS program, Thomas Henning, of the Max-Planck-Institute for Astronomy in Germany. “Several features in the Webb data are also still unidentified, so more spectroscopy is required to fully interpret our observations.”

This work also highlights the crucial need for scientists to collaborate across disciplines. The team notes that these results and the accompanying data can contribute towards other fields including theoretical physics, chemistry, and astrochemistry, to interpret the spectra and to investigate new features in this wavelength range.

The James Webb Space Telescope is the world’s premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

Right click any image to save it or open a larger version in a new tab/window via the browser's popup menu.

View/Download full resolution images for this article from the Space Telescope Science Institute.

Laura Betz - laura.e.betz@nasa.gov, Rob Gutro - rob.gutro@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

Christine Pulliam - cpulliam@stsci.eduSpace Telescope Science Institute, Baltimore, Md.

Infographic: Destiny of Dust

Infographic: Recipe for Planet Formation

Animation: Exploring Star and Planet Formation

Video: Scientists’ Perspective: Science Snippets

More Webb News - https://science.nasa.gov/mission/webb/latestnews/

More Webb Images - https://science.nasa.gov/mission/webb/multimedia/images/

Webb Mission Page - https://science.nasa.gov/mission/webb/

What is the Webb Telescope?

SpacePlace for Kids

Ciencia de la NASA

NASA en español

Space Place para niños

James Webb Space Telescope

Exoplanets

Stars

Universe

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Coming in Hot — NASA’s Chandra Checks Habitability of Exoplanets

4 min read

To view this video please enable JavaScript, and consider upgrading to a web browser that

supports HTML5 video

This graphic shows a three-dimensional map of stars near the Sun. These stars are close enough that they could be prime targets for direct imaging searches for planets using future telescopes. The blue haloes represent stars that have been observed with NASA’s Chandra X-ray Observatory and ESA’s XMM-Newton. The yellow star at the center of this diagram represents the position of the Sun. The concentric rings show distances of 5, 10, and 15 parsecs (one parsec is equivalent to roughly 3.2 light-years).

Astronomers are using these X-ray data to determine how habitable exoplanets may be based on whether they receive lethal radiation from the stars they orbit, as described in our latest press release. This type of research will help guide observations with the next generation of telescopes aiming to make the first images of planets like Earth.

Researchers examined stars that are close enough to Earth that telescopes set to begin operating in the next decade or two — including the Habitable Worlds Observatory in space and Extremely Large Telescopes on the ground — could take images of planets in the stars’ so-called habitable zones. This term defines orbits where the planets could have liquid water on their surfaces.

There are several factors influencing what could make a planet suitable for life as we know it. One of those factors is the amount of harmful X-rays and ultraviolet light they receive, which can damage or even strip away the planet’s atmosphere.

Based on X-ray observations of some of these stars using data from Chandra and XMM-Newton, the research team examined which stars could have hospitable conditions on orbiting planets for life to form and prosper. They studied how bright the stars are in X-rays, how energetic the X-rays are, and how much and how quickly they change in X-ray output, for example, due to flares. Brighter and more energetic X-rays can cause more damage to the atmospheres of orbiting planets.

The researchers used almost 10 days of Chandra observations and about 26 days of XMM observations, available in archives, to examine the X-ray behavior of 57 nearby stars, some of them with known planets. Most of these are giant planets like Jupiter, Saturn or Neptune, while only a handful of planets or planet candidates could be less than about twice as massive as Earth.

These results were presented at the 244th meeting of the American Astronomical Society meeting in Madison, Wisconsin, by Breanna Binder (California State Polytechnic University in Pomona).

NASA’s Marshall Space Flight Center manages the Chandra program. The Smithsonian Astrophysical Observatory’s Chandra X-ray Center controls science from Cambridge, Massachusetts and flight operations from Burlington, Massachusetts.

Read more from NASA’s Chandra X-ray Observatory.

For more Chandra images, multimedia and related materials, visit:

https://www.nasa.gov/mission/chandra-x-ray-observatory/

Visual Description:

This video shows a three-dimensional map of stars near the Sun on the left side of our screen and a dramatic illustration of a star with a planet orbiting around it on the right side.

The star map on the left shows many circular dots of different colors floating within an illustrated three-sided box. Each wall of the box is constructed in a grid pattern, with straight lines running horizontally and vertically like chicken wire. Dots that are colored blue represent stars that have been observed with NASA’s Chandra and ESA’s XMM-Newton.

Suspended in the box, at about the halfway point, is a series of three concentric circles surrounding a central dot that indicates the placement of our Sun. The circles represent distances of 5, 10, and 15 parsecs. One parsec is equivalent to roughly 3.2 light-years.

In the animation, the dot filled, chicken wire box spins around slowly, first on its X axis and then on its Y axis, providing a three-dimensional exploration of the plotted stars.

Megan WatzkeChandra X-ray CenterCambridge, Mass.617-496-7998

Jonathan DealMarshall Space Flight CenterHuntsville, Ala.256-544-0034

NASA’s Webb Reveals Long-Studied Star Is Actually Twins

5 min read

Managed by NASA’s Jet Propulsion Laboratory through launch, Webb’s Mid-Infrared Instrument also revealed jets of gas flowing into space from the twin stars.

Scientists recently got a big surprise from NASA’s James Webb Space Telescope when they turned the observatory toward a group of young stars called WL 20. The region has been studied since the 1970s with at least five telescopes, but it took Webb’s unprecedented resolution and specialized instruments to reveal that what researchers long thought was one of the stars, WL 20S, is actually a pair that formed about 2 million to 4 million years ago.

The discovery was made using Webb’s Mid-Infrared Instrument (MIRI) and was presented at the 244th meeting of the American Astronomical Society on June 12. MIRI also found that the twins have matching jets of gas streaming into space from their north and south poles.

“Our jaws dropped,” said astronomer Mary Barsony, lead author of a new paper describing the results. “After studying this source for decades, we thought we knew it pretty well. But without MIRI we would not have known this was two stars or that these jets existed. That’s really astonishing. It’s like having brand new eyes.”

The team got another surprise when additional observations by the Atacama Large Millimeter/submillimeter Array (ALMA), a group of more than 60 radio antennas in Chile, revealed that disks of dust and gas encircle both stars. Based on the stars’ age, it’s possible that planets are forming in those disks.

The combined results indicate that the twin stars are nearing the end of this early period of their lives, which means scientists will have the opportunity to learn more about how the stars transition from youth into adulthood.

“The power of these two telescopes together is really incredible,” said Mike Ressler, project scientist for MIRI at NASA’s Jet Propulsion Laboratory and co-author of the new study. “If we hadn’t seen that these were two stars, the ALMA results might have just looked like a single disk with a gap in the middle. Instead, we have new data about two stars that are clearly at a critical point in their lives, when the processes that formed them are petering out.”

WL 20 resides in a much larger, well-studied star-forming region of the Milky Way galaxy called Rho Ophiuchi, a massive cloud of gas and dust about 400 light-years from Earth. In fact, WL 20 is hidden behind thick clouds of gas and dust that block most of the visible light (wavelengths that the human eye can detect) from the stars there. Webb detects slightly longer wavelengths, called infrared, that can pass through those layers. MIRI detects the longest infrared wavelengths of any instrument on Webb and is thus well equipped for peering into obscured star-forming regions like WL 20.

Radio waves can often penetrate dust as well, though they may not reveal the same features as infrared light. The disks of gas and dust surrounding the two stars in WL 20S emit light in a range that astronomers call submillimeter; these, too, penetrate the surrounding gas clouds and were observed by ALMA.

But scientists could easily have interpreted those observations as evidence of a single disk with a gap in it had MIRI not also observed the two stellar jets. The jets of gas are composed of ions, or individual atoms with some electrons stripped away that radiate in mid-infrared wavelengths but not at submillimeter wavelengths. Only an infrared instrument with spatial and spectral resolution like MIRI's could see them.

ALMA can also observe clouds of leftover formation material around young stars. Composed of whole molecules, like carbon monoxide, these clouds of gas and dust radiate light at these longer wavelengths. The absence of those clouds in the ALMA observations shows that the stars are beyond their initial formation phase.

"It's amazing that this region still has so much to teach us about the life cycle of stars," said Ressler. "I'm thrilled to see what else Webb will reveal."

The James Webb Space Telescope is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

MIRI was developed through a 50-50 partnership between NASA and ESA. A division of Caltech in Pasadena, California, JPL led the U.S. efforts for MIRI, and a multinational consortium of European astronomical institutes contributes for ESA. George Rieke with the University of Arizona is the MIRI science team lead. Gillian Wright is the MIRI European principal investigator.

The MIRI cryocooler development was led and managed by JPL, in collaboration with Northrop Grumman in Redondo Beach, California, and NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

2024-085

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

In a surprise finding, astronomers using NASA's Hubble Space Telescope have discovered that the blowtorch-like…

Arizona Students Go on an Exoplanet Watch

2 min read

NASA Science Editorial Team

Exoplanets, planets outside of our own solar system, hold the keys to finding extraterrestrial life and understanding the origin of our own world. Now online students at Arizona State University (ASU) in a new course called Exoplanet Research Experience have become exoplanet scientists by taking part in NASA's Exoplanet Watch project.

Fifteen students from ASU's Astronomical and Planetary Sciences online degree program enroll in this course each year. These students analyze data on transits, events where the exoplanets block some of the light from their host stars. Each week, the class meets via Zoom to discuss progress, answer questions, and go over assignments. Students begin by completing a module from an online astrobiology course called Habitable Worlds, which is supported by NASA's Infiniscope project. During the last 5 weeks of the course, students work to consolidate their work into a paper draft that is later submitted to a peer-reviewed journal with all of the students listed as co-authors.

"I think [the class] changed the course of my life…" said one student. "Not just in my confidence, but just knowing that people in the field have my back…I have tremendous support from them."

"This course definitely helped kind of show what exactly scientists do and what the expectation is…especially for an online program, to have research opportunities is a great help…" another student said.

After participating in the course, students have gone on to participate in other research experiences, write their own first-author papers, participate in internships, and present their research at national astronomy conferences. An assessment of student outcomes was recently published in the Physics Review Physics Education Research Journal.

You don't need to go to ASU to do real exoplanet research. Anyone can help collect and analyze exoplanet data through Exoplanet Watch, whether you own a telescope or just want to help analyze data. Visit the NASA Exoplanet Watch website to get started!

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Spock’s Home Planet Goes ‘Poof’

Pat Brennan

A planet thought to orbit the star 40 Eridani A – host to Mr. Spock’s fictional home planet, Vulcan, in the “Star Trek” universe – is really a kind of astronomical illusion caused by the pulses and jitters of the star itself, a new study shows.

The possible detection of a planet orbiting a star that Star Trek made famous drew excitement and plenty of attention when it was announced in 2018. Only five years later, the planet appeared to be on shaky ground when other researchers questioned whether it was there at all. Now, precision measurements using a NASA-NSF instrument, installed a few years ago atop Kitt Peak in Arizona, seem to have returned the planet Vulcan even more definitively to the realm of science fiction.

Two methods for detecting exoplanets – planets orbiting other stars – dominate all others in the continuing search for strange new worlds. The transit method, watching for the tiny dip in starlight as a planet crosses the face of its star, is responsible for the vast majority of detections. But the “radial velocity” method also has racked up a healthy share of exoplanet discoveries. This method is especially important for systems with planets that don’t, from Earth’s point of view, cross the faces of their stars. By tracking subtle shifts in starlight, scientists can measure “wobbles” in the star itself, as the gravity of an orbiting planet tugs it one way, then another. For very large planets, the radial velocity signal mostly leads to unambiguous planet detections. But not-so-large planets can be problematic.

Even the scientists who made the original, possible detection of planet HD 26965 b – almost immediately compared to the fictional Vulcan – cautioned that it could turn out to be messy stellar jitters masquerading as a planet. They reported evidence of a “super-Earth” – larger than Earth, smaller than Neptune – in a 42-day orbit around a Sun-like star about 16 light-years away. The new analysis, using high-precision radial velocity measurements not yet available in 2018, confirms that caution about the possible discovery was justified.

The bad news for Star Trek fans comes from an instrument known as NEID, a recent addition to the complex of telescopes at Kitt Peak National Observatory. NEID, like other radial velocity instruments, relies on the “Doppler” effect: shifts in the light spectrum of a star that reveal its wobbling motions. In this case, parsing out the supposed planet signal at various wavelengths of light, emitted from different levels of the star’s outer shell, or photosphere, revealed significant differences between individual wavelength measurements – their Doppler shifts – and the total signal when they were all combined. That means, in all likelihood, the planet signal is really the flickering of something on the star’s surface that coincides with a 42-day rotation – perhaps the roiling of hotter and cooler layers beneath the star’s surface, called convection, combined with stellar surface features such as spots and “plages,” which are bright, active regions. Both can alter a star’s radial velocity signals.

While the new finding, at least for now, robs star 40 Eridani A of its possible planet Vulcan, the news isn’t all bad. The demonstration of such finely tuned radial velocity measurements holds out the promise of making sharper observational distinctions between actual planets and the shakes and rattles on surfaces of distant stars.

Even the destruction of Vulcan has been anticipated in the Star Trek universe. Vulcan was first identified as Spock’s home planet in the original 1960s television series. But in the 2009 film, “Star Trek,” a Romulan villain named Nero employs an artificial black hole to blow Spock’s home world out of existence.

A science team led by astronomer Abigail Burrows of Dartmouth College, and previously of NASA’s Jet Propulsion Laboratory, published a paper describing the new result, “The death of Vulcan: NEID reveals the planet candidate orbiting HD 26965 is stellar activity," in The Astronomical Journal in May 2024 (Note: HD 26965 is an alternate designation for the star, 40 Eridani A.)

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Finds Intriguing World Sized Between Earth, Venus

5 min read

Francis Reddy

Using observations by NASA’s TESS (Transiting Exoplanet Survey Satellite) and many other facilities, two international teams of astronomers have discovered a planet between the sizes of Earth and Venus only 40 light-years away. Multiple factors make it a candidate well-suited for further study using NASA’s James Webb Space Telescope.

TESS stares at a large swath of the sky for about a month at a time, tracking the brightness changes of tens of thousands of stars at intervals ranging from 20 seconds to 30 minutes. Capturing transits — brief, regular dimmings of stars caused by the passage of orbiting worlds — is one of the mission’s primary goals.

“We’ve found the nearest, transiting, temperate, Earth-size world located to date,” said Masayuki Kuzuhara, a project assistant professor at the Astrobiology Center in Tokyo, who co-led one research team with Akihiko Fukui, a project assistant professor at the University of Tokyo. “Although we don’t yet know whether it possesses an atmosphere, we’ve been thinking of it as an exo-Venus, with similar size and energy received from its star as our planetary neighbor in the solar system.”

The host star, called Gliese 12, is a cool red dwarf located almost 40 light-years away in the constellation Pisces. The star is only about 27% of the Sun’s size, with about 60% of the Sun’s surface temperature. The newly discovered world, named Gliese 12 b, orbits every 12.8 days and is Earth’s size or slightly smaller — comparable to Venus. Assuming it has no atmosphere, the planet has a surface temperature estimated at around 107 degrees Fahrenheit (42 degrees Celsius).

Astronomers say that the diminutive sizes and masses of red dwarf stars make them ideal for finding Earth-size planets. A smaller star means greater dimming for each transit, and a lower mass means an orbiting planet can produce a greater wobble, known as “reflex motion,” of the star. These effects make smaller planets easier to detect.

The lower luminosities of red dwarf stars also means their habitable zones — the range of orbital distances where liquid water could exist on a planet’s surface — lie closer to them. This makes it easier to detect transiting planets within habitable zones around red dwarfs than those around stars emitting more energy.

The distance separating Gliese 12 and the new planet is just 7% of the distance between Earth and the Sun. The planet receives 1.6 times more energy from its star as Earth does from the Sun and about 85% of what Venus experiences.

“Gliese 12 b represents one of the best targets to study whether Earth-size planets orbiting cool stars can retain their atmospheres, a crucial step to advance our understanding of habitability on planets across our galaxy,” said Shishir Dholakia, a doctoral student at the Centre for Astrophysics at the University of Southern Queensland in Australia. He co-led a different research team with Larissa Palethorpe, a doctoral student at the University of Edinburgh and University College London.

Both teams suggest that studying Gliese 12 b may help unlock some aspects of our own solar system’s evolution.

“It is thought that Earth’s and Venus’s first atmospheres were stripped away and then replenished by volcanic outgassing and bombardments from residual material in the solar system,” Palethorpe explained. “The Earth is habitable, but Venus is not due to its complete loss of water. Because Gliese 12 b is between Earth and Venus in temperature, its atmosphere could teach us a lot about the habitability pathways planets take as they develop.”

One important factor in retaining an atmosphere is the storminess of its star. Red dwarfs tend to be magnetically active, resulting in frequent, powerful X-ray flares. However, analyses by both teams conclude that Gliese 12 shows no signs of extreme behavior.

A paper led by Kuzuhara and Fukui was published May 23 in The Astrophysical Journal Letters. The Dholakia and Palethorpe findings were published in Monthly Notices of the Royal Astronomical Society on the same day.

During a transit, the host star’s light passes through any atmosphere. Different gas molecules absorb different colors, so the transit provides a set of chemical fingerprints that can be detected by telescopes like Webb.

“We know of only a handful of temperate planets similar to Earth that are both close enough to us and meet other criteria needed for this kind of study, called transmission spectroscopy, using current facilities,” said Michael McElwain, a research astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and a co-author of the Kuzuhara and Fukui paper. “To better understand the diversity of atmospheres and evolutionary outcomes for these planets, we need more examples like Gliese 12 b.”

TESS is a NASA Astrophysics Explorer mission managed by NASA Goddard and operated by MIT in Cambridge, Massachusetts. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.Media Contact:Claire Andreoli301-286-1940claire.andreoli@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Tool Gets Ready to Image Faraway Planets

7 min read

A technology demo on the Nancy Grace Roman Space Telescope will help increase the variety of distant planets scientists can directly image.

The Roman Coronagraph Instrument on NASA's Nancy Grace Roman Space Telescope will help pave the way in the search for habitable worlds outside our solar system by testing new tools that block starlight, revealing planets hidden by the glare of their parent stars. The technology demonstration recently shipped from NASA's Jet Propulsion Laboratory in Southern California to the agency's Goddard Space Flight Center in Greenbelt, Maryland, where it has joined the rest of the space observatory in preparation for launch by May 2027.

Before its cross-country journey, the Roman Coronagraph underwent the most complete test of its starlight-blocking abilities yet — what engineers call "digging the dark hole." In space, this process will enable astronomers to observe light directly from planets around other stars, or exoplanets. Once demonstrated on Roman, similar technologies on a future mission could enable astronomers to use that light to identify chemicals in an exoplanet's atmosphere, including ones that potentially indicate the presence of life.

For the dark hole test, the team placed the coronagraph in a sealed chamber designed to simulate the cold, dark vacuum of space. Using lasers and special optics, they replicated the light from a star as it would look when observed by the Roman telescope. When the light reaches the coronagraph, the instrument uses small circular obscurations called masks to effectively block out the star, like a car visor blocking the Sun or the Moon blocking the Sun during a total solar eclipse. This makes fainter objects near the star easier to see.

Coronagraphs with masks are already flying in space, but they can't detect an Earth-like exoplanet. From another star system, our home planet would appear approximately 10 billion times dimmer than the Sun, and the two are relatively close to one another. So trying to directly image Earth would be like trying to see a speck of bioluminescent algae next to a lighthouse from 3,000 miles (about 5,000 kilometers) away. With previous coronagraphic technologies, even a masked star's glare overwhelms an Earth-like planet.

The Roman Coronagraph will demonstrate techniques that can remove more unwanted starlight than past space coronagraphs by using several movable components. These moving parts will make it the first "active" coronagraph to fly in space. Its main tools are two deformable mirrors, each only 2 inches (5 centimeters) in diameter and backed by more than 2,000 tiny pistons that move up and down. The pistons work together to change the shape of the deformable mirrors so that they can compensate for the unwanted stray light that spills around the edges of the masks.

The deformable mirrors also help correct for imperfections in the Roman telescope's other optics. Although they are too small to affect Roman's other highly precise measurements, the imperfections can send stray starlight into the dark hole. Precise changes made to each deformable mirror's shape, imperceptible to the naked eye, compensate for these imperfections.

"The flaws are so small and have such a minor effect that we had to do over 100 iterations to get it right," said Feng Zhao, deputy project manager for the Roman Coronagraph at JPL. "It's kind of like when you go to see an optometrist and they put different lenses up and ask you, 'Is this one better? How about this one?' And the coronagraph performed even better than we'd hoped."

During the test, the readouts from the coronagraph's camera show a doughnut-shaped region around the central star that slowly gets darker as the team directs more starlight away from it — hence the nickname "digging the dark hole." In space, an exoplanet lurking in this dark region would slowly appear as the instrument does its work with its deformable mirrors.

More than 5,000 planets have been discovered and confirmed around other stars in the last 30 years, but most have been detected indirectly, meaning their presence is inferred based on how they affect their parent star. Detecting these relative changes in the parent star is far easier than seeing the signal of the much fainter planet. In fact, fewer than 70 exoplanets have been directly imaged.

The planets that have been directly imaged to date aren't like Earth: Most are much bigger, hotter, and typically farther from their stars. These features make them easier to detect but also less hospitable to life as we know it.

To look for potentially habitable worlds, scientists need to image planets that are not only billions of times dimmer than their stars, but also orbit them at the right distance for liquid water to exist on the planet's surface — a precursor for the kind of life found on Earth.

Developing the capabilities to directly image Earth-like planets will require intermediate steps like the Roman Coronagraph. At its maximum capability, it could image an exoplanet similar to Jupiter around a star like our Sun: a large, cool planet just outside the star's habitable zone.

What NASA learns from the Roman Coronagraph will help blaze a path for future missions designed to directly image Earth-size planets orbiting in the habitable zones of Sun-like stars. The agency's concept for a future telescope called the Habitable Worlds Observatory aims to image at least 25 planets similar to Earth using an instrument that will build on what the Roman Coronagraph Instrument demonstrates in space.

"The active components, like deformable mirrors, are essential if you want to achieve the goals of a mission like the Habitable Worlds Observatory," said JPL's Ilya Poberezhskiy, the project systems engineer for the Roman Coronagraph. "The active nature of the Roman Coronagraph Instrument allows you to take ordinary optics to a different level. It makes the whole system more complex, but we couldn't do these incredible things without it."

The Nancy Grace Roman Space Telescope is managed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by JPL and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are BAE Space and Mission Systems in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

The Roman Coronagraph Instrument was designed and built at JPL, which manages the instrument for NASA. Contributions were made by ESA (the European Space Agency), JAXA (the Japanese Aerospace Exploration Agency), the French space agency CNES (Centre National d'Études Spatiales), and the Max Planck Institute for Astronomy in Germany. Caltech, in Pasadena, California, manages JPL for NASA. The Roman Science Support Center at Caltech/IPAC partners with JPL on data management for the Coronagraph and generating the instrument's commands.

For more information about the Roman telescope, visit:

https://roman.gsfc.nasa.gov/

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

2024-068

In honor of the completion of our Nancy Grace Roman Space Telescope's spacecraft — the…

Missions

Humans in Space

Climate Change

Solar System

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Mini-Neptune in Double Star System is a Planetary Puzzle

4 min read

Pat Brennan

A planet that could resemble a smaller version of our own Neptune orbits one of two Sun-like stars that also orbit each other. The planet dwells in the “habitable zone,” with a potentially moderate temperature, and poses a challenge to prevailing ideas of planet formation.

Astronomers once imagined that our solar system – with its middle-aged, quiet Sun hosting small, rocky planets in closer orbits and gas giants farther out – might be typical, even run-of-the-mill. But so far, in an era of increasingly powerful planet-hunting technology, it’s turning out to be anything but. Other planetary systems can look very different, if not downright weird (or are we the weird ones?). A system called TOI 4633 seems truly strange: a mysterious type of planet known as a “mini-Neptune” traces an Earth-like, 272-day orbit around one of two stars locked in their own orbital embrace. But the stellar orbits, and those of the mini-Neptune and a possible sibling planet, are raising questions about how planetary systems form – and whether such arrangements can remain stable over time.

Among the thousands of exoplanets – planets beyond our solar system – confirmed in our galaxy so far, most were detected using the “transit” method: measuring the tiny dip in starlight as a planet crosses the face of its star. And most of these transit detections involve planets with short orbits, their “years” – once around the star – lasting a few days or weeks.

So the detection of planet TOI 4633 c was a welcome departure. That isn’t only because its 272-day orbit places it in fairly exclusive company: 175 transiting planets found so far with years longer than 100 days, and only 40 over 250 days. The planet, detected using TESS (the Transiting Exoplanet Survey Satellite), also orbits in the habitable zone, the distance from a star that could allow liquid water to form on a planetary surface. For planet c, of course, that’s almost certainly not the case; it most likely has a large, dense atmosphere, perhaps similar to Neptune’s, that would rule out surface water. A moon might be one way around this. The longer a planet’s orbital period, the more likely it is to host a satellite, so it isn’t difficult to imagine a potentially habitable moon, à la the fictional Pandora. The brightness of this system could make it a likely target in the continuing search for such “exomoons.”

The list of puzzling properties for this system continues. Measurements using a second detection method revealed a possible sibling planet with a 34-day orbit. This one does not, from Earth’s perspective, cross the face of its star, so its potential presence was revealed by “radial velocity.” The light coming from a star shifts slightly to and fro as the gravity of an orbiting planet tugs it one way, then another; follow-up investigations will be needed to confirm that the sibling planet, suggested by radial velocity measurements, is really there.

Further investigation of this system also could prove important for understanding binary star systems, or pairs of stars that orbit each other. A companion star in this case orbits the primary star in just 230 years, allowing them to approach each other closely by interstellar standards. The stars’ oval-shaped mutual orbit and close approach, along with a transiting planet on a long orbit around one of the stars, make this a standout system – one that will allow scientists to test their ideas about how planetary systems form and whether such unusual orbital configurations can manage to keep themselves stable over billions of years.

Planet TOI 4633 c was discovered by 15 “citizen scientists” who pored over TESS data as part of the Planet Hunters TESS citizen science project. Some 40,000 such volunteers regularly inspect “light curves” – lines that trace the amount of light coming from a star and that dip downward during a planet crossing, then curve back up when the crossing is finished. Scientists investigating the system also got an assist from more than a century ago: archival data that was part of the Washington Double Star Catalog, maintained by the U.S. Naval Observatory, and was gathered between 1905 and 2011.

An international team led by astrophysicist Nora L. Eisner of the Flatiron Institute in New York published the study, “Planet Hunters TESS. V. A Planetary System Around a Binary Star, Including a Mini-Neptune in the Habitable Zone,” in The Astronomical Journal on April 30, 2024.

NASA's citizen science projects are collaborations between scientists and interested members of the public. Through these collaborations, volunteers (known as citizen scientists) have helped make thousands of important scientific discoveries. Get involved with a project here.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Webb Cracks Case of Inflated Exoplanet

NASA Webb Mission Team

Goddard Space Flight Center

Why is the warm gas-giant exoplanet WASP-107 b so puffy? Two independent teams of researchers have an answer.

Data collected using NASA's James Webb Space Telescope, combined with prior observations from NASA's Hubble Space Telescope, show surprisingly little methane (CH_4) in the planet's atmosphere, indicating that the interior of WASP-107 b must be significantly hotter and the core much more massive than previously estimated.

The unexpectedly high temperature is thought to be a result of tidal heating caused by the planet's slightly non-circular orbit, and can explain how WASP-107 b can be so inflated without resorting to extreme theories of how it formed.

The results, which were made possible by Webb's extraordinary sensitivity and accompanying ability to measure light passing through exoplanet atmospheres, may explain the puffiness of dozens of low-density exoplanets, helping solve a long-standing mystery in exoplanet science.

At more than three-quarters the volume of Jupiter but less than one-tenth the mass, the "warm Neptune" exoplanet WASP-107 b is one of the least dense planets known. While puffy planets are not uncommon, most are hotter and more massive, and therefore easier to explain.

"Based on its radius, mass, age, and assumed internal temperature, we thought WASP-107 b had a very small, rocky core surrounded by a huge mass of hydrogen and helium," explained Luis Welbanks from Arizona State University (ASU), lead author on a paper published today in Nature. "But it was hard to understand how such a small core could sweep up so much gas, and then stop short of growing fully into a Jupiter-mass planet."

If WASP-107 b instead has more of its mass in the core, the atmosphere should have contracted as the planet cooled over time since it formed. Without a source of heat to re-expand the gas, the planet should be much smaller. Although WASP-107 b has an orbital distance of just 5 million miles (one-seventh the distance between Mercury and the Sun), it doesn't receive enough energy from its star to be so inflated.

"WASP-107 b is such an interesting target for Webb because it's significantly cooler and more Neptune-like in mass than many of the other low-density planets, the hot Jupiters, we've been studying," said David Sing from the Johns Hopkins University (JHU), lead author on a parallel study also published today in Nature. "As a result, we should be able to detect methane and other molecules that can give us information about its chemistry and internal dynamics that we can't get from a hotter planet."

WASP-107 b's giant radius, extended atmosphere, and edge-on orbit make it ideal for transmission spectroscopy, a method used to identify the various gases in an exoplanet atmosphere based on how they affect starlight.

Combining observations from Webb's NIRCam (Near-Infrared Camera), Webb's MIRI (Mid-Infrared Instrument), and Hubble's WFC3 (Wide Field Camera 3), Welbanks' team was able to build a broad spectrum of 0.8- to 12.2-micron light absorbed by WASP-107 b's atmosphere. Using Webb's NIRSpec (Near-Infrared Spectrograph), Sing's team built an independent spectrum covering 2.7 to 5.2 microns.

The precision of the data makes it possible to not just detect, but actually measure the abundances of a wealth of molecules, including water vapor (H_2O), methane (CH_4), carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), and ammonia (NH_3).

Both spectra show a surprising lack of methane in WASP-107 b's atmosphere: one-thousandth the amount expected based on its assumed temperature.

“This is evidence that hot gas from deep in the planet must be mixing vigorously with the cooler layers higher up,” explained Sing. “Methane is unstable at high temperatures. The fact that we detected so little, even though we did detect other carbon-bearing molecules, tells us that the interior of the planet must be significantly hotter than we thought.”

A likely source of WASP-107 b's extra internal energy is tidal heating caused by its slightly elliptical orbit. With the distance between the star and planet changing continuously over the 5.7-day orbit, the gravitational pull is also changing, stretching the planet and heating it up.

Researchers had previously proposed that tidal heating could be the cause of WASP-107 b's puffiness, but until the Webb results were in, there was no evidence.

Once they established that the planet has enough internal heat to thoroughly churn up the atmosphere, the teams realized that the spectra could also provide a new way to estimate the size of the core.

“If we know how much energy is in the planet, and we know what proportion of the planet is heavier elements like carbon, nitrogen, oxygen, and sulfur, versus how much is hydrogen and helium, we can calculate how much mass must be in the core,” explained Daniel Thorngren from JHU.

It turns out that the core is at least twice as massive as originally estimated, which makes more sense in terms of how planets form.

All together, WASP-107 b is not as mysterious as it once appeared.

“The Webb data tells us that planets like WASP-107 b didn't have to form in some odd way with a super small core and a huge gassy envelope,” explained Mike Line from ASU. “Instead, we can take something more like Neptune, with a lot of rock and not as much gas, just dial up the temperature, and poof it up to look the way it does.”

The James Webb Space Telescope is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

Right click any image to open (or save) a larger version in a new tab/window via the browser's popup menu.

View/Download full resolution images for this article from the Space Telescope Science Institute.

Research Paper: "A high internal heat flux and large core in a warm Neptune exoplanet" by L. Welbanks, et al.

Research Paper: "A warm Neptune's methane reveals core mass and vigorous atmospheric mixing" by D. Sing, et al.

Laura Betz - laura.e.betz@nasa.gov, Rob Gutro - rob.gutro@nasa.govNASA's Goddard Space Flight Center, Greenbelt, Md.

Margaret Carruthers mcarruthers@stsci.edu, Christine Pulliam - cpulliam@stsci.eduSpace Telescope Science Institute, Baltimore, Md.

What is an Exoplanet?

VIDEO: How do we learn about a planet's Atmosphere?

Webb's Impact on Exoplanet Research

More Webb News - https://science.nasa.gov/mission/webb/latestnews/

More Webb Images - https://science.nasa.gov/mission/webb/multimedia/images/

Webb Mission Page - https://science.nasa.gov/mission/webb/

What is a exoplanet?

VIDEO: Reading the Rainbow of Light from an Exoplanet's Atmosphere

What is the Webb Telescope?

SpacePlace for Kids

Para Niños : Qué es una exoplaneta?

Ciencia de la NASA

NASA en español

Space Place para niños

James Webb Space Telescope

Exoplanets

Stars

Universe

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Hints at Possible Atmosphere Surrounding Rocky Exoplanet

NASA Webb Mission Team

Goddard Space Flight Center

Researchers using NASA’s James Webb Space Telescope may have detected atmospheric gases surrounding 55 Cancri e, a hot rocky exoplanet 41 light-years from Earth. This is the best evidence to date for the existence of any rocky planet atmosphere outside our solar system.

Renyu Hu from NASA’s Jet Propulsion Laboratory (JPL) in Pasadena, California, is lead author on a paper published today in Nature. “Webb is pushing the frontiers of exoplanet characterization to rocky planets,” Hu said. “It is truly enabling a new type of science.”

55 Cancri e (image below, details/download), also known as Janssen, is one of five known planets orbiting the Sun-like star 55 Cancri, in the constellation Cancer. With a diameter nearly twice that of Earth and density slightly greater, the planet is classified as a super-Earth: larger than Earth, smaller than Neptune, and likely similar in composition to the rocky planets in our solar system.

To describe 55 Cancri e as “rocky,” however, could leave the wrong impression. The planet orbits so close to its star (about 1.4 million miles, or one-twenty-fifth the distance between Mercury and the Sun) that its surface is likely to be molten – a bubbling ocean of magma. With such a tight orbit, the planet is also likely to be tidally locked, with a dayside that faces the star at all times and a nightside in perpetual darkness.

In spite of numerous observations since it was discovered to transit in 2011, the question of whether or not 55 Cancri e has an atmosphere – or even could have one given its high temperature and the continuous onslaught of stellar radiation and wind from its star – has gone unanswered.

“I’ve worked on this planet for more than a decade,” said Diana Dragomir, an exoplanet researcher at the University of New Mexico and co-author on the study. “It’s been really frustrating that none of the observations we’ve been getting have robustly solved these mysteries. I am thrilled that we’re finally getting some answers!”

Unlike the atmospheres of gas giant planets, which are relatively easy to spot (the first was detected by NASA’s Hubble Space Telescope more than two decades ago), thinner and denser atmospheres surrounding rocky planets have remained elusive.

Previous studies of 55 Cancri e using data from NASA’s now-retired Spitzer Space Telescope suggested the presence of a substantial atmosphere rich in volatiles (molecules that occur in gas form on Earth) like oxygen, nitrogen, and carbon dioxide. But researchers could not rule out another possibility: that the planet is bare, save for a tenuous shroud of vaporized rock, rich in elements like silicon, iron, aluminum, and calcium. “The planet is so hot that some of the molten rock should evaporate,” explained Hu.

To distinguish between the two possibilities, the team used Webb’s NIRCam (Near-Infrared Camera) and MIRI (Mid-Infrared Instrument) to measure 4- to 12-micron infrared light coming from the planet.

Although Webb cannot capture a direct image of 55 Cancri e, it can measure subtle changes in light from the system as the planet orbits the star.

By subtracting the brightness during the secondary eclipse (image below, details/download), when the planet is behind the star (starlight only), from the brightness when the planet is right beside the star (light from the star and planet combined), the team was able to calculate the amount of various wavelengths of infrared light coming from the dayside of the planet.

This method, known as secondary eclipse spectroscopy, is similar to that used by other research teams to search for atmospheres on other rocky exoplanets, like TRAPPIST-1 b.

The first indication that 55 Cancri e could have a substantial atmosphere came from temperature measurements based on its thermal emission (image below, details/download), or heat energy given off in the form of infrared light. If the planet is covered in dark molten rock with a thin veil of vaporized rock or no atmosphere at all, the dayside should be around 4,000 degrees Fahrenheit (~2,200 degrees Celsius).

“Instead, the MIRI data showed a relatively low temperature of about 2,800 degrees Fahrenheit [~1540 degrees Celsius],” said Hu. “This is a very strong indication that energy is being distributed from the dayside to the nightside, most likely by a volatile-rich atmosphere.” While currents of lava can carry some heat around to the nightside, they cannot move it efficiently enough to explain the cooling effect.

When the team looked at the NIRCam data, they saw patterns consistent with a volatile-rich atmosphere. “We see evidence of a dip in the spectrum between 4 and 5 microns — less of this light is reaching the telescope,” explained co-author Aaron Bello-Arufe, also from NASA JPL. “This suggests the presence of an atmosphere containing carbon monoxide or carbon dioxide, which absorb these wavelengths of light.” A planet with no atmosphere or an atmosphere consisting only of vaporized rock would not have this specific spectral feature.

“We’ve spent the last ten years modelling different scenarios, trying to imagine what this world might look like,” said co-author Yamila Miguel from the Leiden Observatory and the Netherlands Institute for Space Research (SRON). “Finally getting some confirmation of our work is priceless!”

The team thinks that the gases blanketing 55 Cancri e would be bubbling out from the interior, rather than being present ever since the planet formed. “The primary atmosphere would be long gone because of the high temperature and intense radiation from the star,” said Bello-Arufe. “This would be a secondary atmosphere that is continuously replenished by the magma ocean. Magma is not just crystals and liquid rock; there’s a lot of dissolved gas in it, too.”

While 55 Cancri e is far too hot to be habitable, researchers think it could provide a unique window for studying interactions between atmospheres, surfaces, and interiors of rocky planets, and perhaps provide insights into the early conditions of Earth, Venus, and Mars, which are thought to have been covered in magma oceans far in the past. “Ultimately, we want to understand what conditions make it possible for a rocky planet to sustain a gas-rich atmosphere: a key ingredient for a habitable planet,” said Hu.

This research was conducted as part of Webb’s General Observers (GO) Program 1952. Analysis of additional secondary eclipse observations of 55 Cancri e are currently in progress.

The James Webb Space Telescope is the world’s premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Right click the images in this article to open a larger version in a new tab/window.Download full resolution images for this article from the Space Telescope Science Institute.The research results are published in Nature.

Laura Betz - laura.e.betz@nasa.gov, Rob Gutro - rob.gutro@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

Margaret Carruthers mcarruthers@stsci.edu, Christine Pulliam - cpulliam@stsci.eduSpace Telescope Science Institute, Baltimore, Md.

What is an Exoplanet?

VIDEO: How do we learn about a planets Atmosphere?

55 Cancri e exoplanet and 55 Cancri system simulated in 3d

Webb's Impact on Exoplanet Research

More Webb News - https://science.nasa.gov/mission/webb/latestnews/

More Webb Images - https://science.nasa.gov/mission/webb/multimedia/images/

Webb Mission Page - https://science.nasa.gov/mission/webb/

What is a exoplanet?

What is the Webb Telescope?

SpacePlace for Kids

Para Niños : Qué es una exoplaneta?

Ciencia de la NASA

NASA en español

Space Place para niños

James Webb Space Telescope

Exoplanets

Stars

Universe

Discovery Alert: An Earth-sized World and Its Ultra-cool Star

4 min read

dbolles

Our galaxy is a jewel box of red stars. More than 70% of the stars in the Milky Way are M dwarfs, also known as red dwarfs. These stars are cool and dim compared with our Sun, but they often blast orbiting exoplanets with high-energy radiation, especially early in their lives. And those ‘‘lives’’ last a long time. Stars like our Sun burn for about 10 billion years before turning into hungry red giants devouring any planets too nearby. M dwarfs keep burning for 100 billion years or more, perhaps offering a foothold for life, and an even longer window for life to develop.

An international team using robotic telescopes around the world recently spotted an Earth-sized planet orbiting an ultra-cool red dwarf, the dimmest and longest-lived of stars. When the universe grows cold and dark, these will be the last stars burning.

The exoplanet SPECULOOS-3 b is about 55 light-years from Earth (really close when you consider the cosmic scale!) and nearly the same size. A year there, one orbit around the star, takes about 17 hours. The days and nights, though, may never end: The planet is thought to be tidally locked, so the same side, known as the dayside, always faces the star, like the Moon to Earth. The nightside would be locked in never-ending darkness.

In our corner of the galaxy, ultra-cool dwarf stars are ubiquitous. They are so faint that their planetary population is largely unexplored. The SPECULOOS (Search for Planets EClipsing ULtra-cOOl Stars) project, led by Michael Gillon at the University of Liège, Belgium, was designed to change that. Ultra-cool dwarf stars are scattered across the sky, so you need to observe them one by one, for weeks, to get a good chance to detect transiting planets. For that, you need a dedicated network of professional telescopes. This is the concept of SPECULOOS.

‘‘We designed SPECULOOS specifically to explore nearby ultra-cool dwarf stars in search of rocky planets,’’ Gillon said. ‘‘With the SPECULOOS prototype and the crucial help of the NASA Spitzer Space Telescope, we discovered the famous TRAPPIST-1 system. That was an excellent start!’’

Gillon is the lead author of the paper announcing the planet’s discovery, published May 15, 2024, in Nature Astronomy. The project is a true international endeavor, with partnership with the Universities of Cambridge, Birmingham, Bern, Massachusetts Institute of Technology, and ETH Zürich.

The SPECULOOS-3 star is thousands of degrees cooler than our Sun with an average temperature of about 4,760 F (2,627 C), but it pummels its planet with radiation, meaning there’s likely no atmosphere.

Seeing the star, let alone the planet, is a feat in itself. “Though this particular red dwarf is more than a thousand times dimmer than the Sun, its planet orbits much, much closer than the Earth, heating up the planetary surface,” said co-author Catherine Clark, a postdoctoral researcher at NASA’s Jet Propulsion Laboratory in Southern California.

SPECULOOS-3 b is an excellent candidate for followup observations by the James Webb Space Telescope. Not only might we learn about the potential for an atmosphere and about the surface mineralogy, but it might also help us understand the stellar neighborhood and our place in it.

‘‘We're making great strides in our study of planets orbiting other stars. We have now reached the stage where we can detect and study Earth-sized exoplanets in detail. The next step will be to determine whether any of them are habitable, or even inhabited,’’ said Steve B. Howell, one of the planet’s discoverers at NASA Ames Research Center in Silicon Valley.

This story was written by the late Kristen Walbolt, who managed both exoplanets.nasa.gov and @NASAExoplanets social accounts, growing the latter from a following of 126,000 to over 1.9 million in just five years. This Discovery Alert and the associated illustration are among the final pieces of Kristen’s work for NASA Exoplanets.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Breaking the Scaling Limits: New Ultralow-noise Superconducting Camera for Exoplanet Searches

NASA Science Editorial Team

When imaging faint objects such as distant stars or exoplanets, capturing every last bit of light is crucial to get the most out of a scientific mission. These cameras must be extremely low-noise, and be able to detect the smallest quantities of light—single photons. Superconducting cameras excel in both of these criteria, but have historically not been widely applicable because their camera sizes have been small, rarely exceeding a few thousand pixels, which limits their ability to capture high-resolution images. However, a team of researchers has recently shattered that barrier, developing a superconducting camera with 400,000 pixels, which could be used to detect faint astronomical signals in a wide range of wavelengths—from the ultraviolet to the infrared.

While plenty of other camera technologies exist, cameras using superconducting detectors are very appealing for use in astronomical missions due to their extremely low-noise operation. When imaging faint sources, it is crucial that a camera report the quantity of received light faithfully, and not skew the amount of light received or inject its own false signals. Superconducting detectors are more than capable of this task, owing to their low-temperature operation and unique composition. As described by project lead Dr. Adam McCaughan, "with these detectors you could take data all day long, capturing billions of photons, and fewer than ten of those photons would be the result of noise."

But while superconducting detectors hold great promise for astronomical applications, their usage in that field has been stymied by small camera sizes that permit relatively few pixels. Because these detectors are so sensitive, it is difficult to pack a lot of them into a small area without them interfering with each other. In addition, since these detectors need to be kept cold in a cryogenic refrigerator, only a handful of wires can be used to carry the signals from the camera to the warmer readout electronics.

To overcome these limitations, researchers at the National Institute of Standards and Technology (NIST), the NASA Jet Propulsion Laboratory (JPL), and the University of Colorado Boulder applied time-domain multiplexing technology to the interrogation of two-dimensional superconducting-nanowire single photon detector (SNSPD) arrays. The individual SNSPD nanowires are arranged as intersecting rows and columns. When a photon arrives, the times it takes to trigger a row detector and a column detector are measured to ascertain which pixel sent the signal. This method allows the camera to efficiently encode its many rows and columns onto just a few readout wires instead of thousands of wires.

SNSPDs are one type of detector in a collection of many such superconducting detector technologies, including microwave kinetic inductance detectors (MKID), transition-edge sensors (TES), and quantum capacitance detectors (QCD). SNSPDs are unique in that they are able to operate much warmer than the millikelvin temperatures required by those other technologies, and can have extremely good timing resolution, although they are not able to resolve the color of individual photons. SNSPDs have been collaboratively researched by NIST, JPL, and others in the community for almost two decades, and this most recent work was only possible thanks to the advances generated by the wider superconducting detector community.

Once the team implemented this readout architecture, they found it immediately became straightforward to construct superconducting cameras with extremely large numbers of pixels. As described by technical lead Dr. Bakhrom Oripov, "The big advance here is that the detectors are truly independent, so if you want a camera with more pixels, you just add more detectors to the chip." The researchers note that while their recent project was a 400,000 pixel device, they also have an upcoming demonstration of a device with over a million pixels, and have not found an upper limit yet.

One of the most exciting things that the researchers think their camera could be useful for is a search for Earth-like planets outside of our solar system. To detect these planets successfully, future space telescopes will observe distant stars and look for tiny portions of reflected or emitted light coming from orbiting planets. Detecting and analyzing these signals is extremely challenging and requires very long exposures, which means that every photon collected by the telescope is very valuable. A reliable, low-noise camera will be critical to detect these incredibly small quantities of light.

SNSPD cameras can also be used on Earth to detect optical communication signals from missions in deep space. In fact, NASA is currently demonstrating this capability via the Deep Space Optical Communications (DSOC) project, which is the first demonstration of free-space optical communication from interplanetary space. DSOC is sending data from a spacecraft called Psyche—which was launched on October 13 and is on its way to the Psyche asteroid—to an SNSPD-based ground terminal at Palomar Observatory. Optical links can transmit data at a much higher rate than radio frequency links from interplanetary distances. The excellent timing resolution of the camera developed for the ground station receiving Psyche data allows it to decode optical data from the spacecraft, which enables much more data to be received in a given time than if radio signals were employed.

These sensors will also be useful for many applications on Earth. Because the operating wavelength of this camera is very flexible, it could be optimized for applications in biomedical imaging to detect faint signals from cells and molecules, which were previously not detectable. Dr. McCaughan noted, “We would love to get these cameras in the hands of neuroscientists. This technology could provide them with a new tool to study our brains, in a completely non-intrusive way.”

Finally, the rapidly growing field of quantum technology, which promises to change the way we secure communications and transactions as well as the way we simulate and optimize complex processes, also stands to gain from this exciting technology. A single photon can be used to transfer or compute a single bit of quantum information. Many companies and governments are currently trying to scale up quantum computers and communication links and access to a single-photon camera that is so easily scalable, could overcome one of the major hurdles to unlocking the full potential of quantum technologies.

According to the research team, the next steps will be to take this initial demonstration and optimize it for space applications. "Right now, we have a proof-of-concept demonstration," says co-project lead Dr. Boris Korzh, "but we'll need to optimize it to show its full potential." The research team is currently planning ultra-high-efficiency camera demonstrations that will validate the utility of this new technology in both the ultraviolet and the infrared.

Dr. Adam McCaughan (NIST) and Dr. Boris Korzh (JPL)

Astrophysics Research and Analysis (APRA) Program, DARPA Invisible Headlight Program

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: a Long Year for a ‘Cold Saturn’

3 min read

Pat Brennan

Two giant planets comparable to our own system’s Saturn orbit a star not unlike our Sun some 700 light-years away. The outer planet has the longest year – 483 days – of any found so far by NASA’s TESS (the Transiting Exoplanet Survey Satellite). It’s also among the coldest.

The two planets, TOI-4600 b and c, could prove important to astronomers who investigate how large, gaseous planets form and evolve. And they begin to fill a gap in knowledge between gas giants like Jupiter and Saturn in our solar system, and “hot Jupiters” (as well as “warm Jupiters”) elsewhere in our galaxy.

The decades-long hunt for exoplanets – planets around other stars – has so far yielded more than 5,500 that are confirmed to be scattered across the Milky Way, which likely contains hundreds of billions. But the prevailing detection method turns up relatively few “long period” planets, those with years lasting 50 days or more. This method, seeking “shadows,” much more easily reveals planets orbiting their stars closely, with far shorter years. The search for shadows, called the transit method, captures the tiny dip in starlight as an orbiting planet crosses the face of its star.

Spaceborne telescopes like TESS that rely on this method are responsible for the vast majority of exoplanet detections. But the longer a planet’s orbit, the harder it is for TESS to catch it transiting its star. Still, in a study published in September 2023, an international team of scientists using TESS data determined that TOI-4600 b and c have long-period orbits: 83 days for planet b, 483 for planet c (a year that’s a bit longer than Earth’s).

These orbits might not sound very impressive compared to the gas giants in our solar system. For Jupiter, one trip around the Sun takes 12 years; a “year” on Saturn equals more than 29 years on Earth. But because fewer long-period exoplanets transiting their stars have been detected, TOI-4600 b and c could prove to be a gold mine of data. While space telescopes have been able to measure some atmospheric components of hot and warm Jupiters, TOI-4600 b and c offer the rarer prospect of revealing atmospheric ingredients of “temperate” gas giants – those without scorching atmospheres.

“Temperate” is, of course, a relative term. If you’re looking for vacation spots, it’s best to leave these two planets off the list. TOI-4600 b, a bit smaller than Saturn at nearly seven times the width of Earth, has an estimated atmospheric temperature of 165 degrees Fahrenheit (74 Celsius). Planet c, about the size of Saturn at more than nine times the width of Earth, has an estimated temperature of minus 116 Fahrenheit (minus 82 Celsius). That’s among the coldest exoplanets TESS has discovered so far.

An international team led by astronomer Ismael Mireles of the University of New Mexico published their paper on the two planets, “TOI-4600 b and c: Two Long-period Giant Planets Orbiting an Early K Dwarf,” in “The Astrophysical Journal Letters” in September 2023.

Exoplanets

Planet Hunters TESS

Universe

Our Solar System

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Maps Weather on Planet 280 Light-Years Away

NASA Webb Mission Team

Goddard Space Flight Center

An international team of researchers has successfully used NASA’s James Webb Space Telescope to map the weather on the hot gas-giant exoplanet WASP-43 b.

Precise brightness measurements over a broad spectrum of mid-infrared light, combined with 3D climate models and previous observations from other telescopes, suggest the presence of thick, high clouds covering the nightside, clear skies on the dayside, and equatorial winds upwards of 5,000 miles per hour mixing atmospheric gases around the planet.

The investigation is just the latest demonstration of the exoplanet science now possible with Webb’s extraordinary ability to measure temperature variations and detect atmospheric gases trillions of miles away.

WASP-43 b is a “hot Jupiter” type of exoplanet: similar in size to Jupiter, made primarily of hydrogen and helium, and much hotter than any of the giant planets in our own solar system. Although its star is smaller and cooler than the Sun, WASP-43 b orbits at a distance of just 1.3 million miles – less than 1/25th the distance between Mercury and the Sun.

With such a tight orbit, the planet is tidally locked, with one side continuously illuminated and the other in permanent darkness. Although the nightside never receives any direct radiation from the star, strong eastward winds transport heat around from the dayside.

Since its discovery in 2011, WASP-43 b has been observed with numerous telescopes, including NASA’s Hubble and now-retired Spitzer space telescopes.

“With Hubble, we could clearly see that there is water vapor on the dayside. Both Hubble and Spitzer suggested there might be clouds on the nightside,” explained Taylor Bell, researcher from the Bay Area Environmental Research Institute and lead author of a study published today in Nature Astronomy. “But we needed more precise measurements from Webb to really begin mapping the temperature, cloud cover, winds, and more detailed atmospheric composition all the way around the planet.”

Although WASP-43 b is too small, dim, and close to its star for a telescope to see directly, its short orbital period of just 19.5 hours makes it ideal for phase curve spectroscopy, a technique that involves measuring tiny changes in brightness of the star-planet system as the planet orbits the star.

Since the amount of mid-infrared light given off by an object depends largely on how hot it is, the brightness data captured by Webb can then be used to calculate the planet’s temperature.

The team used Webb’s MIRI (Mid-Infrared Instrument) to measure light from the WASP-43 system every 10 seconds for more than 24 hours. “By observing over an entire orbit, we were able to calculate the temperature of different sides of the planet as they rotate into view,” explained Bell. “From that, we could construct a rough map of temperature across the planet.”

The measurements show that the dayside has an average temperature of nearly 2,300 degrees Fahrenheit (1,250 degrees Celsius) – hot enough to forge iron. Meanwhile, the nightside is significantly cooler at 1,100 degrees Fahrenheit (600 degrees Celsius). The data also helps locate the hottest spot on the planet (the “hotspot”), which is shifted slightly eastward from the point that receives the most stellar radiation, where the star is highest in the planet’s sky. This shift occurs because of supersonic winds, which move heated air eastward.

“The fact that we can map temperature in this way is a real testament to Webb’s sensitivity and stability,” said Michael Roman, a co-author from the University of Leicester in the U.K.

To interpret the map, the team used complex 3D atmospheric models like those used to understand weather and climate on Earth. The analysis shows that the nightside is probably covered in a thick, high layer of clouds that prevent some of the infrared light from escaping to space. As a result, the nightside – while very hot – looks dimmer and cooler than it would if there were no clouds.

The broad spectrum of mid-infrared light captured by Webb also made it possible to measure the amount of water vapor (H2O) and methane (CH4) around the planet. “Webb has given us an opportunity to figure out exactly which molecules we’re seeing and put some limits on the abundances,” said Joanna Barstow, a co-author from the Open University in the U.K.

The spectra show clear signs of water vapor on the nightside as well as the dayside of the planet, providing additional information about how thick the clouds are and how high they extend in the atmosphere.

Surprisingly, the data also shows a distinct lack of methane anywhere in the atmosphere. Although the dayside is too hot for methane to exist (most of the carbon should be in the form of carbon monoxide), methane should be stable and detectable on the cooler nightside.

“The fact that we don't see methane tells us that WASP-43b must have wind speeds reaching something like 5,000 miles per hour,” explained Barstow. “If winds move gas around from the dayside to the nightside and back again fast enough, there isn’t enough time for the expected chemical reactions to produce detectable amounts of methane on the nightside.”

The team thinks that because of this wind-driven mixing, the atmospheric chemistry is the same all the way around the planet, which wasn’t apparent from past work with Hubble and Spitzer.

The MIRI observation of WASP-43 b was conducted as part of the Webb Early Release Science programs, which are providing researchers with a vast set of robust, open-access data for studying a wide array of cosmic phenomena.The James Webb Space Telescope is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Right click the images in this article to open a larger version in a new tab/window.Download full resolution images for this article from the Space Telescope Science Institute.The research results can be viewed in the Nature Astronomy.

Laura Betz - laura.e.betz@nasa.gov, Rob Gutro - rob.gutro@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

Margaret Carruthers mcarruthers@stsci.edu, Christine Pulliam - cpulliam@stsci.eduSpace Telescope Science Institute, Baltimore, Md.

What is an Exoplanet?

What is a Gas Giant?

Hubble's View of WASP- 43b

More Webb News - https://science.nasa.gov/mission/webb/latestnews/

More Webb Images - https://science.nasa.gov/mission/webb/multimedia/images/

Webb Mission Page - https://science.nasa.gov/mission/webb/

What is a exoplanet?

What is the Webb Telescope?

SpacePlace for Kids

Para Niños : Qué es una exoplaneta?

Ciencia de la NASA

NASA en español

Space Place para niños

James Webb Space Telescope

Exoplanets

Stars

Universe

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

That Starry Night Sky? It’s Full of Eclipses

5 min read

Pat Brennan

Our star, the Sun, on occasion joins forces with the Moon to offer us Earthlings a spectacular solar eclipse – like the one that will be visible to parts of the United States, Mexico, and Canada on April 8.

But out there, among the other stars, how often can we see similar eclipses? The answer depends on your point of view. Literally.

On Earth, a total solar eclipse occurs when the Moon blocks the Sun’s disk as seen from part of Earth’s surface. In this case, the “path of totality” will be a strip cutting across the country, from Texas to Maine.

We also can see “eclipses” involving Mercury and Venus, the two planets in our solar system that orbit the Sun more closely than Earth, as they pass between our telescopes and the Sun (though only by using telescopes with protective filters to avoid eye damage). In these rare events, the planets are tiny dots crossing the Sun’s much larger disk.

And astronomers can, in a sense, “see” eclipses among other systems of planets orbiting their parent stars. In this case, the eclipse is a tiny drop in starlight as a planet, from our point of view, crosses the face of its star. That crossing, called a transit, can register on sensitive light sensors attached to telescopes on Earth and those in space, such as NASA’s Hubble Space Telescope, James Webb Space Telescope, or TESS (the Transiting Exoplanet Survey Satellite). It’s how the bulk of the more than 5,500 confirmed exoplanets – planets around other stars – have been detected so far, although other methods also are used to detect exoplanets.

“A solar eclipse is a huge transit,” said Allison Youngblood, the deputy project scientist for TESS at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

And both types of “transits” – whether they involve solar eclipses or exoplanets – can yield world-changing science. Solar eclipse observations in 1919 helped prove Einstein’s theory of general relativity, when the bending of a star’s light by the Sun’s gravity caused the star’s apparent position to shift – showing that gravity causes space and time to curve around it.

Exoplanet transits also provide far more than just detections of distant planets, Youngblood said.

“The planet passes in front of the star, and blocks a certain amount of the star’s light,” she said. “The dip [in starlight] tells us about the size of the planet. It gives us a measurement of the radius of the planet.”

Careful measurements of multiple transits also can reveal how long a year is on an exoplanet, and provide insights into its formation and history. Careful measurements of multiple transits also can provide insights into exoplanet formation and history.

And the starlight shining through the exoplanet’s atmosphere during its transit, if measured using an instrument called a spectrograph, can reveal deeper characteristics of the planet itself. The light is split into a rainbow-like spectrum, and slices missing from the spectrum can indicate gases in the planet’s atmosphere that absorbed that “color” – or wavelength.

“Measuring the planet at many wavelengths tells us what chemicals and what molecules are in that planet’s atmosphere,” Youngblood said.

Eclipses are such a handy way to capture information about distant worlds that scientists have learned how to create their own. Instead of waiting for eclipses to occur in nature, they can engineer them right inside their telescopes. Instruments called coronagraphs, first used on Earth to study the Sun's outer atmosphere (the corona), are now carried aboard several space telescopes. And when NASA's next flagship space telescope, the Nancy Grace Roman Space Telescope, launches by May 2027, it will demonstrate new coronagraph technologies that have never been flown in space before. Coronagraphs use a system of masks and filters to block the light from a central star, revealing the far fainter light of planets in orbit around it.

Of course, that isn't quite as easy as it sounds. Whether searching for transits, or for direct images of exoplanets using a coronagraph, astronomers must contend with the overwhelming light from stars – an immense technological challenge.

"An Earth-like transit in front of stars is equivalent to a mosquito walking in front of a headlight," said David Ciardi, chief scientist at the NASA Exoplanet Science Institute at Caltech. "That's how little light is blocked."

We don't have this problem when viewing solar eclipses – "our very first coronagraphs," Ciardi says. By pure happenstance, the Moon covers the Sun completely during an eclipse.

"A solar eclipse is like a human walking in front of a headlight," he said.

We would have no such luck on other planets in our solar system.

Mars' oddly shaped moons are too small to fully block the Sun during their transits; and while eclipses might be spectacular among the outer planets – for instance, Jupiter and its many moons – they wouldn't match the total coverage of a solar eclipse.

We happen to be living at a fortunate time for eclipse viewing. Billions of years ago, the Moon was far closer to Earth, and would have appeared to dwarf the Sun during an eclipse. And in about 700 million years, the Moon will be so much farther away that it will no longer be able to make total solar eclipses.

"A solar eclipse is the pinnacle of being lucky," Tripathi said. "The Moon's size and distance allow it to completely block out the Sun's light. We're at this perfect time and place in the universe to be able to witness such a perfect phenomenon."

Exoplanets

Universe

Planet Hunters TESS

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

More Planets than Stars: Kepler's Legacy

4 min read

The Kepler mission enabled the discovery of thousands of exoplanets, revealing a deep truth about our place in the cosmos: there are more planets than stars in the Milky Way galaxy. The road to this fundamental change in our understanding of the universe, however, required almost 20 years of persistence before the mission became a reality with its selection in 2001.

Astronomers had assumed, but still had not confirmed, the existence of exoplanets when the mission concept that would become Kepler was first suggested in 1983. It wasn't until the 1990s that the first confirmations of planets orbiting stars outside of our solar system were made, most of them gas giants orbiting close to their host star, not at all similar to what we know from our own solar system.

When Kepler launched in 2009, fewer than 400 exoplanets had been discovered. Today, there are more than 5,500 confirmed exoplanets and over half of them were discovered from Kepler data. Many of these confirmed exoplanets reside in the so-called "habitable zone" of their star, making them prime candidates for future observations to uncover more of the universe's mysteries, including the potential for life.

The Kepler mission was designed to address the questions "How prevalent are other worlds?" and "How unique is our solar system?" Even if Kepler had found the opposite—that exoplanets were rare—Kepler still would have been an historic mission since the question it addressed was so scientifically profound.

Earlier versions of the mission proposal had been rejected four times beginning in 1992. Back then, the mission was known as the FRequency of Earth-Sized Inner Planets (FRESIP). After its second rejection in 1994, team members David Koch, Jill Tarter, and Carl Sagan, suggested the name change from FRESIP to Kepler.

One of the technical changes made to the 1994 proposal before the 1996 submission included changing the orbit from the Lagrange L2 point to a heliocentric orbit. This allowed Kepler to use reaction wheels for pointing the spacecraft, which reduced the thruster fuel consumption and saved on cost.

This wasn't enough to convince NASA. To address concerns about the mission as proposed, two major demonstrations, one each after the 1996 and 1998 rejections, followed. The demonstrations reduced the risk that gave some reviewers pause and provided the Kepler team the opportunity to refine their operations.

The first demonstration showed that the continuous, automatic monitoring of thousands of stars was possible. For that demonstration, an instrument called the Vulcan photometer was installed at Lick Observatory in California, which radioed its data to NASA's Ames Research Center in California's Silicon Valley for automated analysis. The second demonstration (following the 1998 rejection) was the construction of the Kepler Testbed Facility.

The testbed proved that existing charge-coupled device (CCD) technology no different from a consumer digital camera could achieve the precision necessary to detect Earth-size planets in the midst of the various kinds of noise expected in the whole system, from vibrations to image motion to cosmic ray strikes. The Kepler team at Ames built an intricate simulated sky and Ball Aerospace, the industry partner throughout the many years of proposals and the mission itself, built the numerical simulator for the demonstration. The testbed from the laboratory at Ames is now on display at the Smithsonian National Air and Space Museum.

These demonstrations finally put the remaining concerns to rest. In 2001, Kepler was selected more than 17 years after its principal investigator, William Borucki, had written a paper that considered a space-based photometer for detecting Earth-size planets with his colleague Audrey Summers of the Theoretical and Planetary Studies Branch in the Space Science Division at Ames.

In the eight years between selection and launch on March 6, 2009, the mission responded to a number of challenges and changes that were largely beyond the team's control, such as NASA instituting a policy that required either NASA's Goddard Spaceflight Center in Greenbelt, Maryland or the Jet Propulsion Laboratory in Southern California to manage planetary missions, changes in accounting requirements, and increasing launch costs. Those pieces of Kepler's story are told in detail in the latest book from the NASA History Office, NASA's Discovery Program: The First Twenty Years of Competitive Planetary Exploration.

NASA History

Overview Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way.…

Universe

Discovery Program

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Glowing Cloud Points to a Cosmic Collision

3 min read

Chelsea Gohd

A glowing cosmic cloud has revealed a cataclysmic collision.

Even within our own solar system, scientists have seen evidence of giant, planetary collisions from long ago. Remaining clues like Uranus' tilt and the existence of Earth's moon point to times in our distant history when the planets in our stellar neighborhood slammed together, forever changing their shape and place in orbit. Scientists looking outside our solar system to far off exoplanets can spot similar evidence that, across the universe, planets sometimes crash. In this new study, the evidence of such an impact comes from a cloud of dust and gas with a strange, fluctuating luminosity.

Scientists were observing a young (300-million-year-old) Sun-like star when they noticed something odd: the star suddenly and significantly dipped in brightness. A team of researchers looked a little closer and they found that, just before this dip, the star displayed a sudden spike in infrared luminosity.

In studying the star, the team found that this luminosity lasted for 1,000 days. But 2.5 years into this bright event, the star was unexpectedly eclipsed by something, causing the sudden dip in brightness. This eclipse endured for 500 days.

The team investigated further and found that the culprit behind both the spike in luminosity and the eclipse was a giant, glowing cloud of gas and dust. And the most likely reason for the sudden, eclipse-causing cloud? A cosmic collision between two exoplanets, one of which likely contained ice, the researchers think.

In a new study detailing these events, scientists suggest that two giant exoplanets anywhere from several to tens of Earth masses crashed into one another, creating both the infrared spike and the cloud. A crash like this would completely liquify the two planets, leaving behind a single molten core surrounded by a cloud of gas, hot rock, and dust.

After the crash, this cloud, still holding the hot, glowing remnant of the collision, continued to orbit the star, eventually moving in front of and eclipsing the star.

This study was conducted using archival data from NASA's now-retired WISE mission – the spacecraft continues to operate under the name NEOWISE. This star was first detected in 2021 by the ground-based robotic survey ASAS-SN (All-Sky Automated Survey for Supernovae).

While this data revealed remnants of this planetary collision, the glow of this crash should still be visible to telescopes like NASA's James Webb Space Telescope. In fact, the research team behind this study is already putting together proposals to observe the system with Webb.

The study, "A planetary collision afterglow and transit of the resultant debris cloud," was published Oct. 11, 2023, in Nature by lead author Matthew Kenworthy alongside 21 co-authors.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Astronomer Sees Power in Community, Works to Build More

4 min read

Science is often portrayed as a solitary affair, where discoveries are made by lone geniuses toiling in isolation. But Dr. Natasha Batalha, an astronomer at NASA's Ames Research Center in California's Silicon Valley, says solving problems with the people around her is one of the best parts of her job.

"Oh, man, working with people is all I do!" said Batalha, whose current research involves using NASA's James Webb Space Telescope to study exoplanets, planets outside our solar system that orbit other stars.

Batalha's work explores hot, Jupiter-like exoplanets; smaller, rocky exoplanets more similar to Earth; and brown dwarfs, mysterious objects smaller than a star but huge compared to the biggest planets. A single question has driven her since she was a kid: "Does life exist beyond Earth?"

It's a lofty question, bigger than any one scientist. And that's the point.

"I love being part of a larger community," she said, "We're working together to try to solve this question that people have been asking for centuries."

However, the particular joy of belonging wasn't always present in Batalha's life.

When she was 10, her family moved from Brazil to the U.S., where she was met with culture shock, pressure to assimilate, and a language barrier. She thinks the latter is partly why she gravitated toward the universal language of math.

Eventually, her interests and strengths took shape around astronomy. When she chose to study physics in college, followed by a dual PhD in astronomy and astrobiology, her parents – who are also scientists – helped fill in for the community she was otherwise lacking.

"In high school, I watched female students drop out of my physics classes," Batalha said. "The honors physics track in college was devoid of women and people of color. I didn't feel I had a community in my college classes."

Her mother, Natalie Batalha, is an astronomer who served as project scientist for NASA's Kepler space telescope– the mission that taught us there are more planets than stars. Natasha's father is a LatinX physicist. Both her parents had already faced similar challenges in their careers, and having their example to look at of people who had successfully overcome those barriers helped her push on.

"I identify as female and LatinX, which are both underrepresented groups in STEM," she said, "but I also have a ton of privilege because my parents are in the field. That gave me a dual perspective on how powerful community is."

Natasha Batalha

NASA Astronomer

Since then, empowering her own science community has been a focus of Batalha's work.

She builds open-source tools, like computer programs for interpreting data, that are available to all. They help scientists use Webb’s exoplanet data to study what climates they may have, the behavior of clouds in their atmospheres, and the chemistry at work there.

“I saw how limiting closed toolsets could be for the community, when only an ‘inner circle’ had access to them,” Batalha said. “So, I wanted to create new tools that would put everyone on the same footing.”

Batalha herself recently used Webb to explore the skies of exoplanet WASP-39 b, a hot gas giant orbiting a star 700 light-years away. She is part of the team that found carbon dioxide and sulfur dioxide there, marking the first time either was detected in an exoplanet atmosphere. Now, she is turning to the difficult-to-discern characteristics of smaller, cooler planets.

Batalha says she’s exactly where her 6th-grade self imagined she would be. In elementary school, she read a biography of NASA astronaut Sally Ride and was hooked by an idea it contained: that in 20 years the kids reading those words could be the ones pioneering the search for life on Mars.

Today’s youth belong to the Artemis Generation, who will explore farther than people have ever gone before. The Artemis program will send the first woman and first person of color to the lunar surface. Missions over time will build a presence at the Moon to unlock a new era of science and prepare for human missions to Mars and beyond. Along the way, scientists will continue to search for signs of life beyond Earth, an endeavor building on the work of many generations and relying on those in the future to carry on the search.

“That’s something really rewarding about my work at NASA,” she said. “These questions have been asked throughout human history and, by joining the effort to answer them, you’re taking the baton for a while, before passing it on to someone else.”

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Earth-sized Planet Has a 'Lava Hemisphere'

4 min read

Chelsea Gohd

The discovery: In a system with two known planets, astronomers spotted something new: a small object transiting across the Sun-sized star. This turned out to be another planet: extra hot and Earth-sized.

Key Facts: The newly-spotted planet, called HD 63433 d, is tidally locked, meaning there is a dayside which always faces its star and a side that is constantly in darkness. This exoplanet, or planet outside of our solar system, orbits around the star HD 63433 (TOI 1726) in the HD 63433 planetary system. This scorching world is the smallest confirmed exoplanet younger than 500 million years old. It's also the closest discovered Earth-sized planet this young, at about 400 million years old.

Details: A team of astronomers analyzed this system using data from NASA's TESS (Transiting Exoplanet Survey Satellite), which spots "transits," or instances where planets cross in front of their star as they orbit, blocking a tiny piece of the starlight. Two planets had already been previously discovered in this planetary system, so to see what else might be lurking in the star's orbit, the team took the data and removed the signals of the two known planets. This allowed them to see an additional signal - a small transit that would reappear every 4.2 days. Upon further investigation, they were able to validate that this was actually a third, smaller planet.

The tidally locked planet is very close to Earth size (it is approximately 1.1 times the diameter of our own planet) and it's orbiting a star that's similar to the size of our Sun (the star is about 0.91 the size and 0.99 the mass of the Sun).

The star in this system is a G-type star, the same type as our Sun. But HD 63433 d orbits much closer to its star than we do, with a minuscule 4.2 day long "year" and extremely high temperatures on its dayside.

Fun Facts: While this newly found planet and its star are just about the size of our own planet and Sun, HD 63433 d is quite different from our home world.

Firstly, it is a very young planet in a very young system. The planetary system itself is about 10 times younger than ours and this 400-million-year-old planet is in its infancy compared to our 4.5-billion-year-old world.

It is also much closer to its star than we are to ours. This planet is 8 times closer to its star than Mercury is to the Sun. Being so close to its star, this dayside of this tidally-locked planet can reach temperatures of about 2,294 Fahrenheit (1,257 Celsius). Being so hot, so close to its star, and so small, this planet likely lacks a substantial atmosphere.

These scorching temperatures are comparable to lava worlds like CoRoT-7 b and Kepler-10 b, and the team behind this discovery thinks that the planet's dayside could be a "lava hemisphere."

The planet's small size, young age, and closeness to its star make it an interesting candidate for further exploration. Follow-up study could confirm the results of this study and potentially reveal more information about the planet's "dark side," and the status of its (possible) atmosphere. As this study states, "Young terrestrial worlds are critical test beds to constrain prevailing theories of planetary formation and evolution."

The Discoverers: This discovery was described in a new study, accepted for publication in the Astronomical Journal, titled "TESS Hunt for Young and Maturing Exoplanets (THYME) XI: An Earth-sized Planet Orbiting a Nearby, Solar-like Host in the 400 Myr Ursa Major Moving Group." The study, led by co-authors Benjamin Capistrant and Melinda Soares-Furtado, will be discussed in a Jan. 10 presentation at the 2024 American Astronomical Society Meeting.

This study was conducted as part of the TESS Hunt for Young and Maturing Exoplanets, which is a project focused on searching for young exoplanets that are in moving groups, stellar associations, or open clusters.

Read the paper.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

NASA’s TBIRD (TeraByte InfraRed Delivery) demonstration and its host spacecraft — the PTD-3 (Pathfinder Technology Demonstrator-3) — have completed their technology demonstration. The TBIRD payload spent the past two years breaking world records for the fastest satellite downlink from space using laser communications. NASA’s PTD series leverages a common commercial spacecraft to provide a robust […]

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: A ‘Super-Earth’ in the Habitable Zone

4 min read

Pat Brennan

The discovery: A “super-Earth” ripe for further investigation orbits a small, reddish star that is, by astronomical standards, fairly close to us – only 137 light-years away. The same system also might harbor a second, Earth-sized planet.

Key facts: The bigger planet, dubbed TOI-715 b, is about one and a half times as wide as Earth, and orbits within the “conservative” habitable zone around its parent star. That’s the distance from the star that could give the planet the right temperature for liquid water to form on its surface. Several other factors would have to line up, of course, for surface water to be present, especially having a suitable atmosphere. But the conservative habitable zone – a narrower and potentially more robust definition than the broader “optimistic” habitable zone – puts it in prime position, at least by the rough measurements made so far. The smaller planet could be only slightly larger than Earth, and also might dwell just inside the conservative habitable zone.

Details: Astronomers are beginning to write a whole new chapter in our understanding of exoplanets – planets beyond our solar system. The newest spaceborne instruments, including those onboard NASA’s James Webb Space Telescope, are designed not just to detect these distant worlds, but to reveal some of their characteristics. That includes the composition of their atmospheres, which could offer clues to the possible presence of life.

The recently discovered super-Earth, TOI-715 b, might be making its appearance at just the right time. Its parent star is a red dwarf, smaller and cooler than our Sun; a number of such stars are known to host small, rocky worlds. At the moment, they’re the best bet for finding habitable planets. These planets make far closer orbits than those around stars like our Sun, but because red dwarfs are smaller and cooler, the planets can crowd closer and still be safely within the star’s habitable zone. The tighter orbits also mean those that cross the faces of their stars – that is, when viewed by our space telescopes – cross far more often. In the case of planet b, that’s once every 19 days, a “year” on this strange world. So these star-crossing (“transiting”) planets can be more easily detected and more frequently observed. That’s the case for TESS (the Transiting Exoplanet Survey Satellite), which found the new planet and has been adding to astronomers’ stockpile of habitable-zone exoplanets since its launch in 2018. Observing such transits for, say, an Earth-sized planet around a Sun-like star (and waiting for an Earth year, 365 days, to catch another transit) is beyond the capability of existing space telescopes.

Planet TOI-175 b joins the list of habitable-zone planets that could be more closely scrutinized by the Webb telescope, perhaps even for signs of an atmosphere. Much will depend on the planet’s other properties, including how massive it is and whether it can be classed as a “water world” – making its atmosphere, if present, more prominent and far less difficult to detect than that of a more massive, denser and drier world, likely to hold its lower-profile atmosphere closer to the surface.

Fun facts: If the possible second, Earth-sized planet in the system also is confirmed, it would become the smallest habitable-zone planet discovered by TESS so far. The discovery also exceeded early expectations for TESS by finding an Earth-sized world in the habitable zone.

The discoverers: An international team of scientists led by Georgina Dransfield of the University of Birmingham, United Kingdom, published a paper in January 2024 on their discovery, “A 1.55 $R_\oplus$ habitable-zone planet hosted by TOI-715, an M4 star near the ecliptic South Pole,” in the journal, “Monthly Notices of the Royal Astronomical Society.” An international array of facilities used to confirm the planet included Gemini-South, Las Cumbres Observatory telescopes, the ExTrA telescopes, the SPECULOOS network, and the TRAPPIST-south telescope.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

NASA’s TBIRD (TeraByte InfraRed Delivery) demonstration and its host spacecraft — the PTD-3 (Pathfinder Technology Demonstrator-3) — have completed their technology demonstration. The TBIRD payload spent the past two years breaking world records for the fastest satellite downlink from space using laser communications. NASA’s PTD series leverages a common commercial spacecraft to provide a robust […]

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Hubble Finds Water Vapor in Small Exoplanet’s Atmosphere

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers using NASA's Hubble Space Telescope observed the smallest exoplanet where water vapor has been detected in the atmosphere. At only approximately twice Earth's diameter, the planet GJ 9827d could be an example of potential planets with water-rich atmospheres elsewhere in our galaxy.

"This would be the first time that we can directly show through an atmospheric detection, that these planets with water-rich atmospheres can actually exist around other stars," said team member Björn Benneke of the Trottier Institute for Research on Exoplanets at Université de Montréal. "This is an important step toward determining the prevalence and diversity of atmospheres on rocky planets."

"Water on a planet this small is a landmark discovery," added co-principal investigator Laura Kreidberg of Max Planck Institute for Astronomy in Heidelberg, Germany. "It pushes closer than ever to characterizing truly Earth-like worlds."

However, it remains too early to tell whether Hubble spectroscopically measured a small amount of water vapor in a puffy hydrogen-rich atmosphere, or if the planet's atmosphere is mostly made of water, left behind after a primeval hydrogen/helium atmosphere evaporated under stellar radiation.

"Our observing program, led by principal investigator Ian Crossfield of Kansas University in Lawrence, Kansas, was designed specifically with the goal to not only detect the molecules in the planet's atmosphere, but to actually look specifically for water vapor. Either result would be exciting, whether water vapor is dominant or just a tiny species in a hydrogen-dominant atmosphere," said the science paper's lead author, Pierre-Alexis Roy of the Trottier Institute for Research on Exoplanets at Université de Montréal.

"Until now, we had not been able to directly detect the atmosphere of such a small planet. And we're slowly getting in this regime now," added Benneke. "At some point, as we study smaller planets, there must be a transition where there's no more hydrogen on these small worlds, and they have atmospheres more like Venus (which is dominated by carbon dioxide)."

Because the planet is as hot as Venus, at 800 degrees Fahrenheit, it definitely would be an inhospitable, steamy world if the atmosphere were predominantly water vapor.

At present the team is left with two possibilities. One scenario is that the planet is still clinging to a hydrogen-rich atmosphere laced with water, making it a mini-Neptune. Alternatively, it could be a warmer version of Jupiter's moon Europa, which has twice as much water as Earth beneath its crust." The planet GJ 9827d could be half water, half rock. And there would be a lot of water vapor on top of some smaller rocky body," said Benneke.

If the planet has a residual water-rich atmosphere, then it must have formed farther away from its host star, where the temperature is cold and water is available in the form of ice, than its present location. In this scenario, the planet would have then migrated closer to the star and received more radiation. The hydrogen was heated and escaped, or is still in the process of escaping the planet's weak gravity. The alternative theory is that the planet formed close to the hot star, with a trace of water in its atmosphere.

The Hubble program observed the planet during 11 transits – events in which the planet crossed in front of its star – that were spaced out over three years. During transits, starlight is filtered through the planet's atmosphere and has the spectral fingerprint of water molecules. If there are clouds on the planet, they are low enough in the atmosphere so that they don't completely hide Hubble's view of the atmosphere, and Hubble is able to probe water vapor above the clouds.

"Observing water is a gateway to finding other things," said Thomas Greene, astrophysicist at NASA's Ames Research Center in California's Silicon Valley. "This Hubble discovery opens the door to future study of these types of planets by NASA's James Webb Space Telescope. JWST can see much more with additional infrared observations, including carbon-bearing molecules like carbon monoxide, carbon dioxide, and methane. Once we get a total inventory of a planet's elements, we can compare those to the star it orbits and understand how it was formed."

GJ 9827d was discovered by NASA's Kepler Space Telescope in 2017. It completes an orbit around a red dwarf star every 6.2 days. The star, GJ 9827, lies 97 light-years from Earth in the constellation Pisces.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble and Webb science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, MDclaire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore, MD

Science Contacts:

Pierre-Alexis RoyTrottier Institute for Research on Exoplanets at Université de Montréal

Björn BennekeTrottier Institute for Research on Exoplanets at Université de Montréal

Hubble Space Telescope

Exoplanets

Science Missions

James Webb Space Telescope

NASA’s Hubble Observes Exoplanet Atmosphere Changing Over 3 Years

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

By combining several years of observations from NASA's Hubble Space Telescope along with conducting computer modelling, astronomers have found evidence for massive cyclones and other dynamic weather activity swirling on a hot, Jupiter-sized planet 880 light-years away.

The planet, called WASP-121 b, is not habitable. But this result is an important early step in studying weather patterns on distant worlds, and perhaps eventually finding potentially habitable exoplanets with stable, long-term climates.

For the past few decades, detailed telescopic and spacecraft observations of neighboring planets in our solar system show that their turbulent atmospheres are not static but constantly changing, just like weather on Earth. This variability should also apply to planets around other stars, too. But it takes lots of detailed observing and computational modelling to actually measure such changes.

To make the discovery, an international team of astronomers assembled and reprocessed Hubble observations of WASP-121 b taken in 2016, 2018, and 2019.

They found that the planet has a dynamic atmosphere, changing over time. The team used sophisticated modelling techniques to demonstrate that these dramatic temporal variations could be explained by weather patterns in the exoplanet's atmosphere.

The team found that WASP-121 b's atmosphere shows notable differences between observations. Most dramatically, there could be massive weather fronts, storms, and massive cyclones that are repeatedly created and destroyed due to the large temperature difference between the star-facing side and dark side of the exoplanet. They also detected an apparent offset between the exoplanet's hottest region and the point on the planet closest to the star, as well as variability in the chemical composition of the exoplanet's atmosphere (as measured via spectroscopy).

The team reached these conclusions by using computational models to help explain observed changes in the exoplanet's atmosphere. "The remarkable details of our exoplanet atmosphere simulations allows us to accurately model the weather on ultra-hot planets like WASP-121 b," explained Jack Skinner, a postdoctoral fellow at the California Institute of Technology in Pasadena, California, and co-leader of this study. "Here we make a significant step forward by combining observational constraints with atmosphere simulations to understand the time-varying weather on these planets."

"This is a hugely exciting result as we move forward for observing weather patterns on exoplanets," said one of the principal investigators of the team, Quentin Changeat, a European Space Agency Research Fellow at the Space Telescope Science Institute in Baltimore, Maryland. "Studying exoplanets' weather is vital to understanding the complexity of exoplanet atmospheres on other worlds, especially in the search for exoplanets with habitable conditions."

WASP-121 b is so close to its parent star that the orbital period is only 1.27 days. This close proximity means that the planet is tidally locked so that the same hemisphere always faces the star, in the same way that our Moon always has the same side pointed at Earth. Daytime temperatures approach 3,450 degrees Fahrenheit (2,150 degrees Kelvin) on the star-facing side of the planet.

The team used four sets of Hubble archival observations of WASP-121 b. The complete data-set included observations of WASP-121 b transiting in front of its star (taken in June 2016); WASP-121 b passing behind its star, also known as a secondary eclipse (taken in November 2016); and the brightness of WASP-121 b as a function of its phase angle to the star (the varying amount of light received at Earth from an exoplanet as it orbits its parent star, similar to our Moon's phase-cycle). These data were taken in March 2018 and February 2019, respectively.

"The assembled data-set represents a significant amount of observing time for a single planet and is currently the only consistent set of such repeated observations," said Changeat. The information that we extracted from those observations was used to infer the chemistry, temperature, and clouds of the atmosphere of WASP-121 b at different times. This provided us with an exquisite picture of the planet changing over time."

Hubble's capabilities also are evident in the broad expanse of science programs it will enable through its Cycle 31 observations, which began on December 1. About two-thirds of Hubble's time will be devoted to imaging studies, while the remainder is allotted to spectroscopy studies, like those used for WASP-121 b. More details about Cycle 31 science are in a recent announcement.

LEARN MORE:

The Hubble Space Telescope is a project of international cooperation between NASA and ESA. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble and Webb science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, MDclaire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore, MD

Bethany DownerESA/Hubble

Science Contact:

Quentin ChangeatESA/STScI

Hubble Space Telescope

Exoplanet Stories

Exoplanets

Solar System Exploration

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Features New Discoveries at American Astronomical Society Meeting

5 min read

Elizabeth Landau

Experts will discuss new research from NASA missions at the 243rd meeting of the American Astronomical Society (AAS), on topics ranging from planets outside our solar system to fleeting, high-energy explosions in the universe. The meeting will take place Jan. 7-11 at the New Orleans Ernest N. Morial Convention Center in New Orleans.

In press conferences, scientific sessions, and town halls, scientists and agency leaders will present the latest developments in astrophysics. Press conferences – highlighting results enabled by NASA missions such as the James Webb Space Telescope (also called “Webb” or “JWST”), Hubble Space Telescope, Chandra X-ray Observatory, and Fermi Gamma-ray Space Telescope – will stream live to the public on the AAS Press Office YouTube channel.

In addition to press conferences, NASA highlights for registered attendees include:

Throughout the week, expert talks at the NASA Exhibit Booth will discuss science from current NASA missions including Webb, Hubble, IXPE (Imaging X-ray Polarimetry Explorer), NICER (Neutron star Interior Composition Explorer), TESS (Transiting Exoplanet Survey Satellite), and Chandra ahead of its 25th anniversary; NASA’s upcoming Nancy Grace Roman Space Telescope and SPHEREx observatory; the Habitable Worlds Observatory, a concept for a future NASA flagship space telescope; the agency’s scientific Balloon Program; the 2024 total solar eclipse; and open science at NASA, among other topics.

Members of the media can request interviews with NASA experts on any of these topics by contacting Alise Fisher at alise.m.fisher@nasa.gov.

The full list of NASA meeting highlights is as follows. All times are Central.

Monday, Jan. 8

10:15 a.m. CST: AAS News Conference

Room 229

News from NASA’s Chandra, Webb, and retired SOFIA (Stratospheric Observatory for Infrared Astronomy) mission will be featured:

12:45 p.m. CST: NASA Town Hall

Great Hall A

Mark Clampin, director of the Astrophysics Division at NASA Headquarters, will share an update on NASA's astrophysics programs.

2:15 p.m. CST: AAS News Conference

Room 229

News from NASA's Hubble, SOFIA, and Fermi will be highlighted:

Tuesday, Jan. 9

10:15 a.m. CST: AAS News Conference

Room 229

A NASA-funded citizen science program and news from NASA's Webb mission will be highlighted:

2:15 p.m. CST: AAS News Conference

Room 229

News from NASA's Webb and Hubble space telescopes will be highlighted:

Wednesday, Jan. 10

10:15 a.m. CST: AAS News Conference

Room 229

News from NASA’s Fermi satellite will be highlighted: "A 12.4-Day Periodicity in a Close Binary System After a Supernova."

12:45 p.m. CST: Splinter Session – "Habitable Worlds Observatory: Current Status and Opportunities for Engagement"

Room R08/R09

Agency experts will provide a status update as NASA's Great Observatory Maturation Program lays the groundwork for the Habitable Worlds Observatory concept, including the recent formation of planning teams and other opportunities for community participation.

1 p.m. CST: Splinter Session – "Astrophysics and Open Science"

Room 237

NASA experts will discuss the agency’s role in supporting an inclusive culture of open science, and to empower researchers, early career scientists, and underrepresented communities with the knowledge and tools necessary to embrace open science practices.

2:15 p.m. CST: AAS News Conference

Room 229

News from NASA's Webb and TESS missions will be highlighted:

6 p.m. CST: James Webb Space Telescope Town Hall

Room 215

Experts will provide a status update on NASA's James Webb Space Telescope. Now in its second year of science observations, Webb has continued to pull back the curtain on some of the farthest galaxies, stars, and black holes ever observed; solved a longstanding mystery about the early universe; found methane and carbon dioxide in the atmosphere of a planet outside our solar system; and offered new views and insights into planets and small objects in our own cosmic backyard.

Thursday, Jan. 11

10:15 a.m. CST: AAS News Conference

Room 229

News from NASA’s Chandra and Fermi missions, as well as XMM-Newton, an ESA (European Space Agency) mission with NASA contributions, will be highlighted:

12:45 p.m. CST: Nancy Grace Roman Space Telescope Town Hall

Room 207

Mission experts will provide a status update on the development of the Roman Space Telescope, NASA’s next flagship observatory, which is currently in development and planned to launch by May 2027. The Roman team recently finished assembling the spacecraft’s giant camera, and Roman’s fully assembled Coronagraph Instrument passed its first big optics test.

2:15 p.m. CST: AAS News Conference

Room 229

News from NASA's Webb will be highlighted: “A Potentially Isolated Quiescent Dwarf Galaxy.”

For more information on the meeting, including press registration and the complete meeting schedule, visit:

https://aas.org/meetings/aas243

Alise Fisher / Liz LandauHeadquarters, Washington202-358-2546 / 202-358-0845alise.m.fisher@nasa.gov / elizabeth.r.landau@nasa.gov

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Identifies Tiniest Free-Floating Brown Dwarf

Brown dwarfs are objects that straddle the dividing line between stars and planets. They form like stars, growing dense enough to collapse under their own gravity, but they never become dense and hot enough to begin fusing hydrogen and turn into a star. At the low end of the scale, some brown dwarfs are comparable with giant planets, weighing just a few times the mass of Jupiter.

Astronomers are trying to determine the smallest object that can form in a star-like manner. A team using NASA’s James Webb Space Telescope has identified the new record-holder: a tiny, free-floating brown dwarf with only three to four times the mass of Jupiter.

“One basic question you’ll find in every astronomy textbook is, what are the smallest stars? That’s what we’re trying to answer,” explained lead author Kevin Luhman of Pennsylvania State University.

To locate this newfound brown dwarf, Luhman and his colleague, Catarina Alves de Oliveira, chose to study the star cluster IC 348, located about 1,000 light-years away in the Perseus star-forming region. This cluster is young, only about 5 million years old. As a result, any brown dwarfs would still be relatively bright in infrared light, glowing from the heat of their formation.

The team first imaged the center of the cluster using Webb’s NIRCam (Near-Infrared Camera) to identify brown dwarf candidates from their brightness and colors. They followed up on the most promising targets using Webb’s NIRSpec (Near-Infrared Spectrograph) microshutter array.

Webb’s infrared sensitivity was crucial, allowing the team to detect fainter objects than ground-based telescopes. In addition, Webb’s sharp vision enabled them to determine which red objects were pinpoint brown dwarfs and which were blobby background galaxies.

This winnowing process led to three intriguing targets weighing three to eight Jupiter masses, with surface temperatures ranging from 1,500 to 2,800 degrees Fahrenheit (830 to 1,500 degrees Celsius). The smallest of these weighs just three to four times Jupiter, according to computer models.

Explaining how such a small brown dwarf could form is theoretically challenging. A heavy and dense cloud of gas has plenty of gravity to collapse and form a star. However, because of its weaker gravity, it should be more difficult for a small cloud to collapse to form a brown dwarf, and that is especially true for brown dwarfs with the masses of giant planets.

“It’s pretty easy for current models to make giant planets in a disk around a star,” said Catarina Alves de Oliveira of ESA (European Space Agency), principal investigator on the observing program. “But in this cluster, it would be unlikely this object formed in a disk, instead forming like a star, and three Jupiter masses is 300 times smaller than our Sun. So we have to ask, how does the star formation process operate at such very, very small masses?”

In addition to giving clues about the star-formation process, tiny brown dwarfs also can help astronomers better understand exoplanets. The least massive brown dwarfs overlap with the largest exoplanets; therefore, they would be expected to have some similar properties. However, a free-floating brown dwarf is easier to study than a giant exoplanet since the latter is hidden within the glare of its host star.

Two of the brown dwarfs identified in this survey show the spectral signature of an unidentified hydrocarbon, or molecule containing both hydrogen and carbon atoms. The same infrared signature was detected by NASA’s Cassini mission in the atmospheres of Saturn and its moon

Titan. It has also been seen in the interstellar medium, or gas between stars.

“This is the first time we’ve detected this molecule in the atmosphere of an object outside our solar system,” explained Alves de Oliveira. “Models for brown dwarf atmospheres don’t predict its existence. We’re looking at objects with younger ages and lower masses than we ever have before, and we’re seeing something new and unexpected.”

Since the objects are well within the mass range of giant planets, it raises the question of whether they are actually brown dwarfs, or if they’re really rogue planets that were ejected from planetary systems. While the team can’t rule out the latter, they argue that they are far more likely to be a brown dwarf than an ejected planet.

An ejected giant planet is unlikely for two reasons. First, such planets are uncommon in general compared to planets with smaller masses. Second, most stars are low-mass stars, and giant planets are especially rare among those stars. As a result, it’s unlikely that most of the stars in IC 348 (which are low-mass stars) are capable of producing such massive planets. In addition, since the cluster is only 5 million years old, there probably hasn’t been enough time for giant planets to form and then be ejected from their systems.

The discovery of more such objects will help clarify their status. Theories suggest that rogue planets are more likely to be found in the outskirts of a star cluster, so expanding the search area may identify them if they exist within IC 348.

Future work may also include longer surveys that can detect fainter, smaller objects. The short survey conducted by the team was expected to detect objects as small as twice the mass of Jupiter. Longer surveys could easily reach one Jupiter mass.

These observations were taken as part of Guaranteed Time Observation program 1229. The results were published in the Astronomical Journal.

The James Webb Space Telescope is the world’s premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Download full resolution images for this article from the Space Telescope Science Institute.

Read/Download the research results released in The Astronomical Journal.

Right click the images in this article to open a larger version in a new tab/window.

Laura Betz – laura.e.betz@nasa.gov, Rob Gutro– rob.gutro@nasa.govNASA’s Goddard Space Flight Center, , Greenbelt, Md.

Hannah Braun – hbraun@stsci.edu , Christine Pulliam – cpulliam@stsci.eduSpace Telescope Science Institute, Baltimore, Md.

Lifecycle of Stars

More Webb News – https://science.nasa.gov/mission/webb/latestnews/

More Webb Images – https://science.nasa.gov/mission/webb/multimedia/images/

Webb Mission Page – https://science.nasa.gov/mission/webb/

How do we weigh planets?

What is a nebula?

What is the Webb Telescope?

SpacePlace for Kids

Ciencia de la NASA

NASA en español

Space Place para niños

Webb is the premier observatory of the next decade, serving thousands of astronomers worldwide. It studies every phase in the…

Astronomers estimate that the universe could contain up to one septillion stars – that’s a one followed by 24 zeros.…

Galaxies consist of stars, planets, and vast clouds of gas and dust, all bound together by gravity. The largest contain…

Universe

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Webb Study Reveals Rocky Planets Can Form in Extreme Environments

An international team of astronomers has used NASA's James Webb Space Telescope to provide the first observation of water and other molecules in the highly irradiated inner, rocky-planet-forming regions of a disk in one of the most extreme environments in our galaxy. These results suggest that the conditions for terrestrial planet formation can occur in a possible broader range of environments than previously thought.

These are the first results from the eXtreme Ultraviolet Environments (XUE) James Webb Space Telescope program, which focuses on the characterization of planet-forming disks (vast, spinning clouds of gas, dust, and chunks of rock where planets form and evolve) in massive star-forming regions. These regions are likely representative of the environment in which most planetary systems formed. Understanding the impact of environment on planet formation is important for scientists to gain insights into the diversity of the different types of exoplanets.

The XUE program targets a total of 15 disks in three areas of the Lobster Nebula (also known as NGC 6357), a large emission nebula roughly 5,500 light-years away from Earth in the constellation Scorpius. The Lobster Nebula is one of the youngest and closest massive star-formation complexes, and is host to some of the most massive stars in our galaxy. Massive stars are hotter, and therefore emit more ultraviolet (UV) radiation. This can disperse the gas, making the expected disk lifetime as short as a million years. Thanks to Webb, astronomers can now study the effect of UV radiation on the inner rocky-planet forming regions of protoplanetary disks around stars like our Sun.

“Webb is the only telescope with the spatial resolution and sensitivity to study planet-forming disks in massive star-forming regions,” said team lead María Claudia Ramírez-Tannus of the Max Planck Institute for Astronomy in Germany.

Astronomers aim to characterize the physical properties and chemical composition of the rocky-planet-forming regions of disks in the Lobster Nebula using the Medium Resolution Spectrometer on Webb's Mid-Infrared Instrument (MIRI). This first result focuses on the protoplanetary disk termed XUE 1, which is located in the star cluster Pismis 24.

“Only the MIRI wavelength range and spectral resolution allow us to probe the molecular inventory and physical conditions of the warm gas and dust where rocky planets form,” added team member Arjan Bik of Stockholm University in Sweden.

Due to its location near several massive stars in NGC 6357, scientists expect XUE 1 to have been constantly exposed to high amounts of ultraviolet radiation throughout its life. However, in this extreme environment the team still detected a range of molecules that are the building blocks for rocky planets.

“We find that the inner disk around XUE 1 is remarkably similar to those in nearby star-forming regions,” said team member Rens Waters of Radboud University in the Netherlands. “We've detected water and other molecules like carbon monoxide, carbon dioxide, hydrogen cyanide, and acetylene. However, the emission found was weaker than some models predicted. This might imply a small outer disk radius.”

“We were surprised and excited because this is the first time that these molecules have been detected under these extreme conditions,” added Lars Cuijpers of Radboud University. The team also found small, partially crystalline silicate dust at the disk's surface. This is considered to be the building blocks of rocky planets.

These results are good news for rocky planet formation, as the science team finds that the conditions in the inner disk resemble those found in the well-studied disks located in nearby star-forming regions, where only low-mass stars form. This suggests that rocky planets can form in a much broader range of environments than previously believed.

The team notes that the remaining observations from the XUE program are crucial to establish the commonality of these conditions.

“XUE 1 shows us that the conditions to form rocky planets are there, so the next step is to check how common that is,” said Ramírez-Tannus. “We will observe other disks in the same region to determine the frequency with which these conditions can be observed.”

These results have been published in The Astrophysical Journal.

The James Webb Space Telescope is the world’s premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Laura Betz – laura.e.betz@nasa.gov, Rob Gutro– rob.gutro@nasa.govNASA’s Goddard Space Flight Center, , Greenbelt, Md.

Bethany Downer – Bethany.Downer@esawebb.orgESA/Webb Chief Science Communications Officer

Christine Pulliam cpulliam@stsci.eduSpace Telescope Science Institute, Baltimore, Md.

Download full resolution images for this article from the Space Telescope Science Institute.

Research results published in The Astrophysical Journal.

Terrestrial Exoplanets

Exoplanets 101

LIfe and Death of a Planetary System

Webb Mission – https://science.nasa.gov/mission/webb/

Webb News – https://science.nasa.gov/mission/webb/latestnews/

Webb Images – https://science.nasa.gov/mission/webb/multimedia/images/

What is a Planet?

What is an Exoplanet?

How Many Solar Systems are in our Galaxy?

What Is a Galaxy?

What is the Webb Telescope?

SpacePlace for Kids

Ciencia de la NASA

NASA en español

Space Place para niños

Webb is the premier observatory of the next decade, serving thousands of astronomers worldwide. It studies every phase in the…

Overview Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way.…

Astronomers estimate that the universe could contain up to one septillion stars – that's a one followed by 24 zeros.…

Our galaxy, the Milky Way, is typical: it has hundreds of billions of stars, enough gas and dust to make…

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Watch the Synchronized Dance of a 6-Planet System

4 min read

NASA Science Editorial Team

The discovery: Six planets orbit their central star in a rhythmic beat, a rare case of an “in sync” gravitational lockstep that could offer deep insight into planet formation and evolution.

Key facts: A star smaller and cooler than our Sun hosts a truly strange family of planets: six “sub-Neptunes” – possibly smaller versions of our own Neptune – moving in a cyclic rhythm. This orbital waltz repeats itself so precisely it can be readily set to music.

Details: While multi-planet systems are common in our galaxy, those in a tight gravitational formation known as “resonance” are observed by astronomers far less often. In this case, the planet closest to the star makes three orbits for every two of the next planet out – called a 3/2 resonance – a pattern that is repeated among the four closest planets.

Among the outermost planets, a pattern of four orbits for every three of the next planet out (a 4/3 resonance) is repeated twice. And these resonant orbits are rock-solid: The planets likely have been performing this same rhythmic dance since the system formed billions of years ago. Such reliable stability means this system has not suffered the shocks and shakeups scientists might typically expect in the early days of planet formation – smash-ups and collisions, mergers and breakups as planets jockey for position. And that, in turn, could say something important about how this system formed. Its rigid stability was locked in early; the planets’ 3/2 and 4/3 resonances are almost exactly as they were at the time of formation. More precise measurements of these planets’ masses and orbits will be needed to further sharpen the picture of how the system formed.

Fun facts: The discovery of this system is something of a detective story. The first hints of it came from NASA’s TESS (the Transiting Exoplanet Survey Satellite), which tracks the tiny eclipses – the “transits” – that planets make as they cross the faces of their stars. Combining the TESS measurements, made in separate observations two years apart, revealed an assortment of transits for the host star, called HD 110067. But it was difficult to distinguish how many planets they represented, or to pin down their orbits.

Eventually, astronomers singled out the two innermost planets, with orbital periods – “years” – of 9 days for the closest planet, 14 days for the next one out. A third planet, with a year about 20 days long, was identified with the help of data from CHEOPS, The European Space Agency’s CHaracterising ExOPlanets Satellite.

Then the scientists noticed something extraordinary. The three planets’ orbits matched what would be expected if they were locked in a 3/2 resonance. The next steps were all about math and gravity. The science team, led by Rafael Luque of the University of Chicago, worked through a well-known list of resonances that potentially could be found in such systems, trying to match them to the remaining transits that had been picked up by TESS. The only resonance chain that matched up suggested a fourth planet in the system, with an orbit about 31 days long. Two more transits had been seen, but their orbits remained unaccounted for because they were only single observations (more than one transit observation is needed to pin down a planet’s orbit). The scientists again ran through the list of possible orbits if there were two additional, outer planets that fit the expected chain of resonances across the whole system. The best fit they found: a fifth planet with a 41-day orbit, and a sixth just shy of 55.

At this point the science team almost hit a dead end. The slice of the TESS observations that had any chance of confirming the predicted orbits of the two outer planets had been set aside during processing. Excessive light scattered through the observation field by Earth and the Moon seemed to make them unusable. But not so fast. Scientist Joseph Twicken, of the SETI Institute and of the NASA Ames Research Center, took notice of the scattered light problem. He knew that scientist David Rapetti, also of Ames and of the Universities Space Research Association, happened to be working on a new computer code to recover transit data thought to be lost because of scattered light. At Twicken’s suggestion, Rapetti applied his new code to the TESS data. He found two transits for the outer planets – exactly where the science team led by Luque had predicted.

The discoverers: An international team of researchers led by Rafael Luque, of the University of Chicago, published a paper online on the discovery, “A resonant sextuplet of sub-Neptunes transiting the bright star HD 110067,” in the journal Nature on Nov. 29.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Seeing and Believing: 15 Years of Exoplanet Images

NASA Science Editorial Team

First there was a gloriously dusty disk. Then the traceable tracks of “exocomets.” But 15 years ago this fall, the star system Beta Pictoris yielded one of the most iconic pictures in astrophysics: a direct image of a planet orbiting another star.

The young, bright star, some 63 light-years distant and visible to the naked eye, all but overwhelmed the faint light of the planet. When astronomers, using a European Southern Observatory telescope, subtracted the starlight, all that remained of the planet was a tiny dot, a few pixels. But it was enough to throw open a new window on direct imaging.

“After that, I knew what I wanted to do in astronomy,” said Marie Ygouf, a researcher who specializes in direct imaging of exoplanets – planets around other stars – at NASA’s Jet Propulsion Laboratory in Southern California.

An undergraduate when she first saw the image of the planet, called Beta Pictoris b, Ygouf said she was awestruck.

“It was so exciting to try to take pictures of exoplanets, to try to detect life on another planet,” she said. “I was sold.”

Today the Beta Pictoris system, called Beta Pic for short, is famous for the early, breathtaking images of its surrounding disk of dusty debris, and for abundant evidence of exocomets, or comets detected in star systems other than our own. The discovery of a second planet in the system, Beta Pictoris c, was revealed to much scientific excitement in 2018.

It is, as one astronomer said, the gift that keeps on giving.

But the scientists deeply involved in early observations of the system had a bit of an uphill struggle convincing some colleagues that their groundbreaking discoveries were real, said Anne-Marie Lagrange, an astronomer at LESIA, Observatoire de Paris, who has been working to understand the system for more than 30 years.

As an intern, Lagrange began her work on Beta Pic in the mid-1980s, just after the disk image made its big splash. Among her research milestones was the discovery, in the late 1980s, of massive clumps of gas falling onto the surface of the system’s central star – and at high rates of speed, up to 200 miles (350 kilometers) per second.

Lagrange and her fellow researchers relied on observations from the IUE (International Ultraviolet Explorer) satellite – “an ancestor” of NASA’s Hubble Space Telescope, she said – to propose that the infalling gas was caused by evaporating comets.

“They were the first exocomets [observed] around another star,” she said. “At the beginning, many people were laughing at it.” The findings held up, and the presence of exocomets in the system was confirmed by further observations announced in 2022.

Marie Ygouf

Researcher on the Nancy Grace Roman Space Telescope science team

In the mid 1990s, relying on the recently launched Hubble as well as increasingly sophisticated ground-based instruments, scientists realized that the debris disk around Beta Pictoris was warped, like a vinyl record left too long in the Sun.

Computer modeling results suggested the warp was a gravitational skew caused by an orbiting planet. And in 2008, after long effort, Lagrange and her team hit paydirt: a direct image of the giant, gaseous planet, so young it was still glowing from its recent formation.

“The nice thing is, we predicted it 10 years before,” she said.

Still a relatively minor player in the detection of exoplanets, direct imaging’s role will expand in the years and decades to come, promising deep insights into the nature of distant planets as technology improves. But even then, each “image” of a planet will still be just a handful of pixels.

That might sound disappointing, especially in the era of spectacular sci-fi movie effects. If we find an “Earth-like” planet, we won’t see continents and oceans – at least not yet. But that tiny dot of light will contain a flood of information: details of the planet’s atmosphere, clouds, temperature, and perhaps even signs of some form of life.

By splitting the light from that tiny dot into a spectrum of colors, scientists can spot missing lines from that spectrum – slices of light absorbed by molecules in the planet’s atmosphere as starlight is reflected from the atmosphere or surface. The missing slices correspond to specific gases and molecules in the planet’s atmosphere, a detection method known as spectroscopy.

NASA’s James Webb Space Telescope is already using onboard spectrographs to tease out the components of exoplanet atmospheres. In the years ahead, the agency’s Nancy Grace Roman Space Telescope, to be launched by May 2027, is designed to study the cloudy atmospheres of mature, Jupiter-sized exoplanets. The Habitable Worlds Observatory, a mission concept now in the early planning stages, is expected to refine this technology, to measure the atmospheric composition of small, rocky planets like our own, all from those little dots of directly imaged exoplanets.

Ygouf is part of the project science team for the Roman telescope’s coronagraph instrument, which will block the glare from a parent star so the light from its planets can be detected. Meant to be a technology demonstration, the instrument includes two flexible mirrors to correct distortions in the light caused by the instrument and by the telescope itself.

She says the direct imaging techniques that caught fire with Beta Pictoris could someday solve one of the ultimate mysteries.

“With this technique, we may be able to answer that very fundamental question: Is there any life in the universe outside of Earth?” she said. “It’s astonishing, incredible, that from a few pixels we’ll be able to learn so many things about a planet: whether those planets are terrestrial or gaseous, whether they have an atmosphere or not. If it’s done right, in the future we may be able to create pretty maps of those planets, seeing potential clouds. It may be a few pixels, but [there’s] so much information you can get from that.”

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Webb Follows Neon Signs Toward New Thinking on Planet Formation

5 min read

Scientists are following neon signs in a search for clues to one planetary system's future and the past of another – our own solar system. Following up on a peculiar reading by NASA's previous infrared flagship observatory, the now-retired Spitzer Space Telescope, the agency's James Webb Space Telescope detected distinct traces of the element neon in the dusty disk surrounding the young Sun-like star SZ Chamaelontis (SZ Cha).

Differences in the neon readings between Spitzer and Webb point to a never-before-observed change in high-energy radiation that reaches the disk, which eventually causes it to evaporate, limiting the time planets have to form.

"How did we get here? It really goes back to that big question, and SZ Cha is the same type of young star, a T-Tauri star, as our Sun was 4.5 billion years ago at the dawn of the solar system," said astronomer Catherine Espaillat of Boston University, in Massachusetts, who led both the 2008 Spitzer observations and the newly published Webb results. "The raw materials for Earth, and eventually life, were present in the disk of material that surrounded the Sun after it formed, and so studying these other young systems is as close as we can get to going back in time to see how our own story began."

Scientists use neon as an indicator of how much, and what type, of radiation is hitting and eroding the disk around a star. When Spitzer observed SZ Cha in 2008, it saw an outlier, with neon readings unlike any other young T-Tauri disk. The difference was the detection of neon III, which is typically scarce in protoplanetary disks that are being pummeled by high-energy X-rays. This meant that the high-energy radiation in the SZ Cha disk was coming from ultraviolet (UV) light instead of X-rays. Besides being the lone oddball result in a sample of 50-60 young stellar disks, the UV vs. X-ray difference is significant for the lifetime of the disk and its potential planets.

"Planets are essentially in a race against time to form up in the disk before it evaporates," explained Thanawuth Thanathibodee of Boston University, another astronomer on the research team. "In computer models of developing systems, extreme ultraviolet radiation allows for 1 million more years of planet formation than if the evaporation is predominately caused by X-rays."

So, SZ Cha was already quite the puzzle when Espaillat's team returned to study it with Webb, only to find a new surprise: The unusual neon III signature had all but disappeared, indicating the typical dominance of X-ray radiation.

The research team thinks that the differences in neon signatures in the SZ Cha system are the result of a variable wind that, when present, absorbs UV light and leaves X-rays to pummel the disk. Winds are common in a system with a newly formed, energetic star, the team says, but it is possible to catch the system during a quiet, wind-free period, which is what Spitzer happened to do.

"Both the Spitzer and Webb data are excellent, so we knew this had to be something new we were observing in the SZ Cha system – a significant change in conditions in just 15 years," added co-author Ardjan Sturm of Leiden University, Leiden, Netherlands.

Espaillat's team is already planning more observations of SZ Cha with Webb, as well as other telescopes, to get to the bottom of its mysteries. "It will be important to study SZ Cha, and other young systems, in multiple wavelengths of light, like X-ray and visible light, to discover the true nature of this variability we've found," said co-author Caeley Pittman of Boston University. "It's possible that brief, quiet periods dominated by extreme UV radiation are common in many young planetary systems, but we just have not been able to catch them.”

“Once again, the universe is showing us that none of its methods are as simple as we might like to make them. We need to rethink, re-observe, and gather more information. We’ll be following the neon signs,” said Espaillat.

This research has been accepted for publication in Astrophysical Journal Letters.

The James Webb Space Telescope is the world’s premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Laura Betz – laura.e.betz@nasa.gov, Rob Gutro– rob.gutro@nasa.govNASA’s Goddard Space Flight Center, , Greenbelt, Md.

Leah Ramsay lramsay@stsci.edu , Christine Pulliam cpulliam@stsci.edu

Space Telescope Science Institute, Baltimore, Md.

Download full resolution images for this article from the Space Telescope Science Institute.

Research results have been accepted for publication in Astropyisical Journal Letters.

How do Planets Form? https://exoplanets.nasa.gov/faq/43/how-do-planets-form/

Planetary Systems – https://universe.nasa.gov/stars/planetary-systems/

Webb Mission – https://science.nasa.gov/mission/webb/

Webb News – https://science.nasa.gov/mission/webb/latestnews/

Webb Images – https://science.nasa.gov/mission/webb/multimedia/images/

Planet Formation in a Snap (video)

SpacePlace About Our Solar System and Planets

Ciencia de la NASA

NASA en español

Space Place para niños

Webb is the premier observatory of the next decade, serving thousands of astronomers worldwide. It studies every phase in the…

The solar system has eight planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. There are five officially recognized…

Overview Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way.…

Astronomers estimate that the universe could contain up to one septillion stars – that’s a one followed by 24 zeros.…

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Data Reveals Possible Reason Some Exoplanets Are Shrinking

6 min read

A new study could explain the ‘missing’ exoplanets between super-Earths and sub-Neptunes.

Some exoplanets seem to be losing their atmospheres and shrinking. In a new study using NASA’s retired Kepler Space Telescope, astronomers find evidence of a possible cause: The cores of these planets are pushing away their atmospheres from the inside out.

Exoplanets (planets outside our solar system) come in a variety of sizes, from small, rocky planets to colossal gas giants. In the middle lie rocky super-Earths and larger sub-Neptunes with puffy atmospheres. But there’s a conspicuous absence – a “size gap” – of planets that fall between 1.5 to 2 times the size of Earth (or in between super-Earths and sub-Neptunes) that scientists have been working to better understand.

“Scientists have now confirmed the detection of over 5,000 exoplanets, but there are fewer planets than expected with a diameter between 1.5 and 2 times that of Earth,” said Caltech/IPAC research scientist Jessie Christiansen, science lead for the NASA Exoplanet Archive and lead author of the new study in The Astronomical Journal. “Exoplanet scientists have enough data now to say that this gap is not a fluke. There’s something going on that impedes planets from reaching and/or staying at this size.”

Researchers think that this gap could be explained by certain sub-Neptunes losing their atmospheres over time. This loss would happen if the planet doesn’t have enough mass, and therefore gravitational force, to hold onto its atmosphere. So sub-Neptunes that aren’t massive enough would shrink to about the size of super-Earths, leaving the gap between the two sizes of planets.

But exactly how these planets are losing their atmospheres has remained a mystery. Scientists have settled on two likely mechanisms: One is called core-powered mass loss; and the other, photoevaporation. The study has uncovered new evidence supporting the first.

Core-powered mass loss occurs when radiation emitted from a planet’s hot core pushes the atmosphere away from the planet over time, “and that radiation is pushing on the atmosphere from underneath,” Christiansen said.

The other leading explanation for the planetary gap, photoevaporation, happens when a planet’s atmosphere is essentially blown away by the hot radiation of its host star. In this scenario, “the high-energy radiation from the star is acting like a hair dryer on an ice cube,” she said.

While photoevaporation is thought to occur during a planet’s first 100 million years, core-powered mass loss is thought to happen much later – closer to 1 billion years into a planet’s life. But with either mechanism, “if you don’t have enough mass, you can’t hold on, and you lose your atmosphere and shrink down,” Christiansen added.

For this study, Chistiansen and her co-authors used data from NASA’s K2, an extended mission of the Kepler Space Telescope, to look at the star clusters Praesepe and Hyades, which are 600 million to 800 million years old. Because planets are generally thought to be the same age as their host star, the sub-Neptunes in this system would be past the age where photoevaporation could have taken place but not old enough to have experienced core-powered mass loss.

So if the team saw that there were a lot of sub-Neptunes in Praesepe and Hyades (as compared to older stars in other clusters), they could conclude that photoevaporation hadn't taken place. In that case, core-powered mass loss would be the most likely explanation of what happens to less massive sub-Neptunes over time.

In observing Praesepe and Hyades, the researchers found that nearly 100% of stars in these clusters still have a sub-Neptune planet or planet candidate in their orbit. Judging from the size of these planets, the researchers think they have retained their atmospheres.

This differs from the other, older stars observed by K2 (stars more than 800 million years old), only 25% of which have orbiting sub-Neptunes. The older age of these stars is closer to the timeframe in which core-powered mass loss is thought to take place.

From these observations, the team concluded that photoevaporation could not have taken place in Praesepe and Hyades. If it had, it would have occurred hundreds of millions of years earlier, and these planets would have little, if any, atmosphere left. This leaves core-powered mass loss as the leading explanation for what likely happens to the atmospheres of these planets.

Christiansen's team spent more than five years building the planet candidate catalog necessary for the study. But the research is far from complete, she said, and it is possible that the current understanding of photoevaporation and/or core-powered mass loss could evolve. The findings will likely be put to the test by future studies before anyone can declare the mystery of this planetary gap solved once and for all.

This study was conducted using the NASA Exoplanet Archive, which is operated by Caltech in Pasadena under contract with NASA as part of the Exoplanet Exploration Program, which is located at NASA's Jet Propulsion Laboratory in Southern California. JPL is a division of Caltech.

On Oct. 30, 2018, Kepler ran out of fuel and ended its mission after nine years, during which it discovered more than 2,600 confirmed planets around other stars along with thousands of additional candidates astronomers are working to confirm.

NASA's Ames Research Center in Silicon Valley, California, manages the Kepler and K2 missions for NASA's Science Mission Directorate. JPL managed Kepler mission development. Ball Aerospace & Technologies Corporation operated the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

For more information about the Kepler and K2 missions, visit:

https://science.nasa.gov/mission/kepler

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Karen Fox / Alise Fisher NASA Headquarters, Washington202-358-1257 / 202-358-2546karen.c.fox@nasa.gov / alise.m.fisher@nasa.gov

Written by Chelsea Gohd

2023-169

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Hubble Measures the Size of the Nearest Transiting Earth-Sized Planet

3 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA's Hubble Space Telescope has measured the size of the nearest Earth-sized exoplanet that passes across the face of a neighboring star. This alignment, called a transit, opens the door to follow-on studies to see what kind of atmosphere, if any, the rocky world might have.

The diminutive planet, LTT 1445Ac, was first discovered by NASA's Transiting Exoplanet Survey Satellite (TESS) in 2022. But the geometry of the planet's orbital plane relative to its star as seen from Earth was uncertain because TESS does not have the required optical resolution. This means the detection could have been a so-called grazing transit, where a planet only skims across a small portion of the parent star's disk. This would yield an inaccurate lower limit of the planet's diameter.

"There was a chance that this system has an unlucky geometry and if that's the case, we wouldn't measure the right size. But with Hubble's capabilities we nailed its diameter," said Emily Pass of the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts.

Hubble observations show that the planet makes a normal transit fully across the star's disk, yielding a true size of only 1.07 times Earth's diameter. This means the planet is a rocky world, like Earth, with approximately the same surface gravity. But at a surface temperature of roughly 500 degrees Fahrenheit, it is too hot for life as we know it.

The planet orbits the star LTT 1445A, which is part of a triple system of three red dwarf stars that is 22 light-years away in the constellation Eridanus. The star has two other reported planets that are larger than LTT 1445Ac. A tight pair of two other dwarf stars, LTT 1445B and C, lies about 3 billion miles away from LTT 1445A, also resolved by Hubble. The alignment of the three stars and the edge-on orbit of the BC pair suggests that everything in the system is co-planar, including the known planets.

"Transiting planets are exciting since we can characterize their atmospheres with spectroscopy, not only with Hubble but also with the James Webb Space Telescope. Our measurement is important because it tells us that this is likely a very nearby terrestrial planet. We are looking forward to follow-on observations that will allow us to better understand the diversity of planets around other stars," said Pass.

This research has been accepted for publication in The Astronomical Journal.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, MDclaire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore, Maryland

Science Contact:Emily PassCenter for Astrophysics | Harvard & Smithsonian, Cambridge, Massachusetts

Hubble Space Telescope

Exoplanets

Stars Stories

Our Solar System

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Construction on NASA Mission to Map 450 Million Galaxies Is Under Way

6 min read

Key elements are coming together for NASA's SPHEREx mission, a space telescope that will create a map of the universe like none before.

NASA's SPHEREx space telescope is beginning to look much like it will when it arrives in Earth orbit and starts mapping the entire sky. Short for Specto-Photometer for the History of the Universe, Epoch of Reionization, and Ices Explorer, SPHEREx resembles a bullhorn, albeit one that will stand almost 8.5 feet tall (2.6 meters) and stretch nearly 10.5 feet (3.2 meters) wide. Giving the observatory its distinctive shape are its cone-shaped photon shields, which are being assembled in a clean room at NASA's Jet Propulsion Laboratory in Southern California.

Three cones, each nestled within the other, will surround SPHEREx's telescope to protect it from the light and heat of the Sun and Earth. The spacecraft will sweep over every section of the sky, like scanning the inside of a globe, to complete two all-sky maps every year.

"SPHEREx has to be quite agile because the spacecraft has to move relatively quickly as it scans the sky," said JPL's Sara Susca, deputy payload manager and payload systems engineer for the mission. "It doesn't look that way, but the shields are actually quite light and made with layers of material like a sandwich. The outside has aluminum sheets, and inside is an aluminum honeycomb structure that looks like cardboard – light but sturdy."

When it launches – no later than April 2025 – SPHEREx will help scientists better understand where water and other key ingredients necessary for life originated. To do this, the mission will measure the abundance of water ice in interstellar clouds of gas and dust, where new stars are born and from which planets eventually form. It will study the cosmic history of galaxies by measuring the collective light they produce. Those measurements will help tease out when galaxies began to form and how their formation has changed over time. Finally, by mapping the location of millions of galaxies relative to one another, SPHEREx will look for new clues about how the rapid expansion, or inflation, of the universe took place a fraction of a second after the big bang.

SPHEREx will do all this by detecting infrared light, a range of wavelengths longer than the visible light human eyes can see. Infrared light is also sometimes called heat radiation because all warm objects emit it. Even the telescope can create infrared light. Because that light would interfere with its detectors, the telescope has to be kept cold – below minus 350 degrees Fahrenheit (about minus 210 degrees Celsius).

The outer photon shield will block light and heat from the Sun and Earth, and the gaps between the cones will prevent heat from making its way inward toward the telescope. But to ensure SPHEREx gets down to its frigid operating temperature, it also needs something called a V-groove radiator: three conical mirrors, each like an upside-down umbrella, stacked atop one another. Sitting below the photon shields, each is composed of a series of wedges that redirect infrared light so it bounces through the gaps between the shields and out into space. This removes heat carried through the supports from the room-temperature spacecraft bus that contains the computer and electronics.

"We're not just concerned with how cold SPHEREx is, but also that its temperature stays the same," said JPL's Konstantin Penanen, payload manager for the mission. "If the temperature varies, it could change the sensitivity of the detector, which could translate as a false signal."

The heart of SPHEREx is, of course, its telescope, which collects infrared light from distant sources using three mirrors and six detectors. The telescope is tilted on its base so it can see as much of the sky as possible while remaining within the protection of the photon shields.Built by Ball Aerospace in Boulder, Colorado, the telescope arrived in May at Caltech in Pasadena, California, where it was integrated with the detectors and the V-groove radiator. Then, at JPL, engineers secured it to a vibration table that simulates the shaking that the telescope will endure on the rocket ride to space. After that, it went back to Caltech, where scientists confirmed its mirrors are still in focus following the vibration testing.

The mirrors inside SPHEREx's telescope collect light from distant objects, but it's the detectors that can "see" the infrared wavelengths the mission is trying to observe.

A star like our Sun emits the entire range of visible wavelengths, so it is white (though Earth's atmosphere causes it to look more yellow to our eyes). A prism can break that light into its component wavelengths – a rainbow. This is called spectroscopy.

SPHEREx will use filters installed on top of its detectors to perform spectroscopy. Only about the size of a cracker, each filter appears iridescent to the naked eye and has multiple segments to block all but one specific wavelength of infrared light. Every object SPHEREx observes will be imaged by each segment, enabling scientists to see the specific infrared wavelengths emitted by that object, whether it's a star or a galaxy. In total, the telescope can observe more than 100 distinct wavelengths.

And from that, SPHEREx will create maps of the universe unlike any that have come before.

SPHEREx is managed by JPL for NASA's Astrophysics Division within the Science Mission Directorate in Washington. Ball Aerospace built the telescope and will supply the spacecraft bus. The science analysis of the SPHEREx data will be conducted by a team of scientists located at 10 institutions across the U.S. and in South Korea. Data will be processed and archived at IPAC at Caltech. The SPHEREx data set will be publicly available.

For more information about the SPHEREx mission visit:

https://www.jpl.nasa.gov/missions/spherex/

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

2023-164

Why NASA’s Roman Mission Will Study Milky Way’s Flickering Lights

6 min read

NASA’s Nancy Grace Roman Space Telescope will provide one of the deepest-ever views into the heart of our Milky Way galaxy. The mission will monitor hundreds of millions of stars in search of tell-tale flickers that betray the presence of planets, distant stars, small icy objects that haunt the outskirts of our solar system, isolated black holes, and more. Roman will likely set a new record for the farthest-known exoplanet, offering a glimpse of a different galactic neighborhood that could be home to worlds quite unlike the more than 5,500 that are currently known.

Roman’s long-term sky monitoring, which will enable these results, represents a boon to what scientists call time-domain astronomy, which studies how the universe changes over time. Roman will join a growing, international fleet of observatories working together to capture these changes as they unfold. Roman’s Galactic Bulge Time-Domain Survey will focus on the Milky Way, using the telescope’s infrared vision to see through clouds of dust that can block our view of the crowded central region of our galaxy.

“Roman will be an incredible discovery machine, pairing a vast view of space with keen vision,” said Julie McEnery, the Roman senior project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Its time-domain surveys will yield a treasure trove of new information about the cosmos.”

When Roman launches, expected by May 2027, the mission will scour the center of the Milky Way for microlensing events, which occur when an object such as a star or planet comes into near-perfect alignment with an unrelated background star from our viewpoint. Because anything with mass warps the fabric of space-time, light from the distant star bends around the nearer object as it passes close by. The nearer object therefore acts as a natural magnifying glass, creating a temporary spike in the brightness of the background star’s light. That signal lets astronomers know there’s an intervening object, even if they can’t see it directly.

In current plans, the survey will involve taking an image every 15 minutes around the clock for about two months. Astronomers will repeat the process six times over Roman’s five-year primary mission for a combined total of more than a year of observations.

“This will be one of the longest exposures of the sky ever taken,” said Scott Gaudi, an astronomy professor at Ohio State University in Columbus, whose research is helping inform Roman’s survey strategy. “And it will cover territory that is largely uncharted when it comes to planets.”

Astronomers expect the survey to reveal more than a thousand planets orbiting far from their host stars and in systems located farther from Earth than any previous mission has detected. That includes some that could lie within their host star’s habitable zone – the range of orbital distances where liquid water can exist on the surface – and worlds that weigh in at as little as a few times the mass of the Moon.

Roman can even detect “rogue” worlds that don’t orbit a star at all using microlensing. These cosmic castaways may have formed in isolation or been kicked out of their home planetary systems. Studying them offers clues about how planetary systems form and evolve.

Roman’s microlensing observations will also help astronomers explore how common planets are around different types of stars, including binary systems. The mission will estimate how many worlds with two host stars are found in our galaxy by identifying real-life “Tatooine” planets, building on work started by NASA’s Kepler Space Telescope and TESS (the Transiting Exoplanet Survey

Satellite).

Some of the objects the survey will identify exist in a cosmic gray area. Known as brown dwarfs, they’re too massive to be characterized as planets, but not quite massive enough to ignite as stars. Studying them will allow astronomers to explore the boundary between planet and star formation.

Roman is also expected to spot more than a thousand neutron stars and hundreds of stellar-mass black holes. These heavyweights form after a massive star exhausts its fuel and collapses. The black holes are nearly impossible to find when they don’t have a visible companion to signal their presence, but Roman will be able to detect them even if unaccompanied because microlensing relies only on an object’s gravity. The mission will also find isolated neutron stars – the leftover cores of stars that weren’t quite massive enough to become black holes.

Astronomers will use Roman to find thousands of Kuiper belt objects, which are icy bodies scattered mostly beyond Neptune. The telescope will spot some as small as about six miles across (about 1 percent of Pluto’s diameter), sometimes by seeing them directly from reflected sunlight and others as they block the light of background stars.

A similar type of shadow play will reveal 100,000 transiting planets between Earth and the center of the galaxy. These worlds cross in front of their host star as they orbit and temporarily dim the light we receive from the star. This method will reveal planets orbiting much closer to their host stars than microlensing reveals, and likely some that lie in the habitable zone.

Scientists will also conduct stellar seismology studies on a million giant stars. This will involve analyzing brightness changes caused by sound waves echoing through a star’s gaseous interior to learn about its structure, age, and other properties.

All of these scientific discoveries and more will come from Roman’s Galactic Bulge Time-Domain Survey, which will account for less than a fourth of the observing time in Roman’s five-year primary mission. Its broad view of space will allow astronomers to conduct many of these studies in ways that have never been possible before, giving us a new view of an ever-changing universe.

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

Download high-resolution video and images from NASA’s Scientific Visualization Studio

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire AndreoliNASA’s Goddard Space Flight Center301-286-1940

Scorching, Seven-Planet System Revealed by New Kepler Exoplanet List

3 min read

A system of seven sweltering planets has been revealed by continued study of data from NASA's retired Kepler space telescope: Each one is bathed in more radiant heat from their host star per area than any planet in our solar system. Also unlike any of our immediate neighbors, all seven planets in this system, named Kepler-385, are larger than Earth but smaller than Neptune. It is one of only a few planetary systems known to contain more than six verified planets or planet candidates. The Kepler-385 system is among the highlights of a new Kepler catalog that contains almost 4,400 planet candidates, including more than 700 multi-planet systems.

"We've assembled the most accurate list of Kepler planet candidates and their properties to date," said Jack Lissauer, a research scientist at NASA's Ames Research Center in California's Silicon Valley and lead author on the paper presenting the new catalog. "NASA's Kepler mission has discovered the majority of known exoplanets, and this new catalog will enable astronomers to learn more about their characteristics."

At the center of the Kepler-385 system is a Sun-like star about 10% larger and 5% hotter than the Sun. The two inner planets, both slightly larger than Earth, are probably rocky and may have thin atmospheres. The other five planets are larger – each with a radius about twice the size of Earth's – and expected to be enshrouded in thick atmospheres.

The ability to describe the properties of the Kepler-385 system in such detail is testament to the quality of this latest catalog of exoplanets. While the Kepler mission's final catalogs focused on producing lists optimized to measure how common planets are around other stars, this study focuses on producing a comprehensive list that provides accurate information about each of the systems, making discoveries like Kepler-385 possible.

The new catalog uses improved measurements of stellar properties and calculates more accurately the path of each transiting planet across its host star. This combination illustrates that when a star hosts several transiting planets, they typically have more circular orbits than when a star hosts only one or two.

Kepler's primary observations ceased in 2013 and were followed by the telescope's extended mission, called K2, which continued until 2018. The data Kepler collected continues to reveal new discoveries about our galaxy. After the mission already showed us there are more planets than stars, this new study paints a more detailed picture of what each of those planets and their home systems look like, giving us a better view of the many worlds beyond our solar system.

The research article, "Updated Catalog of Kepler Planet Candidates: Focus on Accuracy and Orbital Periods" is forthcoming in The Journal of Planetary Science.

Learn more:

Listen to a sonification of the orbit data of the seven planets in the Kepler-385 system: https://www.youtube.com/watch?v=2BCiOTJjcQQ

For news media:

Members of the news media interested in covering this topic should reach out to the NASA Ames newsroom.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: The Planet that Shouldn’t Be There

3 min read

dbolles

By Pat Brennan

NASA's Exoplanet Exploration Program

The discovery: A large planet is somehow orbiting a star that should have destroyed it.

Key facts: Planet 8 Ursae Minoris b orbits a star some 530 light-years away that is in its death throes. A swollen red giant, the star would have been expected to expand beyond the planet’s orbit before receding to its present (still giant) size. In other words, the star would have engulfed and ripped apart any planets orbiting closely around it. Yet the planet remains in a stable, nearly circular orbit. The discovery of this seemingly impossible situation, relying on precise measurements using NASA’s Transiting Exoplanet Survey Satellite (TESS), shows that planet formation – and destruction – are likely far more intricate and unpredictable than many scientists might have thought.

Details: As stars like our Sun approach the ends of their lives, they begin to exhaust their nuclear fuel. They become red giants, expanding to their maximum size. If that happened in this case, the star would have grown outward from its center to 0.7 astronomical units – that is, about three-quarters the distance from Earth to the Sun. It would have swallowed and destroyed any nearby orbiting planets in the process. But planet b, a large gaseous world, sits at about 0.5 astronomical units, or AU. Because the planet could not have survived engulfment, Marc Hon, the lead author of a recent paper on the discovery, instead proposes two other possibilities: The planet is really the survivor of a merger between two stars, or it’s a new planet – formed out of the debris left behind by that merger.

The first scenario begins with two stars about the size of our Sun in close orbit around each other, the planet orbiting both. One of the stars “evolves” a bit faster than the other, going through its red giant phase, casting off its outer layers and turning into a white dwarf – the tiny but high-mass remnant of a star. The other just reaches the red giant stage before the two collide; what remains is the red giant we see today. This merger, however, stops the red giant from expanding further, sparing the orbiting planet from destruction. In the second scenario, the violent merger of the two stars ejects an abundance of dust and gas, which forms a disk around the remaining red giant. This “protoplanetary” disk provides the raw material for a new planet to coalesce. It’s a kind of late-stage second life for a planetary system – though the star still is nearing its end.

Fun facts: How can astronomers infer such a chaotic series of events from present-day observations? It all comes down to well understood stellar physics. Planet-hunting TESS also can be used to observe the jitters and quakes on distant stars, and these follow known patterns during the red-giant phase. (Tracking such oscillations in stars is known as “asteroseismology.”) The pattern of oscillations on 8 Ursae Minoris, the discovery team found, match those of red giants at a late, helium-burning stage – not one that is still expanding as it burns hydrogen. So it isn’t that the star is still growing and hasn’t yet reached the planet. The crisis has come and gone, but the planet somehow continues to exist.

The discoverers: The paper describing the TESS result, “A close-in giant planet escapes engulfment by its star,” was published in the journal Nature in June 2023 by an international science team led by astronomer Marc Hon of the University of Hawaii.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Roman Mission Gears Up for a Torrent of Future Data

5 min read

NASA’s Nancy Grace Roman Space Telescope team is exploring ways to support community efforts that will prepare for the deluge of data the mission will return. Recently selected infrastructure teams will serve a vital role in the preliminary work by creating simulations, scouting the skies with other telescopes, calibrating Roman’s components, and much more.

Their work will complement additional efforts by other teams and individuals around the world, who will join forces to maximize Roman’s scientific potential. The goal is to ensure that, when the mission launches by May 2027, scientists will already have the tools they need to uncover billions of cosmic objects and help untangle mysteries like dark energy.

“We’re harnessing the science community at large to lay a foundation, so when we get to launch we’ll be able to do powerful science right out of the gate,” said Julie McEnery, Roman’s senior project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “There’s a lot of exciting work to do, and many different ways for scientists to get involved.”

Simulations lie at the heart of the preparatory efforts. They enable scientists to test algorithms, estimate Roman’s scientific return, and fine-tune observing strategies so that we’ll learn as much as possible about the universe.

Teams will be able to sprinkle different cosmic phenomena through a simulated dataset and then run machine learning algorithms to see how well they can automatically find the phenomena. Developing fast and efficient ways to identify underlying patterns will be vital given Roman’s enormous data collection rate. The mission is expected to amass 20,000 terabytes (20 petabytes) of observations containing trillions of individual measurements of stars and galaxies over the course of its five-year primary mission.

“The preparatory work is complex, partly because everything Roman will do is quite interconnected,” McEnery said. “Each observation is going to be used by multiple teams for very different science cases, so we’re creating an environment that makes it as easy as possible for scientists to collaborate.”

Some scientists will conduct precursor observations using other telescopes, including NASA’s Hubble Space Telescope, the Keck Observatory in Hawaii, and Japan’s PRIME (Prime-focus Infrared Microlensing Experiment) located in the South African Astronomical Observatory in Sutherland. These observations will help astronomers optimize Roman’s observing plan by identifying the best individual targets and regions of space for Roman and better understand the data the mission is expected to deliver.

Some teams will explore how they might combine data from different observatories and use multiple telescopes in tandem. For example, using PRIME and Roman together would help astronomers learn more about objects found via warped space-time. And Roman scientists will be able to lean on archived Hubble data to look back in time and see where cosmic objects were and how they were behaving, building a more complete history of the objects astronomers will use Roman to study. Roman will also identify interesting targets that observatories such as NASA’s James Webb Space Telescope can zoom in on for more detailed studies.

It will take many teams working in parallel to plan for each Roman science case. “Scientists can take something Roman will explore, like wispy streams of stars that extend far beyond the apparent edges of many galaxies, and consider all of the things needed to study them really well,” said

Dominic Benford, Roman’s program scientist at NASA Headquarters in Washington, D.C. “That could include algorithms for dim objects, developing ways to measure star positions very precisely, understanding how detector effects could influence the observations and knowing how to correct for them, coming up with the most effective strategy to image stellar streams, and much more.”

One group is developing processing and analysis software for Roman’s Coronagraph Instrument. This instrument will demonstrate several cutting-edge technologies that could help astronomers directly image planets beyond our solar system. This team will also simulate different objects and planetary systems the Coronagraph could unveil, from dusty disks surrounding stars to old, cold worlds similar to Jupiter.

The mission’s science centers are gearing up to manage Roman’s data pipeline and archive and establishing systems to plan and execute observations. As part of a separate, upcoming effort, they will convene a survey definition team that will take in all of the preparatory information scientists are generating now and all the interests from the broader astronomical community to determine Roman’s optimal observation plans in detail.

“The team is looking forward to coordinating and funneling all the preliminary work,” McEnery said. “It’s a challenging but also exciting opportunity to set the stage for Roman and ensure each of its future observations will contribute to a wealth of scientific discoveries.”

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

Introduction The tenth Surface Water Ocean Topography (SWOT) Applications Workshop took place December 7–8, 2023…

In honor of the completion of our Nancy Grace Roman Space Telescope’s spacecraft — the…

Webb Detects Tiny Quartz Crystals in the Clouds of a Hot Gas Giant

6 min read

Researchers using NASA's James Webb Space Telescope have detected evidence for quartz nanocrystals in the high-altitude clouds of WASP-17 b, a hot Jupiter exoplanet 1,300 light-years from Earth. The detection, which was uniquely possible with MIRI (Webb's Mid-Infrared Instrument), marks the first time that silica (SiO_2) particles have been spotted in an exoplanet atmosphere.

"We were thrilled!" said David Grant, a researcher at the University of Bristol in the UK and first author on a paper being published today in the Astrophysical Journal Letters. "We knew from Hubble observations that there must be aerosols—tiny particles making up clouds or haze—in WASP-17 b's atmosphere, but we didn't expect them to be made of quartz."

Silicates (minerals rich in silicon and oxygen) make up the bulk of Earth and the Moon as well as other rocky objects in our solar system, and are extremely common across the galaxy. But the silicate grains previously detected in the atmospheres of exoplanets and brown dwarfs appear to be made of magnesium-rich silicates like olivine and pyroxene, not quartz alone – which is pure SiO_2.

The result from this team, which also includes researchers from NASA's Ames Research Center and NASA's Goddard Space Flight Center, puts a new spin on our understanding of how exoplanet clouds form and evolve. "We fully expected to see magnesium silicates," said co-author Hannah Wakeford, also from the University of Bristol. "But what we're seeing instead are likely the building blocks of those, the tiny 'seed' particles needed to form the larger silicate grains we detect in cooler exoplanets and brown dwarfs."

With a volume more than seven times that of Jupiter and a mass less than one-half Jupiter, WASP-17 b is one of the largest and puffiest known exoplanets. This, along with its short orbital period of just 3.7 Earth-days, makes the planet ideal for transmission spectroscopy : a technique that involves measuring the filtering and scattering effects of a planet's atmosphere on starlight.

Webb observed the WASP-17 system for nearly 10 hours, collecting more than 1,275 brightness measurements of 5- to 12-micron mid-infrared light as the planet crossed its star. By subtracting the brightness of individual wavelengths of light that reached the telescope when the planet was in front of the star from those of the star on its own, the team was able to calculate the amount of each wavelength blocked by the planet's atmosphere.

What emerged was an unexpected "bump" at 8.6 microns, a feature that would not be expected if the clouds were made of magnesium silicates or other possible high temperature aerosols like aluminum oxide, but which makes perfect sense if they are made of quartz.

Download full resolution images for this article from the Space Telescope Science Institute (STScI)

While these crystals are probably similar in shape to the pointy hexagonal prisms found in geodes and gem shops on Earth, each one is only about 10 nanometers across—one-millionth of one centimeter.

"Hubble data actually played a key role in constraining the size of these particles," explained co-author Nikole Lewis of Cornell University, who leads the Webb Guaranteed Time Observation (GTO) program designed to help build a three-dimensional view of a hot Jupiter atmosphere. "We know there is silica from Webb's MIRI data alone, but we needed the visible and near-infrared observations from Hubble for context, to figure out how large the crystals are."

Unlike mineral particles found in clouds on Earth, the quartz crystals detected in the clouds of WASP-17 b are not swept up from a rocky surface. Instead, they originate in the atmosphere itself. “WASP-17 b is extremely hot—around 1,500 degrees Celsius (2,700°F)—and the pressure where they form high in the atmosphere is only about one-thousandth of what we experience on Earth’s surface,” explained Grant. “In these conditions, solid crystals can form directly from gas, without going through a liquid phase first.”

Understanding what the clouds are made of is crucial for understanding the planet as a whole. Hot Jupiters like WASP-17 b are made primarily of hydrogen and helium, with small amounts of other gases like water vapor (H2O) and carbon dioxide (CO2). “If we only consider the oxygen that is in these gases, and neglect to include all of the oxygen locked up in minerals like quartz (SiO2), we will significantly underestimate the total abundance,” explained Wakeford. “These beautiful silica crystals tell us about the inventory of different materials and how they all come together to shape the environment of this planet.”

Exactly how much quartz there is, and how pervasive the clouds are, is hard to determine. “The clouds are likely present along the day/night transition (the terminator), which is the region that our observations probe,” said Grant. Given that the planet is tidally locked with a very hot day side and cooler night side, it is likely that the clouds circulate around the planet, but vaporize when they reach the hotter day side. “The winds could be moving these tiny glassy particles around at thousands of miles per hour.”

WASP-17 b is one of three planets targeted by the JWST-Telescope Scientist Team’s Deep Reconnaissance of Exoplanet Atmospheres using Multi-instrument Spectroscopy (DREAMS) investigations, which are designed to gather a comprehensive set of observations of one representative from each key class of exoplanets: a hot Jupiter, a warm Neptune, and a temperate rocky planet. The MIRI observations of hot Jupiter WASP-17 b were made as part of GTO program 1353.

The James Webb Space Telescope is the world’s premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Laura Betz – laura.e.betz@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

Hannah Braun – hbraun@stsci.edu , Christine Pulliam – cpulliam@stsci.ediSpace Telescope Science Institute, Baltimore, Md.

Download full resolution images for this article from the Space Telescope Science Institute.

NASA’s Exoplanet Website – https://exoplanets.nasa.gov/

More Webb News – https://science.nasa.gov/mission/webb/latestnews/

More Webb Images – https://science.nasa.gov/mission/webb/multimedia/images/

Webb Mission Page – https://science.nasa.gov/mission/webb/

Ciencia de la NASA

NASA en español

Space Place para niños

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Sees Evaporating Planet Getting the Hiccups

6 min read

NASA Hubble Mission Team

Goddard Space Flight Center

A young planet whirling around a petulant red dwarf star is changing in unpredictable ways orbit-by-orbit. It is so close to its parent star that it experiences a consistent, torrential blast of energy, which evaporates its hydrogen atmosphere — causing it to puff off the planet.

But during one orbit observed with NASA's Hubble Space Telescope, the planet looked like it wasn't losing any material at all, while an orbit observed with Hubble a year and a half later showed clear signs of atmospheric loss.

This extreme variability between orbits shocked astronomers. "We've never seen atmospheric escape go from completely not detectable to very detectable over such a short period when a planet passes in front of its star," said Keighley Rockcliffe of Dartmouth College in Hanover, New Hampshire. "We were really expecting something very predictable, repeatable. But it turned out to be weird. When I first saw this, I thought 'That can't be right.'"

Rockcliffe was equally puzzled to see, when it was detectable, the planet's atmosphere puffing out in front of the planet, like a headlight on a fast-bound train. "This frankly strange observation is kind of a stress-test case for the modeling and the physics about planetary evolution. This observation is so cool because we're getting to probe this interplay between the star and the planet that is really at the most extreme," she said.

Located 32 light-years from Earth, the parent star AU Microscopii (AU Mic) hosts one of the youngest planetary systems ever observed. The star is less than 100 million years old (a tiny fraction of the age of our Sun, which is 4.6 billion years old). The innermost planet, AU Mic b, has an orbital period of 8.46 days and is just 6 million miles from the star (about 1/10th the planet Mercury's distance from our Sun). The bloated, gaseous world is about four times Earth's diameter.

AU Mic b was discovered by NASA’s Spitzer and TESS (Transiting Exoplanet Survey Satellite) space telescopes in 2020. It was spotted with the transit method, meaning telescopes can observe a slight dip in the star's brightness when the planet crosses in front of it.

Red dwarfs like AU Microscopii are the most abundant stars in our Milky Way galaxy. They therefore should host the majority of planets in our galaxy. But can planets orbiting red dwarf stars like AU Mic b be hospitable to life? A key challenge is that young red dwarfs have ferocious stellar flares blasting out withering radiation. This period of high activity lasts a lot longer than that of stars like our Sun.

The flares are powered by intense magnetic fields that get tangled by the roiling motions of the stellar atmosphere. When the tangling gets too intense, the fields break and reconnect, unleashing tremendous amounts of energy that are 100 to 1,000 times more energetic than our Sun unleashes in its outbursts. It's a blistering fireworks show of torrential winds, flares, and X-rays blasting any planets orbiting close to the star. "This creates a really unconstrained and frankly, scary, stellar wind environment that's impacting the planet's atmosphere," said Rockcliffe.

Under these torrid conditions, planets forming within the first 100 million years of the star's birth should experience the most amount of atmospheric escape. This might end up completely stripping a planet of its atmosphere.

"We want to find out what kinds of planets can survive these environments. What will they finally look like when the star settles down? And would there be any chance of habitability eventually, or will they wind up just being scorched planets?" said Rockcliffe. "Do they eventually lose most of their atmospheres and their surviving cores become super-Earths? We don't really know what those final compositions look like because we don't have anything like that in our solar system."

While the star's glare prevents Hubble from directly seeing the planet, the telescope can measure changes in the star's apparent brightness caused by hydrogen bleeding off the planet and dimming the starlight when the planet transits the star. That atmospheric hydrogen has been heated to the point where it escapes the planet's gravity.

The never-before-seen changes in atmospheric outflow from AU Mic b may indicate swift and extreme variability in the host red dwarf's outbursts. There is so much variability because the star has a lot of roiling magnetic field lines. One possible explanation for the missing hydrogen during one of the planet's transits is that a powerful stellar flare, seen seven hours prior, may have photoionized the escaping hydrogen to the point where it became transparent to light, and so was not detectable.

Another explanation is that the stellar wind itself is shaping the planetary outflow, making it observable at some times and not observable at other times, even causing some of the outflow to "hiccup" ahead of the planet itself. This is predicted in some models, like those of John McCann and Ruth Murray-Clay from the University of California at Santa Cruz, but this is the first kind of observational evidence of it happening and to such an extreme degree, say researchers.

Hubble follow-up observations of more AU Mic b transits should offer additional clues to the star and planet's odd variability, further testing scientific models of exoplanetary atmospheric escape and evolution.

Rockcliffe is lead author on the science paper accepted for publication in The Astronomical Journal.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, MDclaire.andreoli@nasa.gov301-286-1940

Ray VillardSpace Telescope Science Institute, Baltimore, Md.villard@stsci.edu

Science Contact:

Keighley RockcliffeDartmouth College, Hanover, New Hampshire

As a radio frequency wireless engineer in NASA’s Johnson Space Center Avionic Systems Division in Houston, Melissa Moreno makes an impact in space exploration while proudly sharing her cultural heritage in the NASA community. Moreno works in the Electronic Systems Test Laboratory, developing communication systems critical to Gateway, NASA’s first lunar-orbiting space station. But her […]

Researchers found that long-duration spaceflight affected the mechanical properties of eye tissues, including reducing the stiffness of tissue around the eyeball. A better understanding of these changes could help researchers prevent, diagnose, and treat the vision impairment often seen in crew members. SANSORI, a Canadian Space Agency investigation, examined whether reduced stiffness of eye tissue contributes to […]

On Sept. 30, 1994, space shuttle Endeavour took to the skies on its 7th trip into space. During the 11-day mission, the STS-68 crew of Commander Michael A. Baker, Pilot Terrence “Terry” W. Wilcutt, and Mission Specialists Steven L. Smith, Daniel W. Bursch, Peter J.K. “Jeff” Wisoff, and Payload Commander Thomas “Tom” D. Jones operated […]

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Begins Integrating ‘Nervous System’ for Roman Space Telescope

3 min read

NASA’s Nancy Grace Roman Space Telescope team has begun integrating and testing the spacecraft’s electrical cabling, or harness, which enables different parts of the observatory to communicate with one another. Additionally, the harness provides power and helps the central computer monitor the observatory’s function via an array of sensors. This brings the mission a step closer to surveying billions of cosmic objects and untangling mysteries like dark energy following its launch by May 2027.

“Just as the nervous system carries signals throughout the human body, Roman’s harness connects its components, providing both power and commands to each electronic box and instrument,” said Deneen Ferro, the Roman harness project development lead at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Without a harness, there is no spacecraft.”

Weighing around 1,000 pounds, the harness is made up of approximately 32,000 wires and 900 connectors. If the wires were laid out end-to-end, they would span 45 miles. Directed upward, they would reach eight times higher than the peak of Mount Everest.

Achieving this milestone was no small task. Over the course of about two years, a team of 11 Goddard technicians spent time at the workbench and perched on ladders, cutting wire to length, meticulously cleaning each component, and repeatedly connecting everything together.

The entire harness was built on an observatory mock-up structure before being transported to Goddard’s Space Environment Simulator – a massive thermal vacuum chamber used in this case for “bakeout.” When observatories like Roman are sent to space, the resulting vacuum and orbital temperatures can cause certain materials to release harmful vapors, which can then condense within electronics and create problems like short circuits or deposits on sensitive optics, degrading the telescope’s performance. Bakeout releases these gases on Earth so they aren’t emitted inside the spacecraft when in space.

Now, engineers will weave the harness through the flight structure in Goddard’s big clean room. This ongoing process will continue until most of the spacecraft components are assembled. In the meantime, the Goddard team will soon begin installing electronics boxes that will eventually provide power via the harness to all the spacecraft’s science instruments.

For more information about the Roman Space Telescope visit: roman.gsfc.nasa.gov or www.nasa.gov/roman. To virtually tour an interactive version of the telescope, visit: https://roman.gsfc.nasa.gov/interactive/.

By Nora LoweNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire Andreoli NASA’s Goddard Space Flight Center301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Webb Discovers Methane, Carbon Dioxide in Atmosphere of K2-18 b

6 min read

A new investigation with NASA's James Webb Space Telescope into K2-18 b, an exoplanet 8.6 times as massive as Earth, has revealed the presence of carbon-bearing molecules including methane and carbon dioxide. Webb's discovery adds to recent studies suggesting that K2-18 b could be a Hycean exoplanet, one which has the potential to possess a hydrogen-rich atmosphere and a water ocean-covered surface.

The first insight into the atmospheric properties of this habitable-zone exoplanet came from observations with NASA's Hubble Space Telescope, which prompted further studies that have since changed our understanding of the system.

K2-18 b orbits the cool dwarf star K2-18 in the habitable zone and lies 120 light-years from Earth in the constellation Leo. Exoplanets such as K2-18 b, which have sizes between those of Earth and Neptune, are unlike anything in our solar system. This lack of equivalent nearby planets means that these 'sub-Neptunes' are poorly understood, and the nature of their atmospheres is a matter of active debate among astronomers.

The suggestion that the sub-Neptune K2-18 b could be a Hycean exoplanet is intriguing, as some astronomers believe that these worlds are promising environments to search for evidence for life on exoplanets.

"Our findings underscore the importance of considering diverse habitable environments in the search for life elsewhere," explained Nikku Madhusudhan, an astronomer at the University of Cambridge and lead author of the paper announcing these results. "Traditionally, the search for life on exoplanets has focused primarily on smaller rocky planets, but the larger Hycean worlds are significantly more conducive to atmospheric observations."

The abundance of methane and carbon dioxide, and shortage of ammonia, support the hypothesis that there may be a water ocean underneath a hydrogen-rich atmosphere in K2-18 b. These initial Webb observations also provided a possible detection of a molecule called dimethyl sulfide (DMS). On Earth, this is only produced by life. The bulk of the DMS in Earth's atmosphere is emitted from phytoplankton in marine environments.

The inference of DMS is less robust and requires further validation. "Upcoming Webb observations should be able to confirm if DMS is indeed present in the atmosphere of K2-18 b at significant levels," explained Madhusudhan.

While K2-18 b lies in the habitable zone, and is now known to harbor carbon-bearing molecules, this does not necessarily mean that the planet can support life. The planet's large size — with a radius 2.6 times the radius of Earth — means that the planet's interior likely contains a large mantle of high-pressure ice, like Neptune, but with a thinner hydrogen-rich atmosphere and an ocean surface. Hycean worlds are predicted to have oceans of water. However, it is also possible that the ocean is too hot to be habitable or be liquid.

"Although this kind of planet does not exist in our solar system, sub-Neptunes are the most common type of planet known so far in the galaxy," explained team member Subhajit Sarkar of Cardiff University. "We have obtained the most detailed spectrum of a habitable-zone sub-Neptune to date, and this allowed us to work out the molecules that exist in its atmosphere."

Characterizing the atmospheres of exoplanets like K2-18 b — meaning identifying their gases and physical conditions — is a very active area in astronomy. However, these planets are outshone — literally — by the glare of their much larger parent stars, which makes exploring exoplanet atmospheres particularly challenging.

The team sidestepped this challenge by analyzing light from K2-18 b’s parent star as it passed through the exoplanet’s atmosphere. K2-18 b is a transiting exoplanet, meaning that we can detect a drop in brightness as it passes across the face of its host star. This is how the exoplanet was first discovered in 2015 with NASA’s K2 mission. This means that during transits a tiny fraction of starlight will pass through the exoplanet’s atmosphere before reaching telescopes like Webb. The starlight’s passage through the exoplanet atmosphere leaves traces that astronomers can piece together to determine the gases of the exoplanet’s atmosphere.

“This result was only possible because of the extended wavelength range and unprecedented sensitivity of Webb, which enabled robust detection of spectral features with just two transits,” said Madhusudhan. “For comparison, one transit observation with Webb provided comparable precision to eight observations with Hubble conducted over a few years and in a relatively narrow wavelength range.”

“These results are the product of just two observations of K2-18 b, with many more on the way,” explained team member Savvas Constantinou of the University of Cambridge. “This means our work here is but an early demonstration of what Webb can observe in habitable-zone exoplanets.”

The team’s results were accepted for publication in The Astrophysical Journal Letters.

The team now intends to conduct follow-up research with the telescope’s MIRI (Mid-Infrared Instrument) spectrograph that they hope will further validate their findings and provide new insights into the environmental conditions on K2-18 b.

“Our ultimate goal is the identification of life on a habitable exoplanet, which would transform our understanding of our place in the universe,” concluded Madhusudhan. “Our findings are a promising step towards a deeper understanding of Hycean worlds in this quest.”

The James Webb Space Telescope is the world’s premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Laura Betz – laura.e.betz@nasa.govNASA’s Goddard Space Flight Center, Greenbelt, Md.

Hannah Braun – hbraun@stsci.edu , Christine Pulliam – cpulliam@stsci.ediSpace Telescope Science Institute, Baltimore, Md.

Bethany DownerEuropean Space Agency, Paris, France

Download full resolution images for this article from the Space Telescope Science Institute.

Exoplanets – https://exoplanets.nasa.gov/

More Webb News – https://science.nasa.gov/mission/webb/latestnews/

More Webb Images – https://science.nasa.gov/mission/webb/multimedia/images/

Webb Mission Page – https://science.nasa.gov/mission/webb/

Ciencia de la NASA

NASA en español

Space Place para niños

Overview Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way.…

Exoplanet Stories

Overview Our planetary system is located in an outer spiral arm of the Milky Way galaxy. We call it the…

Universe

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Webb Detects Water Vapor in Rocky Planet-Forming Zone

4 min read

New measurements by NASA's James Webb Space Telescope's MIRI (Mid-Infrared Instrument) have detected water vapor in the system's inner disk, at distances of less than 100 million miles (160 million kilometers) from the star – the region where rocky, terrestrial planets may be forming. (The Earth orbits 93 million miles from our Sun.)

Water is essential for life as we know it. However, scientists debate how it reached the Earth and whether the same processes could seed rocky exoplanets orbiting distant stars. New insights may come from the planetary system PDS 70, located 370 light-years away. The star hosts both an inner disk and outer disk of gas and dust, separated by a 5 billion-mile-wide (8 billion kilometer) gap, and within that gap are two known gas-giant planets.

New measurements by NASA's James Webb Space Telescope's MIRI (Mid-Infrared Instrument) have detected water vapor in the system's inner disk, at distances of less than 100 million miles (160 million kilometers) from the star – the region where rocky, terrestrial planets may be forming. (The Earth orbits 93 million miles from our Sun.) This is the first detection of water in the terrestrial region of a disk already known to host two or more protoplanets.

"We've seen water in other disks, but not so close in and in a system where planets are currently assembling. We couldn't make this type of measurement before Webb," said lead author Giulia Perotti of the Max Planck Institute for Astronomy (MPIA) in Heidelberg, Germany.

"This discovery is extremely exciting, as it probes the region where rocky planets similar to Earth typically form," added MPIA director Thomas Henning, a co-author on the paper. Henning is co-principal investigator of Webb's MIRI (Mid-Infrared Instrument), which made the detection, and the principal investigator of the MINDS (MIRI Mid-Infrared Disk Survey) program that took the data.

A Steamy Environment for Forming Planets

PDS 70 is a K-type star, cooler than our Sun, and is estimated to be 5.4 million years old. This is relatively old in terms of stars with planet-forming disks, which made the discovery of water vapor surprising.

Over time, the gas and dust content of planet-forming disks declines. Either the central star's radiation and winds blow out such material, or the dust grows into larger objects that eventually form planets. As previous studies failed to detect water in the central regions of similarly aged disks, astronomers suspected it might not survive the harsh stellar radiation, leading to a dry environment for the formation of any rocky planets.

Astronomers haven't yet detected any planets forming within the inner disk of PDS 70. However, they do see the raw materials for building rocky worlds in the form of silicates. The detection of water vapor implies that if rocky planets are forming there, they will have water available to them from the beginning.

"We find a relatively high amount of small dust grains. Combined with our detection of water vapor, the inner disk is a very exciting place," said co-author Rens Waters of Radboud University in The Netherlands.

What is the Water's Origin?

The discovery raises the question of where the water came from. The MINDS team considered two different scenarios to explain their finding.

One possibility is that water molecules are forming in place, where we detect them, as hydrogen and oxygen atoms combine. A second possibility is that ice-coated dust particles are being transported from the cool outer disk to the hot inner disk, where the water ice sublimates and turns into vapor. Such a transport system would be surprising, since the dust would have to cross the large gap carved out by the two giant planets.

Another question raised by the discovery is how water could survive so close to the star, when the star's ultraviolet light should break apart any water molecules. Most likely, surrounding material such as dust and other water molecules serves as a protective shield. As a result, the water detected in the inner disk of PDS 70 could survive destruction.

Ultimately, the team will use two more of Webb's instruments, NIRCam (Near-Infrared Camera) and NIRSpec (Near-Infrared Spectrograph) to study the PDS 70 system in an effort to glean an even greater understanding.

These observations were taken as part of Guaranteed Time Observation program 1282. This finding has been published in the journal Nature.

The James Webb Space Telescope is the world's premier space science observatory. Webb is solving mysteries in our solar system, looking beyond to distant worlds around other stars, and probing the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Media Contacts:

Laura BetzNASA's Goddard Space Flight Center, Greenbelt, Md.laura.e.betz@nasa.gov

Christine PulliamSpace Telescope Science Institute, Baltimore, Md.cpulliam@stsci.edu

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New Study Reveals NASA's Roman Could Find 400 Earth-Mass Rogue Planets

6 min read

New research by scientists from NASA and Japan's Osaka University suggests that rogue planets – worlds that drift through space untethered to a star – far outnumber planets that orbit stars. The results imply that NASA's Nancy Grace Roman Space Telescope, set to launch by May 2027, could find a staggering 400 Earth-mass rogue worlds. Indeed, this new study has already identified one such candidate.

"We estimate that our galaxy is home to 20 times more rogue planets than stars – trillions of worlds wandering alone," said David Bennett, a senior research scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and a co-author of two papers describing the results. "This is the first measurement of the number of rogue planets in the galaxy that is sensitive to planets less massive than Earth."

The team's findings stem from a nine-year survey called MOA (Microlensing Observations in Astrophysics), conducted at the Mount John University Observatory in New Zealand. Microlensing events occur when an object such as a star or planet comes into near-perfect alignment with an unrelated background star from our vantage point. Because anything with mass warps the fabric of space-time, light from the distant star bends around the nearer object as it passes close by. The nearer object acts as a natural lens, creating a brief spike in the brightness of the background star's light that gives astronomers clues about the intervening object that they can't get any other way.

"Microlensing is the only way we can find objects like low-mass free-floating planets and even primordial black holes," said Takahiro Sumi, a professor at Osaka University, and lead author of the paper with a new estimate of our galaxy's rogue planets. "It's very exciting to use gravity to discover objects we could never hope to see directly."

The roughly Earth-mass rogue planet the team found marks the second discovery of its kind. The paper describing the finding will appear in a future issue of The Astronomical Journal. A second paper, which presents a demographic analysis that concludes that rogue planets are six times more abundant than worlds that orbit stars in our galaxy, will be published in the same journal.

In only a few decades, we've gone from wondering whether the worlds in our solar system are alone in the cosmos to discovering more than 5,300 planets outside our solar system. The vast majority of these newfound worlds are either huge, extremely close to their host star, or both. By contrast, the team's results suggest that rogue planets tend to be on the petite side.

"We found that Earth-size rogues are more common than more massive ones," Sumi said. "The difference in star-bound and free-floating planets' average masses holds a key to understanding planetary formation mechanisms."

World-building can be chaotic, with all of the forming celestial bodies gravitationally interacting as they settle into their orbits. Planetary lightweights aren't tethered as strongly to their star, so some of these interactions end up flinging such worlds off into space. So begins a solitary existence, hidden amongst the shadows between stars.

In one of the early episodes of the original Star Trek series, the crew encounters one such lone planet amid a so-called star desert. They were surprised to ultimately find Gothos, the starless planet, habitable. While such a world may be plausible, the team emphasizes that the newly detected "rogue Earth" probably doesn't share many other characteristics with Earth beyond a similar mass.

Microlensing events that reveal solitary planets are extraordinarily rare, so one key to finding more is to cast a wider net. That’s just what Roman will do when it launches by May 2027.

“Roman will be sensitive to even lower-mass rogue planets since it will observe from space,” said Naoki Koshimoto, who led the paper announcing the detection of a candidate terrestrial-mass rogue world. Now an assistant professor at Osaka University, he conducted this research at Goddard. “The combination of Roman’s wide view and sharp vision will allow us to study the objects it finds in more detail than we can do using only ground-based telescopes, which is a thrilling prospect.”

Previous best estimates, based on planets found orbiting stars, suggested Roman would spot 50 terrestrial-mass rogue worlds. These new results suggest it could actually find about 400, though we’ll have to wait until Roman begins scanning the skies to make more certain predictions. Scientists will couple Roman’s future data with ground-based observations from facilities such as Japan’s PRIME (Prime-focus Infrared Microlensing Experiment) telescope, located at the South African Astronomical Observatory in Sutherland. This 1.8-meter telescope will build on MOA’s work by conducting the first wide-area microlensing survey in near-infrared light. It’s equipped with four detectors from Roman’s detector development program, contributed by NASA as part of an international agreement with JAXA (Japan Aerospace Exploration Agency).

Each microlensing event is a one-time occurrence, meaning astronomers can’t go back and repeat the observations once they’re over. But they’re not instantaneous.

“A microlensing signal from a rogue planet can take from a few hours up to about a day, so astronomers will have a chance to do simultaneous observations with Roman and PRIME,” Koshimoto said.

Seeing them from both Earth and Roman’s location a million miles away will help scientists measure the masses of rogue planets much more accurately than ever before, deepening our understanding of the worlds that grace our galaxy.

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire AndreoliNASA’s Goddard Space Flight Center301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Finding Life Beyond Earth: What Comes Next?

6 min read

Pat Brennan

The future is full of questions for us earthly life-forms. How far can we take our search for life elsewhere? Which new technologies are best for detecting life? Could we ever visit planets beyond our solar system?

And if we find life beyond Earth, how will it change us?

Scientists and technological experts suggest a variety of possibilities, but many seem to agree on at least one observation: The search for life is accelerating, sprouting new technologies and new ideas even as our view of the cosmos grows sharper.

A question often asked, so far without an answer, is whether we'll detect the first signs of life on another body within our solar system, or on an exoplanet – a planet orbiting another star.

Exploration of the solar system has the advantage of landing on planets, moons, or asteroids, and collecting samples for analysis. For the planets beyond our solar system, remote detection of signs of life will have to suffice.

Still, we might have good reason to expect the first detection will come from an exoplanet, said Mary Voytek, director of NASA's Astrobiology Program at the agency's headquarters in Washington.

Although solar system planets are more directly accessible, finding life among them poses enormous technical challenges – whether we're seeking life on Mars or on Jupiter's moon, Europa, or Saturn's Enceladus.

"The best hope on Mars is the subsurface," Voytek said. "How long will it take before we're able to drill into the subsurface? For Enceladus and Europa, we're talking about being in a subsurface ocean below kilometers of ice. How soon will it be before we actually get into those? It becomes more an issue of access and not of, I think, greater probability."

Exoplanets, on the other hand, despite the challenges of remote detection, offer a vast number of targets: thousands of planets confirmed so far in our galaxy, which likely contains hundreds of billions.

"Think about all the exoplanets out there," she said. "Suddenly we have this giant, vast possibility of things to search on."

And the right technology to conduct such a search is just coming online. NASA's James Webb Space Telescope is already adding to inventories of ingredients in exoplanet atmospheres; more powerful and sensitive observatories are being readied for the future search for life signs – also called biosignatures.

"In the short term, of course, we're hoping [the Webb telescope] is able to make detection of biosignature gases in the atmospheres of a couple of terrestrial worlds," said Michael Way, a physical scientist at NASA's Goddard Institute for Space Studies in New York who creates computer models of possible exoplanet atmospheres.

Hopes are also high for the next generation of ground-based telescopes, massive instruments 100 or 130 feet (30 or 40 meters) wide.

“It’s not clear to me that the instruments coming online in the early 2030s will be capable of that or not,” Way said. “There are calculations that show it’s possible.”

Farther off, one of the most anticipated life-seeking technologies is a possible future space telescope, NASA’s Habitable Worlds Observatory. Now in the early conceptual stages, the proposal is an answer to recommendations from the National Academy of Sciences as part of a “decadal survey” released in 2021. It outlines scientific priorities for the decade ahead, including the discovery and exploration of habitable planets.

The observatory’s imaging capability, well beyond that of any existing space telescope, would be used to observe 25 potentially Earth-like planets to search for signs of life.

Such initiatives, combined with missions to come, like NASA’s Mars Sample Return and the exploration of icy moons in the outer solar system, represent a turning point for our species, said Shawn Domagal-Goldman, the NASA program scientist for the program responsible for early development of the Habitable Worlds mission concept.

“We’re going to tell the story of life in the cosmos by using that unprecedented imaging capability – to study the long-term evolution of galaxies, the stars they’re made of, the matter that makes up those stars, and to help us understand how habitable worlds came to be,” he said. “And we’re going to search for signs of life on those habitable worlds.”

More exotic ideas for decades or even centuries ahead remain speculative, but include sending probes to other star systems. One private-sector concept, called Breakthrough Starshot, would use lasers to push a fleet of tiny “light sail” probes to a fraction of light speed, perhaps to reach the nearest star, Proxima Centauri, in 20 to 30 years.

But sending humans to other star systems, Way said, remains firmly in the realm of science fiction. While further human exploration of the solar system in decades ahead seems within reach, no existing or planned technology could preserve human life for the tens of thousands of years it might take to reach another star.

A shortcut to finding life, of course, would be picking up signals or evidence of intelligent life. “Technosignatures,” or signs of technological civilization, are gaining renewed attention from scientists at NASA and around the world.

The search would not be limited to signals via radio, or even the broader light spectrum. They might include evidence of pollution or artificial chemicals in exoplanet atmospheres, “city lights” on a planet’s night side, large artificial structures passing in front of a star, constellations of satellites, or waste heat detected as infrared radiation.

“Advanced civilizations, any civilizations using energy need to emit waste heat,” said Ravi Kopparapu, a researcher at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, who focuses much of his work on the hunt for non-radio technosignatures.

However the search plays out, whatever might be found, astronomer Jill Tarter, one of the world’s best-known seekers of intelligent life beyond Earth, hopes it will push humanity toward what she calls the “cosmic perspective.”

“We’re all Earthlings,” she said. “The cosmic perspective trivializes the differences among humans. So we need to become Earthlings, and act like that.”

In the very distant future Earth itself is, of course, expected to meet its demise. In about five billion years, our dying Sun should swell into a red-giant phase, engulfing some of its nearer planets and perhaps Earth along with them. By then, an increasingly hot Sun would have long-since rendered our planet uninhabitable in any case.

Would that end our chapter in the cosmic history of life? Maybe not. If humanity hasn’t become extinct by then, we might have migrated to another planetary system.

“Assuming we don’t exterminate ourselves in the meantime, we’ll find a way to go somewhere else,” Way said.

Such a story could, in fact, have been repeated many times throughout the history of the cosmos.

This article is one in a series about how NASA is searching for life in the cosmos.

Beginnings: Life on Our World and Others

Life on Other Planets: What is Life and What Does It Need?

The Hunt for Life on Mars – and Elsewhere in the Solar System

'Life' in the Lab

Searching for Signs of Intelligent Life: Technosignatures

Finding Life Beyond Earth: What Comes Next?

Search for Life

Stars

Universe

Black Holes

‘Life’ in the Lab

10 min read

Pat Brennan

Growing chemical gardens. Searching for life’s building blocks in meteorites. Sketching out a path to exotic life on a moon of Saturn.

Interplanetary probes and space telescopes take the search for life beyond Earth to new heights. But just as indispensable is the laboratory work on Earth itself. Experimenters seek to puzzle out the chemical origins of life, or capture evidence of molecules common to living things in samples from other objects in the solar system.

Some even have kickstarted Darwinian evolution in a test-tube. The process of natural selection, made famous by Charles Darwin, was seen in the well-known experiment, and appeared to meet, at least technically, NASA’s working definition of life: “a self-sustaining chemical system capable of Darwinian evolution.”

NASA scientists are part of a global push to understand how life began on our planet, how it might develop on others, and how we can use technology to detect it, within our solar system or in the stars beyond.

“My origin-of-life work is focused on how to get from a geochemical environment to the start of organic chemistry,” said Laurie Barge, co-leader of the Origins and Habitability Lab at NASA’s Jet Propulsion Laboratory in Southern California. “We don’t know what pieces of the first life came when. What came first? What came later? Was it before or after the cell emerged?”

Barge is known for chemical gardens – flasks full of materials that attempt to simulate the environment, chemistry and even the electrical charge of hydrothermal vents on the floors of primordial oceans. They’re designed to explore how metabolism, a critical component of all life, might have chugged into operation in such vents some 4 billion years ago.

It's only one of several scenarios astrobiologists have suggested as early paths to eventual life, and metabolism is not even life itself – just a way of turning organic compounds into energy, a baseline requirement for any living thing. The process later might have been co-opted by opportunistic, incipient life forms, though no one knows just how that could have happened.

These hydrothermal vents, or “chimneys,” also might be present on the sea floor of Saturn’s moon, Enceladus, or other “ocean worlds” that hide global oceans under shells of ice.

“These chimneys on the early Earth, also Enceladus: What types of environments, what sort of chemistry do those drive?” Barge asks. “What kind of energy do they generate?”

Whether the elements of eventual life began on a sea floor or, say, a pond on the land surface, they might have been infused with ingredients delivered from above.

Rocks as Time Travelers

While we can’t travel back in time to early Earth, many asteroids have remained unchanged for billions of years, making them akin to time capsules of the infant solar system. What’s more, pieces of space rocks that fall to Earth, called meteorites, also contain clues about the building blocks of early planets, and maybe even life.

At NASA's Goddard Space Flight Center in Greenbelt, Maryland, Jason Dworkin, senior scientist for astrobiology, is investigating the composition and chemistry of meteorites.

Dworkin's lab also analyzes samples of other solar system bodies returned to Earth by missions like Hayabusa2 from the Japanese space agency, JAXA, NASA's Stardust, and Apollo, and soon-to-be-delivered asteroid samples from NASA's OSIRIS-REx.

Organic compounds in rocks from space, though not signs of biology in themselves, might have been important to the origin of life on Earth – especially in the early period after Earth's formation, when large asteroids were striking the surface more frequently.

"We try to understand the chemistry that could have been happening on Earth," Dworkin said. "Though we know extraterrestrial material was raining down on Earth, we don't know how important it was for life. We don't know if it was a major or minor component, or the silver bullet that caused it to happen."

Still, research by Dworkin and others has yielded potentially significant clues. In 2009, his lab was the first to detect an amino acid called glycine – a building block of life – in a comet, after analyzing samples returned by NASA's Stardust spacecraft.

A more recent sample return in 2020, material from the rocky Ryugu asteroid delivered by Hayabusa2, provided evidence of amino acids, sulfur compounds, and even uracil, an important informational unit in the RNA found in Earth life, and niacin, a form of vitamin B3.

And OSIRIS-REx, now carrying a sample of material from the asteroid Bennu back to Earth, already has revealed veins of carbonate on the asteroid's surface. The sample could shed light on the chemistry of such bodies, perhaps analogous to early chemistry on Earth.

Even the composition of asteroids could offer insight into the early formation of Earth and other planets.

The coming Artemis missions, taking humans back to the Moon, will include collection of samples by Artemis III; another planned "Sample Return" mission to Mars will gather cached sample tubes and bring them back to Earth.

"I love being able to look at a sample directly from an object, and interrogate that," Dworkin said. "With Hayabusa2, OSIRIS-REx, Artemis III coming up, Mars sample-return coming up, there's going to be so much to look at. We'll do comparative geochemistry, comparative astrobiology, across different objects."

Titan on Earth

Within the solar system or beyond, another intriguing – if perhaps less likely – possibility is sometimes called "life as we don't know it:" life-forms based on unfamiliar molecular components, or using a solvent other than water. Saturn's moon, Titan, often has been cited as a potential environment for such exotic forms.

Titan's surface is in such a deep freeze that water is essentially rock. Yet the moon has a thick atmosphere, lakes, rivers, and precipitation – the only solar system body other than Earth with such a liquid cycle.

The lakes and rivers are composed of methane and ethane. Could some form of life thrive on these liquids, as Earth life does on water?

Laboratory work has provided some surprising clues. Titan's extremely low surface temperatures – minus 290 degrees Fahrenheit (minus 179 Celsius) – make heat energy for chemistry hard to come by. And chemical reactions require liquid to act as a solvent, though methane has proven to be a poor one, ethane only marginally better, said Jonathan Lunine, an astronomy professor at Cornell University who has studied possible paths of chemistry on Titan's surface.

"If you can't get things dissolved in a liquid, not much is going to happen," Lunine said.

But experiments by researchers at JPL showed that, at least under some conditions, organic material can condense out of these liquids. One possibility involves precipitation from these liquids of crystal structures. The structures could then act as templates to form similar crystals, in essence reproducing themselves.

"Maybe stuff like that would lead to something sort of lifelike," said Robert Hodyss, a laboratory studies group supervisor at JPL.

The lab work is suggestive, he said, but much more data will be needed from Titan itself. That is expected to come from NASA's Dragonfly spacecraft, a dual-quadcopter that will fly from site to site on Titan's surface to conduct some "lab work" of its own. Dragonfly is expected to reach the smoggy moon in the mid 2030s after a seven-year journey.

"The Dragonfly mission is looking for prebiotic molecules that look familiar to us," said Melissa Trainer at NASA Goddard, the deputy principal investigator for the mission. "We're looking at the chemical inventory once we get there, to get an idea of relative abundances, the context in which we find them."

That will allow investigators to interpret the findings, and perhaps determine whether the molecules and chemistry suggest the potential for life. "We could see an indication, with our best understanding, that could be relevant for some kind of biochemistry, even if it's one that isn't familiar," she said.

Evidence of exotic life forms thriving on methane or ethane, however, might be difficult to detect, even if they somehow developed on Titan's surface.

"Once you get into 'life as we don't know it,' there are a lot of open questions there," Trainer said.

Yet Titan – like Jupiter's moon, Europa, or Saturn's Enceladus – also is likely to be an ocean world, harboring liquid water beneath an ice-covered surface. That raises another possibility: organic material from the surface pushed deep into the moon, making contact with the subsurface ocean and, finding higher temperatures and pressures, interacting in ways that could produce a habitable environment.

Scientists also have proposed that surface impacts could drive organics from the surface into the underlying ocean.

Or, Trainer said, such an impact, or even volcanic eruptions of frozen material – "cryovolcanoes" – could create warm conditions allowing liquid water environments to thrive for a time. Lab work has shown that compounds containing carbon, hydrogen, and nitrogen that might be building blocks of biochemistry could accumulate on the surface under such conditions.

How Life Began

While such findings can yield key insights, astrobiology in the lab is not limited to creation of potentially habitable conditions, exotic or otherwise. Other experiments explore pathways to the start of life itself.

Among the best known of these was conducted by Gerald Joyce, a research professor at the Salk Institute in La Jolla, California, and collaborator Tracey Lincoln. They created an RNA-based system, then coaxed it into sustained Darwinian evolution in a test-tube. Lincoln, lead author and Joyce's PhD student at the time, published the finding in 2009.

Although it technically met NASA's working definition of life – a self-sustaining chemical system capable of Darwinian evolution – Joyce says that in his view, it still didn't qualify as a true life-form.

"I was the first to say, 'It doesn't make it,'" Joyce said. Left to its own, the system, with its fragile, low-capacity RNA molecule, would hardly be able to evolve from where it started.

"It wouldn't have been too long till it was dead," he said. "There was just not enough information carrying capacity" in the relatively short strands of RNA that were used.

In Joyce's view, life's system for recording and transmitting information must, in itself, possess enough information capacity to evolve entirely new processes – body armor, locomotion, or reproductive strategies, for example.

"We're talking about more than just being 'capable' of undergoing Darwinian evolution," he said. "It has to have – this is where it gets hard – some broad capacity to undergo Darwinian evolution. You need enough information to keep evolving: sensory systems, nervous systems, things like photosynthesis. If there's enough complexity to invent a new biochemical function – that would do it for me."

Still, his system might have borne at least a passing resemblance to some of the earliest forms of life. Research suggests that an "RNA" world might have preceded our DNA-dominated present. Although a more delicate molecule with far lower capacity to store information, RNA could have taken the first, halting steps toward life as we know it.

"There's very good circumstantial evidence, based on the way biology unfolded, that RNA-based life preceded DNA," Joyce said.

In the broad view, he said, momentum in astrobiology appears to be building. Advances in laboratory understanding of life's components are beginning to converge with groundbreaking exploration of our solar system and deeper observation of planets around other stars.

"Many exciting things are happening," he said. "There's a focus on extrasolar planets, but what is happening on Mars is also incredible, with rovers, a helicopter, and a sample-return mission coming. And the next target will be the icy outer moons. It's a really fun time in astrobiology."

This article is one in a series about how NASA is searching for life in the cosmos.

Beginnings: Life on Our World and Others

Life on Other Planets: What is Life and What Does It Need?

The Hunt for Life on Mars – and Elsewhere in the Solar System

'Life' in the Lab

Searching for Signs of Intelligent Life: Technosignatures

Finding Life Beyond Earth: What Comes Next?

Climate change is rapidly reshaping a region of the world that's home to millions of people. In the next 30 years, Pacific Island nations such as Tuvalu, Kiribati, and Fiji will experience at least 6 inches (15 centimeters) of sea level rise, according to an analysis by NASA's sea level change science team. This amount […]

Arctic sea ice retreated to near-historic lows in the Northern Hemisphere this summer, likely melting to its minimum extent for the year on Sept.11, 2024, according to researchers at NASA and the

National Snow and Ice Data Center (NSIDC). The decline continues the decades-long trend of shrinking and thinning ice cover in the Arctic Ocean. […]

Designed to be user-friendly, the resource contains the latest sea level data, explainers, and other information from several U.S. agencies. The U.S. Interagency Task Force on Sea Level Change launched the U.S. Sea Level Change website on Monday, Sept. 23. Designed to help communities prepare for rising seas, the site features the latest science on […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The Hunt for Life on Mars – and Elsewhere in the Solar System

8 min read

Pat Brennan

While Mars seems to be a promising nearby place to search for life beyond Earth, the Red Planet has held on stubbornly to its secrets. Despite decades of investigation – and even two initially exciting results – sure signs of life have yet to emerge.

Now this long search could be on the cusp of bearing fruit. The Perseverance rover has been scouring an ancient Martian crater, once filled with water, for evidence of past life, and caching samples of rock and surface material in metal tubes for eventual return to Earth.

And those past exciting results, though now considered to have fallen short of proving life ever thrived on our neighboring planet, are seen as an essential foundation to the focused, multi-layered search that is underway today.

“Previous missions have helped us understand better how to search for life,” said Lindsay Hays, deputy program scientist for the Astrobiology Program – studying the possibility of life beyond Earth – at NASA Headquarters in Washington, and the deputy lead scientist for the Mars Sample Return mission.

The in-depth exploration of Mars also will serve as a proving ground for the broader search to come: surveying ice-covered moons in the outer solar system for some sign of life in the vast oceans hidden beneath their surfaces.

“NASA has invested a lot in the search for life on Mars, and learned a lot that is going to help us as we look at other habitable places in the solar system – like the icy moons orbiting Saturn and Jupiter,” said Mary Voytek, director of the NASA Astrobiology Program at the agency’s headquarters in Washington.

Searching in Mars Rocks

To find the roots of NASA’s strategy in the search for life among our neighboring worlds, we might look back to the 1970s: the days of Carl Sagan and the twin Viking landers, which made history when both touched down on Mars in 1976.

Sagan, host of the original “Cosmos” television series, helped design and manage Viking 1 and Viking 2, which transmitted photos and gathered science data from the Martian surface. They also conducted life detection experiments, collecting samples of Martian surface material, called regolith, and adding nutrients. Despite signs that some nutrients were being consumed, most of the scientific community concluded this was likely due to non-biological reactions, dousing an initial spark of excitement over the possible discovery of life on Mars.

A second big moment came in 1996, when NASA scientists published a paper outlining possible chemical traces of life-forms in a Martian rock that fell to Earth. Known colloquially as the Allan Hills meteorite, or by its official number, ALH84001, it had been collected in Antarctica more than a decade earlier.

While meteorites from Mars have fallen to Earth regularly over the history of the two planets – likely blasted into space when large objects like asteroids slammed into the Red Planet, then eventually being captured by Earth’s gravitational field – this one seemed special. It contained chemical traces similar to those left behind by Earth microbes; some photographs even revealed microscopic features that looked something like bacteria. Once again, however, a global thrill of potential discovery subsided into uncertainty. Today, most scientists who have studied this question consider a non-biological source as the likely origin of the “evidence” for traces of past Martian microbes in the meteorite.

The group of researchers who published the paper, led by NASA scientist David S. McKay, “sometimes have been sort of short-changed,” said Andrew Steele, a Carnegie Institution staff scientist who also has investigated the Martian rock. “The actual impact they had on this science should be celebrated more, for taking the chances they did. It’s what led us to being able to ask the next set of really important questions.”

The team’s findings spurred further research and highlighted a new realization: Many non-biological processes could produce lifelike features.

Steele’s own work, for example, aims to set a background level for “no life present” for environments on other worlds, including Mars. Potential life-detection results then could be measured against this background. Building on the work of McKay’s group and others, Steele and his fellow researchers have found three separate chemical processes that could produce life’s building blocks on Mars – each synthesizing organic molecules in the absence of any biological activity.

“Mars is exciting, and still may have signs of life,” he said. “But it is also teaching us about how the building blocks of life can form.”

And those two early attempts to find Martian life also led to another major revelation: The search would have to be comprehensive, not “grab and go,” said Hays, the astrobiologist.

“Both of those interpretations of results were inhibited by a lack of context,” Hays said. “In the case of the Viking, a lack of context about the measurements they were going to be making – what they could tell us about the environment we were measuring them in. In the case of Allan Hills [the Martian meteorite], a lack of context about the environment those rocks came from.”

Looking for Life on Mars

To move the investigation forward, NASA first decided not to take direct aim at detecting life itself. Instead, the twin rovers Spirit and Opportunity took a detailed survey of the Martian environment, confirming habitable conditions on early Mars in part through geological evidence of flowing water. Mars orbiters, such as NASA’s Mars Reconnaissance Orbiter and Mars Odyssey, also played a role, helping map terrain and select landing sites.

The Mars Curiosity rover made the case for habitability even stronger, capturing evidence of abundant water, organic molecules and habitable environments in Mars’ distant past. The rover continues its work today in Gale Crater, where it is still finding evidence of water activity in the past.

NASA turned back to the business of life detection with the arrival of the Perseverance rover at Jezero Crater in February 2021. Once a lake, complete with a river delta, Jezero seemed an ideal spot to search for life signs from Mars’ distant past.

But unlike the Viking landers, Perseverance is equipped with an array of tools both to examine Martian rocks for signs of ancient life and to explore their environmental context.

Also unlike Viking, the rovers can move. Perseverance targets interesting rock formations from a distance – with help from its helicopter scout, Ingenuity – then drives there for a closer look.

That also means Perseverance, which is caching samples that will later be returned to Earth, has an advantage over past investigations that lacked context for what they were finding. “This well-equipped rover is getting all this context as it's making all those great measurements," Hays said.

Other possible future places to look for signs of life include sites where water collected underground on ancient Mars, once forming a system of subsurface lakes.

Searching for Life Elsewhere in the Solar System

Little is known about the deep, ice-encased oceans of the solar system's outer moons, such as the Jupiter moon Europa and Saturn's Enceladus and Titan. But one thing is already clear: They'll offer vastly different conditions for potential life than Mars.

Still, these watery, sunless environments might have recognizable organic material and associated chemistry, and even a heat source – the moons' internal heat, perhaps released through vents in ocean floors. It's one way life might have started on Earth.

During a 13-year mission that ended in 2017, NASA's Cassini spacecraft detected plumes of salty water and organic molecules spewing from fractures known as "tiger stripes" on Enceladus – possibly from the moon's subsurface ocean, suggesting a potentially habitable environment.

Europa might have similar plumes: Data from NASA's Galileo spacecraft and Hubble telescope, as well as Earth-based telescopes, has hinted at their presence. NASA's Europa Clipper spacecraft, now being assembled for possible launch in October 2024, will carry sensors capable of analyzing any plume material it might encounter in a series of flybys past the ice-encrusted moon.

And Saturn's Titan, though best known for its thick hydrocarbon atmosphere and lakes of ethane and methane, is likely an ocean world as well – like the others, concealing a deep, liquid-water ocean beneath an icy shell. If the subsurface somehow makes contact with the surface – now or in the past – evidence of molecules or chemistry suggesting the potential for life might be found there. NASA's Dragonfly mission, a rotor-driven flier, will search for such evidence in a mission planned for the mid 2030s.

Although the Martian and outer moon environments are vastly different, the principles of searching for life remain the same.

"What we've learned about life on Earth is, as long as there are some basic things like nutrients, water, and energy, we're going to find life," Voytek said. "And we believe that many environments within the solar system meet these requirements. But they have yet to be explored."

This article is one in a series about how NASA is searching for life in the cosmos.

Beginnings: Life on Our World and Others

Life on Other Planets: What is Life and What Does It Need?

The Hunt for Life on Mars – and Elsewhere in the Solar System

'Life' in the Lab

Searching for Signs of Intelligent Life: Technosignatures

Finding Life Beyond Earth: What Comes Next?

Climate change is rapidly reshaping a region of the world that's home to millions of people. In the next 30 years, Pacific Island nations such as Tuvalu, Kiribati, and Fiji will experience at least 6 inches (15 centimeters) of sea level rise, according to an analysis by NASA's sea level change science team. This amount […]

Arctic sea ice retreated to near-historic lows in the Northern Hemisphere this summer, likely melting to its minimum extent for the year on Sept.11, 2024, according to researchers at NASA and the National Snow and Ice Data Center (NSIDC). The decline continues the decades-long trend of shrinking and thinning ice cover in the Arctic Ocean. […]

Designed to be user-friendly, the resource contains the latest sea level data, explainers, and other information from several U.S. agencies. The U.S. Interagency Task Force on Sea Level Change launched the U.S. Sea Level Change website on Monday, Sept. 23. Designed to help communities prepare for rising seas, the site features the latest science on […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Searching for Signs of Intelligent Life: Technosignatures

8 min read

Pat Brennan

Our first confirmed proof of life beyond Earth might not involve biology at all. It’s possible that we might intercept communication through electromagnetic waves, like radio, or find telescopic evidence of epic engineering.

While the search remains largely focused on non-technological life, NASA scientists also have begun to consider what technological traces of intelligent life – “technosignatures” – might look like. They wouldn’t come from planets in our solar system, but rather far-flung exoplanets that we cannot see up close. Among the possibilities are laser or radio pulses, signs of artificial chemicals in the atmospheres of distant planets, or “Dyson spheres” – massive structures built around stars to collect their energy.

And as acceptance in the scientific community slowly grows, a field once derided as a search for “little green men” is showing early signs of blossoming into a mature, serious investigation.

“That’s something we’ve worked very hard on: to establish our legitimacy, and distance ourselves from pseudo-science,” said Jill Tarter, an astronomer known for decades as a leader in the search for intelligent life beyond Earth. “If anything, my conviction that this is an important and reasonable thing to do has increased.”

Tarter is the co-founder and former director of the Center for SETI (Search for Extraterrestrial Intelligence) Research at the SETI Institute, as well as the inspiration for the main character in Carl Sagan’s 1985 novel “Contact.” She says one of the biggest challenges today is moving the search for signs of technology beyond just radio signals.

“We still want to look at all the sky all the time, at all wavelengths,” Tarter said, including pulses of laser light that might be used for communication.

Another challenge is short-lived “transient” signals, one-time events that can be bright and energetic. Mixed among the many natural sources for such signals, like gamma-ray bursts or supernovae, might be artificial transients from distant civilizations – an engineered signal lasting less than a few minutes. But teasing them apart likely would require enormous amounts of computer time.

“We’re trying to figure out how to do that,” Tarter said. “That is our focus now.”

Artificial intelligence could prove an ally in such searches. Sophisticated algorithms can sort through large amounts of data for patterns that could indicate an engineered signal. And AI searches likely would have fewer of the possible biases of human analysts, who might tend to focus their search on types of signals they’ve defined in advance, or view as more likely.

Stretching boundaries in the search for technosignatures is a high priority for Ravi Kopparapu, a researcher at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, who specializes in the hunt for habitable worlds as well as technosignatures.

He, like Tarter, seeks to define potential signals beyond the radio realm.

In published work, Kopparapu has explored using “nitrogen dioxide pollution as a signature for technology,” he said. After all, Earth’s pollution levels reflect human activity. Satellites monitoring our own planet have observed changes, too – for example, a temporary dip in such pollution around urban centers during COVID-19 lockdowns.

“I thought, OK, can we use that as a signature of technology another civilization might be using?” he said.

Carbon is the fourth most abundant element in the observable universe, and is relatively reactive, making it a natural candidate for involvement in synthetic reactions that any life-form might use. Carbon has formed the basis of life and many technologies on Earth.

“We should expect similar things to happen on other planets,” Kopparapu said. “They should be having the same elements we have here; then they could have carbon-based life, carbon-based technology, and fossil fuel technology as well.”

Another clearly artificial chemical would be chlorofluorocarbons, or CFCs, once heavily used as refrigerants here on Earth. Highly damaging to the planet’s protective ozone layer, they were phased out after the Montreal Protocol agreement in the late 1980s. Detection of the chemical in the atmospheres of exoplanets – planets around other stars – might be possible under some conditions, Kopparapu said.

And another phenomenon sometimes considered a form of “pollution,” at least by astronomers, is artificial light. Though difficult to observe, capturing the glimmer of “city lights” on the night side of a rocky, Earth-sized planet would be a clear sign of at least moderately advanced technology.

One speculative product of a super-advanced civilization could be “Dyson spheres” – megastructures around other stars, as outlined decades ago by the late physicist Freeman Dyson. A hypothetical structure could partially block the light from, say, a mature, Sun-like star, as it gathers the star’s energy. A Dyson sphere’s presence would be revealed by “waste heat” – observed as excess infrared radiation.

“If the technology is using lots of solar energy, giant solar panels in space blocking 1% of the star’s light, there will be a huge, whopping infrared signature,” said Jason Wright, an astronomy and astrophysics professor at Penn State who works on a variety of problems involving stars, planets and the potential for life in the universe.

Infrared radiation is usually associated with young stars, surrounded by dusty disks where planets are forming. The disks absorb the starlight and emit an excess of telltale infrared light.

"An old star like the Sun doesn't have any right having that much [infrared] emission coming off it,” Wright said.

Investigations of these and other potential technosignatures have begun to proliferate, prompting some NASA astrophysicists to conduct a survey of such efforts – and to identify the technologies the investigators might require.

Nick Siegler, chief technologist for the Exoplanet Exploration Program at NASA’s Jet Propulsion Laboratory in Southern California, and his team have so far catalogued more than 40 technosignature investigations by scientists in related fields.

The investigations run from the familiar to the exotic. That includes well-known searches for radio signals as well as novel approaches: looking for strange gamma-ray emissions that might indicate highly advanced propulsion systems, or light signatures of large, obviously artificial structures passing in front of – “transiting” – their stars.

“Imagine that some ETs, for not a huge price, built a massive triangle,” Siegler said. “Those don’t naturally appear in the cosmos. The light curve [measurements of the star’s brightness over time] of a massive, transiting triangle doesn’t look like a disk.”

He sees the renewed focus on technosignatures as a natural outgrowth of NASA’s broader search for life beyond Earth. And he says technosignatures, defined as evidence of advanced life, are a subset of biosignatures – evidence of all biological life, including microorganisms.

“NASA is fully committed to the search for life being one of its key science goals,” Siegler said. “Technosignatures will be part of the continuum of evidence of life we will search for on exoplanets.”

Tarter was, in fact, the project scientist for NASA’s former SETI Microwave Observing Project and High Resolution Microwave Survey from 1989 to 1993. But NASA’s recent, more visible involvement in technosignature searches began with a workshop in Houston in 2018. The organizer, exoplanet researcher Dawn Gelino, says both the number and membership of technosignature working groups have grown since then. And several agency research programs have begun to allow technosignature proposals.

Gelino is deputy director of the NASA Exoplanet Science Institute, and also a co-lead for NASA’s Nexus for Exoplanetary System Science (NExSS) research coordination network. She says NExSS’ technosignatures working group is planning a webinar on the topic in summer 2023. NExSS also supported the NASA-sponsored “Technoclimes” online workshop in 2020 to develop a research agenda for non-radio technosignatures.

More workshops by privately funded groups also are being added to the mix.

“We have to show everyone that technosignatures is a real field of study – quantitative, hard science – and needs funding in order to be able to grow and be part of the whole exoplanet ecosystem,” Gelino said.

One way to grow technosignature studies, Tarter, Siegler and other scientists say, is to “piggyback” on studies of exoplanets and other cosmic phenomena. If a space telescope is already looking at a star for other reasons, the same data can be examined for signs of technosignatures. That would help contain costs while widening the aperture in the search for signs of technological civilizations.

And seeking technosignatures in data beyond radio – chemistry, for example, or patterns in absorption and emission of energy – also could broaden the scientific basis of technosignature investigations.

“It’s a really exciting time to be in the search,” said Wright, the Penn State researcher. “I think we have a real shot if something’s out there.”

This article is one in a series about how NASA is searching for life in the cosmos.

Beginnings: Life on Our World and Others

Life on Other Planets: What is Life and What Does It Need?

The Hunt for Life on Mars – and Elsewhere in the Solar System

'Life' in the Lab

Searching for Signs of Intelligent Life: Technosignatures

Finding Life Beyond Earth: What Comes Next?

Climate change is rapidly reshaping a region of the world that’s home to millions of people. In the next 30 years, Pacific Island nations such as Tuvalu, Kiribati, and Fiji will experience at least 6 inches (15 centimeters) of sea level rise, according to an analysis by NASA’s sea level change science team. This amount […]

Arctic sea ice retreated to near-historic lows in the Northern Hemisphere this summer, likely melting to its minimum extent for the year on Sept.11, 2024, according to researchers at NASA and the National Snow and Ice Data Center (NSIDC). The decline continues the decades-long trend of shrinking and thinning ice cover in the Arctic Ocean. […]

Designed to be user-friendly, the resource contains the latest sea level data, explainers, and other information from several U.S. agencies. The U.S. Interagency Task Force on Sea Level Change launched the U.S. Sea Level Change website on Monday, Sept. 23. Designed to help communities prepare for rising seas, the site features the latest science on […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Webb Rules Out Thick Carbon Dioxide Atmosphere for Rocky Exoplanet

6 min read

Infrared measurements of TRAPPIST-1 c indicate that it is probably not as Venus-like as once imagined.

An international team of researchers has used NASA's James Webb Space Telescope to calculate the amount of heat energy coming from the rocky exoplanet TRAPPIST-1 c. The result suggests that the planet's atmosphere – if it exists at all – is extremely thin.

With a dayside temperature of roughly 380 kelvins (about 225 degrees Fahrenheit), TRAPPIST-1 c is now the coolest rocky exoplanet ever characterized based on thermal emission. The precision necessary for these measurements further demonstrates Webb's utility in characterizing rocky exoplanets similar in size and temperature to those in our own solar system.

The result marks another step in determining whether planets orbiting small red dwarfs like TRAPPIST-1 – the most common type of star in the galaxy – can sustain atmospheres needed to support life as we know it.

"We want to know if rocky planets have atmospheres or not," said Sebastian Zieba, a graduate student at the Max Planck Institute for Astronomy in Germany and first author on results being published today in Nature. "In the past, we could only really study planets with thick, hydrogen-rich atmospheres. With Webb we can finally start to search for atmospheres dominated by oxygen, nitrogen, and carbon dioxide."

"TRAPPIST-1 c is interesting because it's basically a Venus twin: It's about the same size as Venus and receives a similar amount of radiation from its host star as Venus gets from the Sun," explained co-author Laura Kreidberg, also from Max Planck. "We thought it could have a thick carbon dioxide atmosphere like Venus."

TRAPPIST-1 c is one of seven rocky planets orbiting an ultracool red dwarf star (or M dwarf) 40 light-years from Earth. Although the planets are similar in size and mass to the inner, rocky planets in our own solar system, it is not clear whether they do in fact have similar atmospheres. During the first billion years of their lives, M dwarfs emit bright X-ray and ultraviolet radiation that can easily strip away a young planetary atmosphere. In addition, there may or may not have been enough water, carbon dioxide, and other volatiles available to make substantial atmospheres when the planets formed.

To address these questions, the team used MIRI (Webb's Mid-Infrared Instrument) to observe the TRAPPIST-1 system on four separate occasions as the planet moved behind the star, a phenomenon known as a secondary eclipse. By comparing the brightness when the planet is behind the star (starlight only) to the brightness when the planet is beside the star (light from the star and planet combined) the team was able to calculate the amount of mid-infrared light with wavelengths of 15 microns given off by the dayside of the planet.

This method is the same as that used by another research team to determine that TRAPPIST-1 b, the innermost planet in the system, is probably devoid of any atmosphere.

The amount of mid-infrared light emitted by a planet is directly related to its temperature, which is in turn influenced by atmosphere. Carbon dioxide gas preferentially absorbs 15-micron light, making the planet appear dimmer at that wavelength. However, clouds can reflect light, making the planet appear brighter and masking the presence of carbon dioxide.

In addition, a substantial atmosphere of any composition will redistribute heat from the dayside to the nightside, causing the dayside temperature to be lower than it would be without an atmosphere. (Because TRAPPIST-1 c orbits so close to its star – about 1/50th the distance between Venus and the Sun – it is thought to be tidally locked, with one side in perpetual daylight and the other in endless darkness.)

Although these initial measurements do not provide definitive information about the nature of TRAPPIST-1 c, they do help narrow down the likely possibilities. “Our results are consistent with the planet being a bare rock with no atmosphere, or the planet having a really thin CO_2 atmosphere (thinner than on Earth or even Mars) with no clouds,” said Zieba. “If the planet had a thick CO_2 atmosphere, we would have observed a really shallow secondary eclipse, or none at all. This is because the CO_2 would be absorbing all of the 15-micron light, so we wouldn’t detect any coming from the planet.”

The data also shows that it is unlikely the planet is a true Venus analog with a thick CO_2 atmosphere and sulfuric acid clouds.

The absence of a thick atmosphere suggests that the planet may have formed with relatively little water. If the cooler, more temperate TRAPPIST-1 planets formed under similar conditions, they too may have started with little of the water and other components necessary to make a planet habitable.

The sensitivity required to distinguish between various atmospheric scenarios on such a small planet so far away is truly remarkable. The decrease in brightness that Webb detected during the secondary eclipse was just 0.04 percent: equivalent to looking at a display of 10,000 tiny light bulbs and noticing that just four have gone out.

“It is extraordinary that we can measure this,” said Kreidberg. “There have been questions for decades now about whether rocky planets can keep atmospheres. Webb’s ability really brings us into a regime where we can start to compare exoplanet systems to our solar system in a way that we never have before.”

This research was conducted as part of Webb’s General Observers (GO) program 2304, which is one of eight programs from Webb’s first year of science designed to help fully characterize the TRAPPIST-1 system. This coming year, researchers will conduct a follow-up investigation to observe the full orbits of TRAPPIST-1 b and TRAPPIST-1 c. This will make it possible to see how the temperatures change from the day to the nightsides of the two planets and will provide further constraints on whether they have atmospheres or not.

The James Webb Space Telescope is the world’s premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency), and CSA (Canadian Space Agency). MIRI was contributed by NASA and ESA, with the instrument designed and built by a consortium of nationally funded European Institutes (the MIRI European Consortium) and NASA’s Jet Propulsion Laboratory, in partnership with the University of Arizona.

Media Contacts:

Laura BetzNASA’s Goddard Space Flight Center, Greenbelt, Md.laura.e.betz@nasa.gov

Margaret Carruthers / Christine PulliamSpace Telescope Science Institute, Baltimore, Md.mcarruthers@stsci.edu / cpulliam@stsci.edu

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Life on Other Planets: What is Life and What Does It Need?

7 min read

Pat Brennan

One day, perhaps in the not-too-distant future, a faraway planet could yield hints that it might host some form of life – but surrender its secrets reluctantly.

Our space telescopes might detect a mixture of gases in its atmosphere that resembles our own. Computer models would offer predictions about the planet's life-bearing potential. Experts would debate whether the evidence made a strong case for the presence of life, or try to find still more evidence to support such a groundbreaking interpretation.

"We are in the beginning of a golden era right now," said Ravi Kopparapu, a scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, who studies habitable planets. "For the first time in the history of civilization we might be able to answer the question: Is there life beyond Earth?"

For exoplanets – planets around other stars – that era opens with NASA's James Webb Space Telescope. Instruments aboard the spacecraft are detecting the composition of atmospheres on exoplanets. As the power of telescopes increases in the years ahead, future advanced instruments could capture possible signs of life – "biosignatures" – from a planet light-years away.

Within our solar system, the Perseverance rover on Mars is gathering rock samples for eventual return to Earth, so scientists can probe them for signs of life. And the coming Europa Clipper mission will visit an icy moon of Jupiter. Its goal: to determine whether conditions on that moon would allow life to thrive in its global ocean, buried beneath a global ice shell.

But any hints of life beyond Earth would come with another big question: How certain could any scientific conclusions really be?

"The challenge is deciding what is life – when to say, 'I found it,'" said Laurie Barge of the Origins and Habitability Lab at NASA's Jet Propulsion Laboratory in Southern California.

With so much unknown about what even constitutes a "sign of life," astrobiologists are working on a new framework to understand the strength of the evidence. A sample framework, proposed in 2021, includes a scale ranging from 1 to 7, with hints of other life at level 1, to increasingly substantial evidence, all the way to certainty of life elsewhere at level 7. This framework, which is being discussed and revised, acknowledges that scientific exploration in the search for life is a twisted, winding road, rather than a straightforward path.

And identifying definitive signs remains difficult enough for "life as we know it." Even more uncertain would be finding evidence of life as we don't know it, made of unfamiliar molecular combinations or based on a solvent other than water.

Still, as the search for life begins in earnest, among the planets in our own solar system as well as far distant systems known only by their light, NASA scientists and their partners around the world have some ideas that serve as starting points.

Life That Evolves

First, there’s NASA’s less-than-formal, non-binding but still helpful working definition of life: “A self-sustaining chemical system capable of Darwinian evolution.” Charles Darwin famously described evolution by natural selection, with characteristics preserved across generations leading to changes in organisms over time.

Derived in the 1990s by a NASA exobiology working group, the definition is not used to design missions or research projects. It does help to set expectations, and to focus debate on the critical issues around another thorny question: When does non-life become life?

“Biology is chemistry with history,” says Gerald Joyce, one of the members of the working group that helped create the NASA definition and now a research professor at the Salk Institute in La Jolla, California.

That means history recorded by the chemistry itself – in our case, inscribed in our DNA, which encodes genetic data that can be translated into the structures and physical processes that make up our bodies.

The DNA record must be robust, complex, self-replicating and open-ended, Joyce suggests, to endure and adapt over billions of years.

“That would be a smoking gun: evidence for information having been recorded in molecules,” Joyce said.

Such a molecule from another world in our solar system, whether DNA, RNA or something else, might turn up in a sample from Mars, say from the Mars sample-return mission now being planned by NASA.

Or it might be found among the “ocean worlds” in the outer solar system – Jupiter’s moon, Europa, Saturn’s Enceladus or one of the other moons of gas giants that hide vast oceans beneath shells of ice.

We can’t obtain samples of such information-bearing molecules from planets beyond our solar system, since they are so far away that it would take tens of thousands of years to travel there even in the fastest spaceships ever built. Instead, we’ll have to rely on remote detection of potential biosignatures, measuring the types and quantities of gases in exoplanet atmospheres to try to determine whether they were generated by life-forms. That likely will require deeper knowledge of what life needs to get its start – and to persist long enough to be detected.

A Place Where Life Emerges

There is no true consensus on a list of requirements for life, whether in our solar system or the stars beyond. But Joyce, who researches life’s origin and development, suggests a few likely “must-haves.”

Topping the list is liquid water. Despite a broad spectrum of environmental conditions inhabited by living things on Earth, all life on the planet seems to require it. Liquid water provides a medium for the chemical components of life to persist over time and come together for reactions, in a way that air or the surface of a rock don’t do as well.

Also essential: an energy source, both for chemical reactions that produce structures and to create “order” against the universal tendency toward “disorder” – also known as entropy.

An imbalance in atmospheric gases also might offer a tell-tale sign of the presence of life.

“In Earth’s atmosphere, oxygen and methane are highly reactive with each other,” Kopparapu said. Left to themselves, they would quickly cancel each other out.

“They should not be seen together,” he said. “So why are we seeing methane, why are we seeing oxygen? Something must be constantly replenishing these compounds.”

On Earth, that “something” is life, pumping more of each into the atmosphere and keeping it out of balance. Such an imbalance, in these compounds or others, could be detected on a distant exoplanet, suggesting the presence of a living biosphere. But scientists also will have to rule out geological processes like volcanic or hydrothermal activity that could generate molecules that we might otherwise associate with life.

Careful laboratory work and precision modeling of possible exoplanet atmospheres will be needed to tell the difference.

Going Through Changes

Barge also places high on the list the idea of “gradients,” or changes that occur over time and distance, like wet to dry, hot to cold, and many other possible environments. Gradients create places for energy to go, changing along the way and generating molecules or chemical systems that later might be incorporated into life-forms.

Plate tectonics on Earth, and the cycling of gases like carbon dioxide – buried beneath Earth’s crust by subduction, perhaps, or released back into the atmosphere by volcanoes – represent one kind of gradient.

Barge’s specialty, the chemistry of hydrothermal vents on the ocean floor billions of years ago, is another. It’s one possible pathway to have created a kind of primitive metabolism – the translation of organic compounds into energy – as a potential precursor to true life-forms.

“What gradients existed before life?” she asks. “If life depends so much on gradients, could the origin of life also have benefited from these gradients?”

Clearer mapping of possible pathways to life ultimately could inform the design of future space telescopes, tasked with parsing the gases in the atmospheres of potentially habitable exoplanets.

“If we want to be sure it’s coming from biology, we have to not only look for gases; we have to look at how it’s being emitted from the planet, if it’s emitted in the right quantities, in the right way,” Kopparapu said. “With future telescopes, we’ll be more confident because they’ll be designed to look for life on other planets.”

This article is one in a series about how NASA is searching for life in the cosmos.

Beginnings: Life on Our World and Others

Life on Other Planets: What is Life and What Does It Need?

The Hunt for Life on Mars – and Elsewhere in the Solar System

'Life' in the Lab

Searching for Signs of Intelligent Life: Technosignatures

Finding Life Beyond Earth: What Comes Next?

Climate change is rapidly reshaping a region of the world that’s home to millions of people. In the next 30 years, Pacific Island nations such as Tuvalu, Kiribati, and Fiji will experience at least 6 inches (15 centimeters) of sea level rise, according to an analysis by NASA’s sea level change science team. This amount […]

Arctic sea ice retreated to near-historic lows in the Northern Hemisphere this summer, likely melting to its minimum extent for the year on Sept.11, 2024, according to researchers at NASA and the National Snow and Ice Data Center (NSIDC). The decline continues the decades-long trend of shrinking and thinning ice cover in the Arctic Ocean. […]

Designed to be user-friendly, the resource contains the latest sea level data, explainers, and other information from several U.S. agencies. The U.S. Interagency Task Force on Sea Level Change launched the U.S. Sea Level Change website on Monday, Sept. 23. Designed to help communities prepare for rising seas, the site features the latest science on […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Beginnings: Life on Our World and Others

10 min read

Pat Brennan

Where do we begin?

To chart the course of life in the cosmos, we might start with the first cells, moving and burning energy – perhaps in a hollow on Earth's freshly minted surface, or a superheated vent at the bottom of an ancient sea.

But a true understanding of life, on Earth or some other world, likely will require us to unravel even earlier beginnings: the ignition of stars with their freight of life's building blocks, the formation of planets from protoplanetary disks, the energy and chemistry of surfaces and atmospheres.

With more than 5,000 exoplanets confirmed, and likely billions more in our Milky Way galaxy, possible places where other life might reside have skyrocketed in recent years. And with more sophisticated telescopes scanning the sky and in development, we have better tools than ever to understand these distant worlds.

To seek answers to that age-old question "Are we alone?" with these new tools, what do we need to know?

"We don't know where to look or what to look for if we don't understand what happened on Earth," said Mary Voytek, director of the NASA Astrobiology Program at the agency's headquarters in Washington.

The question of origins quickly becomes a heavy lift, so it might be best to break it into pieces. Let's start with what we know.

How Did Earth End Up With Life?

Much of NASA's astrobiology research, studying the origins and requirements of life in the cosmos, begins right here at home. And it goes all the way back to the birth of our star, the Sun, inside a swirling cloud of gas and dust.

That cloud contained ingredients essential to life, including carbon, water, ammonia, methane, and other building blocks – molecules made from elements mostly forged in the hearts of previous generations of stars, whose explosive deaths scattered their contents through the cosmos.

Seeing the same components in distant families of stars and planets can check the first box on the list of habitable conditions.

"It started with the star," Voytek said. "The reason it ended with life on Earth is in the details: How planets formed out of the rotating disk of dense gas surrounding a newly formed star, the relationship to the whole system – the star, the other planets around it – that made Earth habitable and supported the emergence and evolution of life."

Next on the list of conditions favorable to habitability: where Earth wound up once our solar system formed. Earth dwells in the "habitable zone," the orbital distance from a star that allows liquid water to pool on a planet's surface under a suitable atmosphere. Life on Earth inhabits a shockingly diverse range of conditions, from deep cold to caustic, boiling pools, but all appear to require liquid water. Scientists expect water to be essential to life on other worlds as well.

Venus, otherwise Earth’s twin in size and rocky composition, orbits too close to the Sun, just inside the inner edge of the habitable zone. On its surface, hot enough to melt lead, liquid water is out of the question, though it might have existed in the past. On today’s Martian surface, frozen and exposed beneath the thinnest of atmospheres at the habitable zone’s outer edge, persistent liquid water is highly unlikely.

The icy moons of the outer solar system, with their hidden oceans of liquid water, also might provide habitable conditions – despite being well outside the traditional habitable zone.

While environments similar to those found among our planets and moons could prevail in systems elsewhere in the galaxy, some – such as potentially habitable “exomoons” – are beyond the reach of our present remote sensing technology. So the habitable zone and the possibility of surface water are at best a rough guide, helping astronomers sort through the variety of exoplanets for potential life-bearing targets.

Getting the Right Chemistry

Scientists interested in this question, as well as understanding life’s origin, also focus on molecules and chemistry. How did microscopic interactions on a volatile early Earth, some four billion years ago, create an energy consuming, waste producing package of material we would define as “alive?”

Scientists offer many potential scenarios for jump-starting life, said Betül Kaçar, a professor in the Department of Bacteriology at the University of Wisconsin-Madison. Kaçar heads the Molecular Paleobiology Laboratory at UW-Madison, as well as the NASA Interdisciplinary Consortium for Astrobiology Research (ICAR) project, Metal Utilization and Selection across Eons (MUSE), which studies the delicate dance between evolution, geochemistry and the biology of early life.

“Maybe life started through comet impact,” Kaçar said. “Or shock synthesis, or hydrothermal vents. These are among the more popular, big ideas.”

Her research group takes an experimental approach, focusing in part on enzymes – the proteins that trigger chemical reactions in our cells, aka metabolism, that can help construct or break down cellular material.

“We resurrect multiple important enzymes to explore ancient biological systems that basically go back to the birth of these metabolic innovations – how life learned to use what was available in its environment, including the atmosphere, in the first place,” Kaçar said. “We are using available DNA to reverse the clock and go back billions of years into the past.”

Kaçar says she’s also seen a shift in recent years in astrobiology research, toward exploring the behavior of ancient aggregations of molecules that might be seen as life-like, rather than simply synthesizing the chemical compounds associated with early life.

These might well include “messier” forms of molecules, Voytek said – “proto-molecules,” able to store information or catalyze reactions, but far more primitive and less efficient than the comparatively efficient RNA and DNA we’re familiar with today.

“We’re looking at these as life-like, but not exactly life,” Voytek said.

Voytek and Kaçar see another shift as well: an expansion in our view of the history of life on Earth that ranges from the bottom of the deep ocean at hydrothermal vents – a viable possible pathway for life’s origin – all the way up to potential life-generating chemistry on the earliest land surface. The components and functions of life might even have arisen piecemeal, at various times and places over hundreds of millions of years, only later stitching together to form recognizable, living organisms.

Chemistry across this spectrum can access “more variety of energy sources, mineral diversity, presence of wet-dry cycles,” Kaçar said. “When it comes to the origin of life, it’s about location, location, location, and also chemistry.”

What We Can Learn from Other Planets

Meanwhile, as our eyes on the universe grow in sophistication, so does our ability to find exoplanets and learn more about them.

So far, telescopes have revealed exoplanets come in many flavors, some rocky, some gaseous. They include “super-Earths,” which might or might not be scaled-up, rocky worlds, and “mini-Neptunes,” junior versions of our own Neptune – two planet types that, though common in the galaxy, are strange to us because they don’t occur in our solar system. Add to the menagerie “hot Jupiters” and “hot Saturns,” in tight, scorching orbits around their stars, and rogue planets floating freely through space without a parent star.

Human knowledge of other worlds continues to be profoundly shaped by increasingly powerful space telescopes. Surveys by NASA’s now-retired Kepler and the still-active Transiting Exoplanet Survey Satellite (TESS) have helped us discover planets, while the James Webb Space Telescope has begun delivering a torrent of images and atmospheric data. The Roman Space Telescope, expected to launch in 2027, may discover some 100,000 more of these distant worlds, in addition to testing new technology for directly imaging exoplanets.

Future, even more powerful space telescopes could search exoplanet atmospheres directly for signs of life – what astrobiologists call biosignatures.

But if Earth is our model for seeking evidence of life among the exoplanets, we must learn not only how to detect biosignatures from a planet that resembles our present-day world. We also must try to recognize life signs on planets that resemble Earth’s distant past, when conditions were very different than the present day.

Timothy Lyons, a biogeochemistry professor at the University of California, Riverside, heads the Alternative Earths Team, previously funded through the NASA Astrobiology Institute and now as an ICAR project. The team probes how Earth might have looked to a distant observer at various points in its 4.5-billion-year existence.

“Earth is the only planet we know of with life,” Lyons said. “But Earth has been many different planets over its history. Those are the alternative Earths.”

Would we recognize a living Earth, for instance, before oxygen was abundant enough in the atmosphere to be detected? Life-forms that did not rely on oxygen thrived for billions of years before an oxygenated atmosphere would have registered on the instruments of an observer many light-years away. And after life began producing oxygen, its accumulation in the atmosphere was likely low enough to evade detection for billions of years.

It’s even possible, he said, that oxygen would have remained undetectable until perhaps as recently as 800 million years ago, long after the earliest appearance of complex life – cells with a central nucleus – and about the same time as the earliest animal life.

One of the goals of Lyons’ research team is to use chemical measurements of ancient rocks, which provide a record of the past, as well as computer models, to produce a kind of catalog of gaseous profiles of Earth’s many phases. Using such a platform, they can imagine possibilities on distant planets, even if very different from anything in Earth’s archives. If Webb and future space telescopes capture matching profiles in the atmosphere of an exoplanet, it could be a strong sign of a “biosphere” – a world marked by environmental conditions and changes that drive, and are driven by, some form of life.

“The ultimate objective is to understand how a planet can develop and sustain a detectable biosphere – not only to know that [life] could be there, but that it is there,” Lyons said. “And we hope our work will inform designs of new telescopes and the interpretations of the first waves of atmospheric composition data from planets in habitable zones.”

Future investigators also will have to recognize non-biological processes that might yield gases we interpret as biosignatures. Photochemistry and certain atmospheric properties could produce abundant oxygen, for instance, on a planet devoid of life.

Taking such a holistic view of the potential for life beyond Earth requires multi-disciplinary teams like Lyons’ and Kaçar’s, involving biologists, geochemists, geologists, exoplanet researchers and others.

“It’s almost like a biologist, a geologist and an astronomer walk into a bar, and life happens,” Kaçar said. Or they might order a “smoothie,” she says, a blend of many scientific disciplines to crack the code of life detection – among our neighboring planets or the exoplanets scattered across the galaxy.

“There’s amazing interest right now, more than I’ve ever seen, toward pursuing this problem, an amazing amount of students,” she said. “It’s really wild and incredibly inspirational. That’s why I think we’re very close to solving this. It’s great fun.”

This article is one in a series about how NASA is searching for life in the cosmos.

Beginnings: Life on Our World and Others

Life on Other Planets: What is Life and What Does It Need?

The Hunt for Life on Mars – and Elsewhere in the Solar System

'Life' in the Lab

Searching for Signs of Intelligent Life: Technosignatures

Finding Life Beyond Earth: What Comes Next?

Climate change is rapidly reshaping a region of the world that’s home to millions of people. In the next 30 years, Pacific Island nations such as Tuvalu, Kiribati, and Fiji will experience at least 6 inches (15 centimeters) of sea level rise, according to an analysis by NASA’s sea level change science team. This amount […]

Arctic sea ice retreated to near-historic lows in the Northern Hemisphere this summer, likely melting to its minimum extent for the year on Sept.11, 2024, according to researchers at NASA and the National Snow and Ice Data Center (NSIDC). The decline continues the decades-long trend of shrinking and thinning ice cover in the Arctic Ocean. […]

Designed to be user-friendly, the resource contains the latest sea level data, explainers, and other information from several U.S. agencies. The U.S. Interagency Task Force on Sea Level Change launched the U.S. Sea Level Change website on Monday, Sept. 23. Designed to help communities prepare for rising seas, the site features the latest science on […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers Discover Planets in NASA Kepler’s Final Days of Observations

5 min read

Jeanette Kazmierczak

A team of astrophysicists and citizen scientists have identified what may be some of the last planets NASA’s retired Kepler space telescope observed during its nearly decade-long mission.

The trio of exoplanets – worlds beyond our solar system – are all between the size of Earth and Neptune and closely orbit their stars.

"These are fairly average planets in the grand scheme of Kepler observations,” said Elyse Incha, a senior at the University of Wisconsin-Madison. “But they’re exciting because Kepler observed them during its last few days of operations. It showcases just how good Kepler was at planet hunting, even at the end of its life.”

A paper about the planetary trio led by Incha was published in the May 30, 2023 issue of the journal Monthly Notices of the Royal Astronomical Society.

Kepler launched in March 2009. The mission’s initial goal was to continuously monitor a patch of sky in the northern constellations Cygnus and Lyra. This long period of observations allowed the satellite to track changes in stellar brightness caused by planets crossing in front of their stars, events called transits.

After four years, the telescope had observed over 150,000 stars and identified thousands of potential exoplanets. It was the first NASA mission to find an Earth-size world orbiting within its star’s habitable zone, the range of distances where liquid water could exist on a planet’s surface.

In 2014, the spacecraft experienced mechanical issues that temporarily halted observations. The Kepler team devised a fix that allowed it to resume operations, switching its field of view roughly every three months, a period called a campaign. This renewed mission, called K2, lasted another four years and surveyed over 500,000 stars.

When Kepler was retired in October 2018, it had aided the discovery of over 2,600 confirmed exoplanets and many more candidates.

K2’s final campaign, number 19, lasted only a month. As the spacecraft began to run low on attitude control fuel, it couldn’t maintain its position long enough to collect useful observations. In the end, astronomers only had about seven days of high-quality data from Campaign 19.

Incha and her team worked with the Visual Survey Group, a collaboration between citizen scientists and professional astronomers, to scan this dataset for exoplanets. The citizen scientists hunted for signals of transiting worlds over all Campaign 19’s light curves, which record how monitored stars brightened or dimmed.

“People doing visual surveys – looking over the data by eye – can spot novel patterns in the light curves and find single objects that are hard for automated searches to detect. And even we can’t catch them all,” said Tom Jacobs, a former U.S. Navy officer and Visual Survey Group team member. “I have visually surveyed the complete K2 observations three times, and there are still discoveries waiting to be found.”

Jacobs and others found one transit for each of the three planet candidates, each orbiting a different star, in the high-quality dataset.

After their initial discovery, Incha and her team also went back and looked at the lower-quality data from the rest of Campaign 19 and found one additional transit each from two of the three stars flagged in the visual search.

“The second transits for those two planet candidates helped us confirm their discovery,” said Andrew Vanderburg, an assistant professor of physics at the Kavli Institute for Astrophysics and Space Research at the Massachusetts Institute of Technology (MIT) in Cambridge. “No one had found planets in this dataset before, but our collaboration was able to find three. And we’re really pushing up against the last few days, the last few minutes, of observations Kepler collected.”

Using the transit information, Incha and her team calculated the worlds’ potential sizes and orbital periods. The smallest planet, K2-416 b, is about 2.6 times Earth’s size and orbits its red dwarf star about every 13 days. K2-417 b, just over three times Earth’s size, also orbits a red dwarf star but completes an orbit every 6.5 days. The final, unconfirmed planet, EPIC 246251988 b, is almost four times Earth’s size and orbits its Sun-like star in around 10 days. (The first two planets take their name from the K2 era of the mission, the last from the Ecliptic Plane Input Catalog (EPIC) of stars in the K2 fields.)

NASA’s Transiting Exoplanet Survey Satellite (TESS), which launched in April 2018, also uses the transit method, surveying large swaths of sky at a time. During August and September 2021, TESS observed the patch of space containing the three new Kepler planets. Astronomers were able to detect two more potential transits for K2-417 b.

“In many ways, Kepler passed the planet-hunting torch to TESS,” said Knicole Colón, the TESS project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, who worked on the Kepler mission for several years. “Kepler’s dataset continues to be a treasure trove for astronomers, and TESS helps give us new insights into its discoveries.”

NASA's Ames Research Center in California's Silicon Valley managed the Kepler and K2 missions for NASA's Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation in Boulder, Colorado, operated the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT and managed by Goddard. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA Ames; the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

Media Contact:

Claire Andreoli

NASA’s Goddard Space Flight Center, Greenbelt, Md.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Webb Maps and Finds Traces of Water in an Ultra-hot Gas Giant’s Atmosphere

6 min read

dbolles

There’s an intriguing exoplanet out there – 400 light-years out there – that is so tantalizing that astronomers have been studying it since its discovery in 2009. A year for WASP-18 b, one orbit around its star (slightly larger than our Sun), takes just 23 hours. There’s nothing like it in our solar system. In addition to observatories on the ground, NASA’s Hubble, Chandra, TESS, and Spitzer space telescopes have all observed WASP-18 b, an ultra-hot gas giant 10 times more massive than Jupiter. Now astronomers have taken a look with NASA’s James Webb Space Telescope and the ‘‘firsts’’ keep coming.

The discovery: Scientists identified water vapor in the atmosphere of WASP-18 b, and made a temperature map of the planet as it slipped behind, and reappeared from, its star. This event is known as a secondary eclipse. Scientists can read the combined light from star and planet, then refine the measurements from just the star as the planet moves behind it.

The same side, known as the dayside, of WASP-18 b always faces the star, just as the same side of the Moon always faces Earth. The temperature, or brightness, map shows a huge change in temperature – up to 1,000 degrees – from the hottest point facing the star to the terminator, where day and night sides of the tidally-locked planet meet in permanent twilight.

‘‘JWST is giving us the sensitivity to make much more detailed maps of hot giant planets like WASP-18 b than ever before. This is the first time a planet has been mapped with JWST, and it’s really exciting to see that some of what our models predicted, such as a sharp drop in temperature away from the point on the planet directly facing the star, is actually seen in the data!’’ said Megan Mansfield, a Sagan Fellow at the University of Arizona, and one of the authors of the paper describing the results.

The team mapped temperature gradients across the day side of the planet. Given how much cooler the planet is at the terminator, there is likely something hindering winds from efficiently redistributing heat to the night side. But what is affecting the winds is still a mystery.

‘‘The brightness map of WASP-18 b shows a lack of east-west winds that is best matched by models with atmospheric drag. One possible explanation is that this planet has a strong magnetic field, which would be an exciting discovery!’’ said co-author Ryan Challener, of the University of Michigan.

One interpretation of the eclipse map is that magnetic effects force the winds to blow from the planet’s equator up over the North pole and down over the South pole, instead of East-West, as we would otherwise expect.

Researchers recorded temperature changes at different elevations of the gas giant planet’s layers of atmosphere. They saw temperatures increase with elevation, varying by hundreds of degrees.

The spectrum of the planet’s atmosphere clearly shows multiple small but precisely measured water features, present despite the extreme temperatures of almost 5,000 degrees Fahrenheit (2,700 C). It’s so hot that it would tear most water molecules apart, so still seeing its presence speaks to Webb’s extraordinary sensitivity to detect remaining water. The amounts recorded in WASP-18 b’s atmosphere indicate water vapor is present at various elevations.

‘‘It was a great feeling to look at WASP-18 b’s JWST spectrum for the first time and see the subtle but precisely measured signature of water,’’ said Louis-Philippe Coulombe, a graduate student at the University of Montreal and lead author of the WASP-18 b paper. ‘‘Using such measurements, we will be able to detect such molecules for a wide range of planets in the years to come!’’

Researchers looked at WASP-18 b for about six hours with one of Webb’s instruments, the Near-Infrared Imager and Slitless Spectrograph (NIRISS), contributed by the Canadian Space Agency.

‘‘Because the water features in this spectrum are so subtle, they were difficult to identify in previous observations. That made it really exciting to finally see water features with these JWST observations,’’ said Anjali Piette, a postdoctoral fellow at the Carnegie Institution for Science and one of the authors of the new research.

The discoverers: More than 100 scientists around the globe are working on early science from Webb through the Transiting Exoplanet Community Early Release Science Program led by Natalie Batalha, an astronomer at the University of California, Santa Cruz, who helped coordinate the new research. Much of this groundbreaking work is being done by early career scientists like Coulombe, Challener, Piette, and Mansfield.

Proximity, both to its star and to us, helped make WASP-18 b such an intriguing target for scientists, as did its large mass. WASP-18 b is one of the most massive worlds whose atmospheres we can investigate. We want to know how such planets form and come to be where they are. This, too, has some early answers from Webb.

‘‘By analyzing WASP-18b’s spectrum, we not only learn about the various molecules that can be found in its atmosphere but also about the way it formed. We find from our observations that WASP-18 b’s composition is very similar to that of its star, meaning it most likely formed from the leftover gas that was present just after the star was born,’’ Coulombe said. ‘‘Those results are very valuable to get a clear picture of how strange planets like WASP-18 b, which have no counterpart in our solar system, come to exist.’’

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Spitzer, TESS Find Potentially Volcano-Covered Earth-Size World

5 min read

Astronomers have discovered an Earth-size exoplanet, or world beyond our solar system, that may be carpeted with volcanoes. Called LP 791-18 d, the planet could undergo volcanic outbursts as often as Jupiter’s moon Io, the most volcanically active body in our solar system.

They found and studied the planet using data from NASA’s TESS (Transiting Exoplanet Survey Satellite) and retired Spitzer Space Telescope, as well as a suite of ground-based observatories.

A paper about the planet – led by Merrin Peterson, a graduate of the Trottier Institute for Research on Exoplanets (iREx) based at the University of Montreal – appears in the May 17 edition of the scientific journal Nature.

“LP 791-18 d is tidally locked, which means the same side constantly faces its star,” said Björn Benneke, a co-author and astronomy professor at iREx who planned and supervised the study. “The day side would probably be too hot for liquid water to exist on the surface. But the amount of volcanic activity we suspect occurs all over the planet could sustain an atmosphere, which may allow water to condense on the night side.”

LP 791-18 d orbits a small red dwarf star about 90 light-years away in the southern constellation Crater. The team estimates it’s only slightly larger and more massive than Earth.

Astronomers already knew about two other worlds in the system before this discovery, called LP 791-18 b and c. The inner planet b is about 20% bigger than Earth. The outer planet c is about 2.5 times Earth’s size and more than seven times its mass.

During each orbit, planets d and c pass very close to each other. Each close pass by the more massive planet c produces a gravitational tug on planet d, making its orbit somewhat elliptical. On this elliptical path, planet d is slightly deformed every time it goes around the star. These deformations can create enough internal friction to substantially heat the planet’s interior and produce volcanic activity at its surface. Jupiter and some of its moons affect Io in a similar way.

Planet d sits on the inner edge of the habitable zone, the traditional range of distances from a star where scientists hypothesize liquid water could exist on a planet’s surface. If the planet is as geologically active as the research team suspects, it could maintain an atmosphere. Temperatures could drop enough on the planet’s night side for water to condense on the surface.

Planet c has already been approved for observing time on the James Webb Space Telescope, and the team thinks planet d is also an exceptional candidate for atmospheric studies by the mission.

“A big question in astrobiology, the field that broadly studies the origins of life on Earth and beyond, is if tectonic or volcanic activity is necessary for life,” said co-author Jessie Christiansen, a research scientist at NASA’s Exoplanet Science Institute at the California Institute of Technology in Pasadena. “In addition to potentially providing an atmosphere, these processes could churn up materials that would otherwise sink down and get trapped in the crust, including those we think are important for life, like carbon.”

Spitzer’s observations of the system were among the last the satellite collected before it was decommissioned in January 2020.

“It is incredible to read about the continuation of discoveries and publications years beyond Spitzer’s end of mission,” said Joseph Hunt, Spitzer project manager at NASA’s Jet Propulsion Laboratory in Southern California. “That really shows the success of our first-class engineers and scientists. Together they built not only a spacecraft but also a data set that continues to be an asset for the astrophysics community.”

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

The entire body of scientific data collected by Spitzer during its lifetime is available to the public via the Spitzer data archive, housed at the Infrared Science Archive at IPAC at Caltech in Pasadena, California. NASA’s Jet Propulsion Laboratory, a division of Caltech, managed Spitzer mission operations for the agency’s Science Mission Directorate in Washington. Science operations were conducted at the Spitzer Science Center at IPAC at Caltech. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado.

Download high-resolution video and images from NASA’s Scientific Visualization Studio.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Takes Closest Look Yet at Mysterious Planet

5 min read

NASA Science Editorial Team

NASA’s James Webb Space Telescope has observed a distant planet outside our solar system – and unlike anything in it – to reveal what is likely a highly reflective world with a steamy atmosphere. It’s the closest look yet at the mysterious world, a “mini-Neptune” that was largely impenetrable to previous observations.

And while the planet, called GJ 1214 b, is too hot to harbor liquid-water oceans, water in vaporized form still could be a major part of its atmosphere.

“The planet is totally blanketed by some sort of haze or cloud layer,” said Eliza Kempton, a researcher at the University of Maryland and lead author of a new paper, published in Nature, on the planet. “The atmosphere just remained totally hidden from us until this observation.” She noted that, if indeed water-rich, the planet could have been a “water world,” with large amounts of watery and icy material at the time of its formation.

To penetrate such a thick barrier, the research team took a chance on a novel approach: In addition to making the standard observation – capturing the host star’s light that has filtered through the planet’s atmosphere – they tracked GJ 1214 b through nearly its entire orbit around the star.

The observation demonstrates the power of Webb’s Mid-Infrared Instrument (MIRI), which views wavelengths of light outside the part of the electromagnetic spectrum that human eyes can see. Using MIRI, the research team was able to create a kind of “heat map” of the planet as it orbited the star. The heat map revealed – just before the planet’s orbit carried it behind the star, and as it emerged on the other side – both its day and night sides, unveiling details of the atmosphere’s composition.

“The ability to get a full orbit was really critical to understand how the planet distributes heat from the day side to the night side,” Kempton said. “There’s a lot of contrast between day and night. The night side is colder than the day side.” In fact, the temperatures shifted from 535 to 326 degrees Fahrenheit (from 279 to 165 degrees Celsius).

Such a big shift is only possible in an atmosphere made up of heavier molecules, such as water or methane, which appear similar when observed by MIRI. That means the atmosphere of GJ 1214 b is not composed mainly of lighter hydrogen molecules, Kempton said, which is a potentially important clue to the planet’s history and formation – and perhaps its watery start.“This is not a primordial atmosphere,” she said. “It does not reflect the composition of the host star it formed around. Instead, it either lost a lot of hydrogen, if it started with a hydrogen-rich atmosphere, or it was formed from heavier elements to begin with – more icy, water-rich material.”

And while the planet is hot by human standards, it is much cooler than expected, Kempton noted. That’s because its unusually shiny atmosphere, which came as a surprise to the researchers, reflects a large fraction of the light from its parent star rather than absorbing it and growing hotter.

The new observations could open the door to deeper knowledge of a planet type shrouded in uncertainty. Mini-Neptunes – or sub-Neptunes as they’re called in the paper – are the most common type of planet in the galaxy, but mysterious to us because they don’t occur in our solar system. Measurements so far show they are broadly similar to, say, a downsized version of our own Neptune. Beyond that, little is known.

“For the last almost decade, the only thing we really knew about this planet was that the atmosphere was cloudy or hazy,” said Rob Zellem, an exoplanet researcher who works with co-author and fellow exoplanet researcher Tiffany Kataria at NASA’s Jet Propulsion Laboratory in Southern California. “This paper has really cool implications for additional detailed climate interpretations – to look at the detailed physics happening inside this planet’s atmosphere.”

The new work suggests the planet might have formed farther from its star, a type known as a red dwarf, then spiraled gradually inward to its present, close orbit. The planet’s year – one orbit around the star – takes only 1.6 Earth days.

“The simplest explanation, if you find a very water-rich planet, is that it formed farther away from the host star,” Kempton said.

Further observations will be needed to pin down more details about GJ 1214 b as well as the formation histories of other planets in the mini-Neptune class. While a watery atmosphere seems likely for this planet, a significant methane component also is possible. And drawing broader conclusions about how mini-Neptunes form will require more of them to be observed in depth.

“By observing a whole population of objects like this, hopefully we can build up a consistent story,” Kempton said.

The James Webb Space Telescope is the world’s premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency), and CSA (Canadian Space Agency).

MIRI was developed through a 50-50 partnership between NASA and ESA. NASA’s Jet Propulsion Laboratory led the U.S. efforts for MIRI, and a multinational consortium of European astronomical institutes contributes for ESA. George Rieke with the University of Arizona is the MIRI science team lead. Gillian Wright is the MIRI European principal investigator. Alistair Glasse with UK ATC is the MIRI instrument scientist, and Michael Ressler is the U.S. project scientist at JPL. Laszlo Tamas with UK ATC manages the European Consortium. The MIRI cryocooler development was led and managed by JPL, in collaboration with Northrop Grumman in Redondo Beach, California, and NASA’s Goddard Space Flight Center in Greenbelt, Maryland. Caltech manages JPL for NASA.

For more information about the Webb mission, visit:

https://www.nasa.gov/webb

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Takes Closest Look Yet at Mysterious Planet

6 min read

A science team gains new insight into the atmosphere of a “mini-Neptune,” a class of planet common in the galaxy but about which little is known.

A science team gains new insight into the atmosphere of a “mini-Neptune,” a class of planet common in the galaxy but about which little is known.

NASA’s James Webb Space Telescope has observed a distant planet outside our solar system – and unlike anything in it – to reveal what is likely a highly reflective world with a steamy atmosphere. It’s the closest look yet at the mysterious world, a “mini-Neptune” that was largely impenetrable to previous observations.

And while the planet, called GJ 1214 b, is too hot to harbor liquid-water oceans, water in vaporized form still could be a major part of its atmosphere.

“The planet is totally blanketed by some sort of haze or cloud layer,” said Eliza Kempton, a researcher at the University of Maryland and lead author of a new paper, published in Nature, on the planet. “The atmosphere just remained totally hidden from us until this observation.” She noted that, if indeed water-rich, the planet could have been a “water world,” with large amounts of watery and icy material at the time of its formation.

To penetrate such a thick barrier, the research team took a chance on a novel approach: In addition to making the standard observation – capturing the host star’s light that has filtered through the planet’s atmosphere – they tracked GJ 1214 b through nearly its entire orbit around the star.

The observation demonstrates the power of Webb’s Mid-Infrared Instrument (MIRI), which views wavelengths of light outside the part of the electromagnetic spectrum that human eyes can see. Using MIRI, the research team was able to create a kind of “heat map” of the planet as it orbited the star. The heat map revealed – just before the planet’s orbit carried it behind the star, and as it emerged on the other side – both its day and night sides, unveiling details of the atmosphere’s composition.

“The ability to get a full orbit was really critical to understand how the planet distributes heat from the day side to the night side,” Kempton said. “There’s a lot of contrast between day and night. The night side is colder than the day side.” In fact, the temperatures shifted from 535 to 326 degrees Fahrenheit (from 279 to 165 degrees Celsius).

Such a big shift is only possible in an atmosphere made up of heavier molecules, such as water or methane, which appear similar when observed by MIRI. That means the atmosphere of GJ 1214 b is not composed mainly of lighter hydrogen molecules, Kempton said, which is a potentially important clue to the planet’s history and formation – and perhaps its watery start.

“This is not a primordial atmosphere,” she said. “It does not reflect the composition of the host star it formed around. Instead, it either lost a lot of hydrogen, if it started with a hydrogen-rich atmosphere, or it was formed from heavier elements to begin with – more icy, water-rich material.”

Cooler Than Expected

And while the planet is hot by human standards, it is much cooler than expected, Kempton noted. That’s because its unusually shiny atmosphere, which came as a surprise to the researchers, reflects a large fraction of the light from its parent star rather than absorbing it and growing hotter.

The new observations could open the door to deeper knowledge of a planet type shrouded in uncertainty. Mini-Neptunes – or sub-Neptunes as they're called in the paper – are the most common type of planet in the galaxy, but mysterious to us because they don't occur in our solar system. Measurements so far show they are broadly similar to, say, a downsized version of our own Neptune. Beyond that, little is known.

"For the last almost decade, the only thing we really knew about this planet was that the atmosphere was cloudy or hazy," said Rob Zellem, an exoplanet researcher who works with co-author and fellow exoplanet researcher Tiffany Kataria at NASA's Jet Propulsion Laboratory in Southern California. "This paper has really cool implications for additional detailed climate interpretations – to look at the detailed physics happening inside this planet's atmosphere."

The new work suggests the planet might have formed farther from its star, a type known as a red dwarf, then spiraled gradually inward to its present, close orbit. The planet's year – one orbit around the star – takes only 1.6 Earth days.

"The simplest explanation, if you find a very water-rich planet, is that it formed farther away from the host star," Kempton said.

Further observations will be needed to pin down more details about GJ 1214 b as well as the formation histories of other planets in the mini-Neptune class. While a watery atmosphere seems likely for this planet, a significant methane component also is possible. And drawing broader conclusions about how mini-Neptunes form will require more of them to be observed in depth.

"By observing a whole population of objects like this, hopefully we can build up a consistent story," Kempton said.

More About the Mission

The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency), and CSA (Canadian Space Agency).

MIRI was developed through a 50-50 partnership between NASA and ESA. NASA's Jet Propulsion Laboratory led the U.S. efforts for MIRI, and a multinational consortium of European astronomical institutes contributes for ESA. George Rieke with the University of Arizona is the MIRI science team lead. Gillian Wright is the MIRI European principal investigator. Alistair Glasse with UK ATC is the MIRI instrument scientist, and Michael Ressler is the U.S. project scientist at JPL. Laszlo Tamas with UK ATC manages the European Consortium. The MIRI cryocooler development was led and managed by JPL, in collaboration with Northrop Grumman in Redondo Beach, California, and NASA's Goddard Space Flight Center in Greenbelt, Maryland. Caltech manages JPL for NASA.

For more information about the Webb mission, visit:

https://www.nasa.gov/webb

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Written by Pat Brennan

2023-066

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Completes Heart of Roman Space Telescope’s Primary Instrument

3 min read

The heart of NASA’s Nancy Grace Roman Space Telescope was recently delivered to Ball Aerospace in Boulder, Colorado, for integration into the WFI (Wide Field Instrument). Called the FPS (Focal Plane System), it serves as the core of Roman’s camera. When the mission launches by May 2027, astronomers will use this system to gather exquisite images to help unravel the secrets of dark energy and dark matter, discover exoplanets, and explore many topics in infrared astrophysics.

The FPS is made up of a large detector array and its associated electronics. The detectors were developed by engineers at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and Teledyne Scientific & Imaging in Camarillo, California. The Goddard team also developed the electronics and assembled the FPS. Each of Roman’s 18 detectors has 16.8 million tiny pixels, which will provide the mission with remarkable image resolution. Through these “eyes,” we will be able to peer through dust and across vast stretches of the cosmos, creating high-resolution panoramas of the universe.

“Roman’s focal plane array is one of the biggest that has ever flown onboard a space-based observatory,” said Mary Walker, the Roman WFI manager at Goddard. “Its creation is the product of many years of innovation from a very dedicated team – one that is eagerly anticipating the incredible science Roman will yield.”

Once the FPS is installed in the spacecraft’s WFI – its camera – technicians will continue the build by integrating the instrument’s radiators.

“For optimal performance, the detectors must be operated at minus 288 degrees Fahrenheit, or minus 178 degrees Celsius,” said Greg Mosby, a research astrophysicist and Roman detector scientist at Goddard. “Roman’s detectors are so sensitive that nearby components in the Wide Field Instrument must also be cooled, otherwise their heat would saturate the detectors, effectively blinding the observatory.” The radiators will redirect waste heat from the instrument’s components away from the detectors out into cold space, ensuring that Roman will be sensitive to faint signals from distant galaxies and other cosmic objects.

After the radiators are installed, Roman’s camera will be complete and ready for thermal vacuum tests this summer. The team expects the entire WFI to return to Goddard in spring of 2024, where it will ultimately be integrated into the rest of the observatory.

For more information about the Roman Space Telescope, visit: roman.gsfc.nasa.gov or www.nasa.gov/roman. To virtually tour an interactive version of the telescope, visit: https://roman.gsfc.nasa.gov/interactive/.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire AndreoliNASA’s Goddard Space Flight Center301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Follows Shadow Play Around Planet-Forming Disk

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

The young star TW Hydrae is playing "shadow puppets" with scientists observing it with NASA's Hubble Space Telescope.

In 2017, astronomers reported discovering a shadow sweeping across the face of a vast pancake-shaped gas-and-dust disk surrounding the red dwarf star. The shadow isn't from a planet, but from an inner disk slightly inclined relative to the much larger outer disk – causing it to cast a shadow. One explanation is that an unseen planet's gravity is pulling dust and gas into the planet's inclined orbit.

Now, a second shadow – playing a game of peek-a-boo – has emerged in just a few years between observations stored in Hubble's MAST archive. This could be from yet another disk nestled inside the system. The two disks are likely evidence of a pair of planets under construction.

TW Hydrae is less than 10 million years old and resides about 200 light-years away. In its infancy, our solar system may have resembled the TW Hydrae system, some 4.6 billion years ago. Because the TW Hydrae system is tilted nearly face-on to our view from Earth, it is an optimum target for getting a bull's-eye-view of a planetary construction yard.

The second shadow was discovered in observations obtained on June 6, 2021, as part of a multi-year program designed to track the shadows in circumstellar disks. John Debes of AURA/STScI for the European Space Agency at the Space Telescope Science Institute in Baltimore, Maryland, compared the TW Hydrae disk to Hubble observations made several years ago.

"We found out that the shadow had done something completely different," said Debes, who is principal investigator and lead author of the study published in The Astrophysical Journal. "When I first looked at the data, I thought something had gone wrong with the observation because it wasn't what I was expecting. I was flummoxed at first, and all my collaborators were like: what is going on? We really had to scratch our heads and it took us a while to actually figure out an explanation."

The best solution the team came up with is that there are two misaligned disks casting shadows. They were so close to each other in the earlier observation they were missed. Over time they've now separated and split into two shadows. "We've never really seen this before on a protoplanetary disk. It makes the system much more complex than we originally thought," he said.

The simplest explanation is that the misaligned disks are likely caused by the gravitational pull of two planets in slightly different orbital planes. Hubble is piecing together a holistic view of the architecture of the system.

The disks may be proxies for planets that are lapping each other as they whirl around the star. It's sort of like spinning two vinyl phonograph records at slightly different speeds. Sometimes labels will match up but then one gets ahead of the other.

"It does suggest that the two planets have to be fairly close to each other. If one was moving much faster than the other, this would have been noticed in earlier observations. It's like two race cars that are close to each other, but one slowly overtakes and laps the other," said Debes.

The suspected planets are located in a region roughly the distance of Jupiter from our Sun. And, the shadows complete one rotation around the star about every 15 years – the orbital period that would be expected at that distance from the star.

Also, these two inner disks are inclined about five to seven degrees relative to the plane of the outer disk. This is comparable to the range of orbital inclinations inside our solar system. "This is right in line with typical solar system style architecture," said Debes.

The outer disk that the shadows are falling on may extend as far as several times the radius of our solar system's Kuiper belt. This larger disk has a curious gap at twice Pluto's average distance from the Sun. This might be evidence for a third planet in the system.

Any inner planets would be difficult to detect because their light would be lost in the glare of the star. Also, dust in the system would dim their reflected light. ESA's Gaia space observatory may be able to measure a wobble in the star if Jupiter-mass planets are tugging on it, but this would take years given the long orbital periods.

The TW Hydrae data are from Hubble's Space Telescope Imaging Spectrograph. The James Webb Space Telescope's infrared vision may also be able to show the shadows in more detail.

Learn More:

The Hubble Space Telescope is a project of international cooperation between NASA and ESA. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contact:Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, MDclaire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore, MD

Science Contact:John DebesAURA/STScI for the European Space Agency, Baltimore, MD

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Webb Finds Water Vapor, But From a Rocky Planet or Its Star?

5 min read

Astronomers used NASA's James Webb Space Telescope to study a rocky exoplanet known as GJ 486 b, and their observations using Webb's Near-Infrared Spectrograph (NIRSpec) show hints of water vapor.

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

The most common stars in the universe are red dwarf stars, which means that rocky exoplanets are most likely to be found orbiting such a star. Red dwarf stars are cool, so a planet has to hug it in a tight orbit to stay warm enough to potentially host liquid water (meaning it lies in the habitable zone). Such stars are also active, particularly when they are young, releasing ultraviolet and X-ray radiation that could destroy planetary atmospheres. As a result, one important open question in astronomy is whether a rocky planet could maintain, or reestablish, an atmosphere in such a harsh environment.

To help answer that question, astronomers used NASA's James Webb Space Telescope to study a rocky exoplanet known as GJ 486 b. It is too close to its star to be within the habitable zone, with a surface temperature of about 800 degrees Fahrenheit (430 degrees Celsius). And yet, their observations using Webb's Near-Infrared Spectrograph (NIRSpec) show hints of water vapor. If the water vapor is associated with the planet, that would indicate that it has an atmosphere despite its scorching temperature and close proximity to its star. Water vapor has been seen on gaseous exoplanets before, but to date no atmosphere has been definitely detected around a rocky exoplanet. However, the team cautions that the water vapor could be on the star itself – specifically, in cool starspots – and not from the planet at all.

"We see a signal, and it's almost certainly due to water. But we can't tell yet if that water is part of the planet's atmosphere, meaning the planet has an atmosphere, or if we're just seeing a water signature coming from the star," said Sarah Moran of the University of Arizona in Tucson, lead author of the study.

"Water vapor in an atmosphere on a hot rocky planet would represent a major breakthrough for exoplanet science. But we must be careful and make sure that the star is not the culprit," added Kevin Stevenson of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, principal investigator on the program.

GJ 486 b is about 30% larger than Earth and three times as massive, which means it is a rocky world with stronger gravity than Earth. It orbits a red dwarf star in just under 1.5 Earth days. It is expected to be tidally locked, with a permanent day side and a permanent night side.

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

GJ 486 b transits its star, crossing in front of the star from our point of view. If it has an atmosphere, then when it transits starlight would filter through those gasses, imprinting fingerprints in the light that allow astronomers to decode its composition through a technique called transmission spectroscopy.

The team observed two transits, each lasting about an hour. They then used three different methods to analyze the resulting data. The results from all three are consistent in that they show a mostly flat spectrum with an intriguing rise at the shortest infrared wavelengths. The team ran computer models considering a number of different molecules, and concluded that the most likely source of the signal was water vapor.

While the water vapor could potentially indicate the presence of an atmosphere on GJ 486 b, an equally plausible explanation is water vapor from the star. Surprisingly, even in our own Sun, water vapor can sometimes exist in sunspots because these spots are very cool compared to the surrounding surface of the star. GJ 486 b's host star is much cooler than the Sun, so even more water vapor would concentrate within its starspots. As a result, it could create a signal that mimics a planetary atmosphere.

"We didn't observe evidence of the planet crossing any starspots during the transits. But that doesn't mean that there aren't spots elsewhere on the star. And that's exactly the physical scenario that would imprint this water signal into the data and could wind up looking like a planetary atmosphere," explained Ryan MacDonald of the University of Michigan in Ann Arbor, one of the study's co-authors.

A water vapor atmosphere would be expected to gradually erode due to stellar heating and irradiation. As a result, if an atmosphere is present, it would likely have to be constantly replenished by volcanoes ejecting steam from the planet's interior. If the water is indeed in the planet's atmosphere, additional observations are needed to narrow down how much water is present.

Future Webb observations may shed more light on this system. An upcoming Webb program will use the Mid-Infrared Instrument (MIRI) to observe the planet's day side. If the planet has no atmosphere, or only a thin atmosphere, then the hottest part of the day side is expected to be directly under the star. However, if the hottest point is shifted, that would indicate an atmosphere that can circulate heat.

Ultimately, observations at shorter infrared wavelengths by another Webb instrument, the Near-Infrared Imager and Slitless Spectrograph (NIRISS), will be needed to differentiate between the planetary atmosphere and starspot scenarios.

"It's joining multiple instruments together that will really pin down whether or not this planet has an atmosphere," said Stevenson.

The study is accepted for publication in The Astrophysical Journal Letters.

The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Laura BetzNASA's Goddard Space Flight Center, Greenbelt, Md.laura.e.betz@nasa.gov

Christine PulliamSpace Telescope Science Institute, Baltimore, Md.cpulliam@stsci.edu

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Caught in the Act: Astronomers Detect a Star Devouring a Planet

6 min read

NASA Science Editorial Team

A star nearing the end of its life swelled up and absorbed a Jupiter-size planet. In about 5 billion years, our Sun will go through a similar end-of-life transition.

A new study published online Wednesday, May 3, in the journal Nature documents the first observation of an aging star swallowing a planet. After running out of fuel in its core, the star began to grow in size, shrinking the gap with its neighboring planet, eventually consuming it entirely. In about 5 billion years, our Sun will go through a similar aging process, possibly reaching 100 times its current diameter and becoming what's known as a red giant. During that growth spurt, it will absorb Mercury, Venus, and possibly Earth.

Astronomers have identified many red giant stars and suspected that in some cases they consume nearby planets, but the phenomenon had never been directly observed before. "This type of event has been predicted for decades, but until now we have never actually observed how this process plays out," said Kishalay De, an astronomer at the Massachusetts Institute of Technology in Cambridge and the study's lead author.

Researchers discovered the event – formally called ZTF SLRN-2020 – using multiple ground-based observatories and NASA's NEOWISE (Near-Earth Object Wide Field Infrared Survey Explorer) spacecraft, which is managed by the agency's Jet Propulsion Laboratory. The planet was likely about the size of Jupiter, with an orbit even closer to its star than Mercury's is to our Sun. The star is at the beginning of the final phase of its life – its red giant phase, which can last more than 100,000 years.

As the star expanded, its outer atmosphere eventually surrounded the planet. Drag from the atmosphere slowed the planet down, shrinking its orbit and eventually sending it below the star's visible surface, like a meteor burning up in Earth's atmosphere. The transfer of energy caused the star to temporarily increase in size and become a few hundred times brighter. Recent observations show the star has returned to the size and brightness it was before merging with the planet.

The flash of optical light (visible to the human eye) after the planet's demise showed up in observations by the Caltech-led Zwicky Transient Facility (ZTF), an instrument based at Palomar Observatory in Southern California that looks for cosmic events that change in brightness rapidly, sometimes in a matter of hours. De was using ZTF to search for events called novae – when a dead, collapsed star (known as a white dwarf) cannibalizes hot gas from another nearby star. Novae are always surrounded by flows of hot gas, but follow-up observations of the flash by other ground-based telescopes showed much cooler gas and dust surrounding the star, meaning it didn't look like a nova or anything else De had ever seen.

So he turned to the NEOWISE observatory, which scans the entire sky in infrared light (a range of wavelengths longer than visible light) every six months. Launched in 2009 and originally called WISE, the observatory produces all-sky maps that enable astronomers to see how objects change over time.

Looking at the NEOWISE data, De saw that the star brightened almost a year before ZTF spotted the flash. That brightening was evidence of dust (which emits infrared light) forming around the star. De and his colleagues think the dust indicates that the planet didn't go down without a fight and that it pulled hot gas away from the puffy star's surface as it spiraled toward its doom. As the gas drifted out into space, it would have cooled and become dust – like water vapor becoming snow. Even more gas was then flung into space during the collision of the star and the planet, producing more dust visible to both the ground-based infrared observatories and NEOWISE.

“Very few things in the universe brighten in infrared light and then brighten in optical light at different times,” said De. “So the fact that NEOWISE saw the star brighten a year before the optical eruption was critical to figuring out what this event was.”

Five billion years from now, when our Sun is expected to become a red giant, swallowing up Mercury, Venus, and possibly Earth, the light show should be much more subdued, according to De, since those planets are many times smaller than the Jupiter-size planet in the ZTF-captured event.

“If I were an observer looking at the solar system 5 billion years from now, I might see the Sun brighten a little, but nothing as dramatic as this, even though it will be the exact same physics at work,” he said.

Most mid-size stars will eventually become red giants, and theorists think that a handful of them consume nearby planets each year in our galaxy. The new observations provide astronomers with a template for what those events should look like, opening up the possibility of finding more.

“This discovery shows that it’s worthwhile to take observations of the entire sky and archive them, because we don’t yet know all of the interesting events we might be capturing,” said Joe Masiero, deputy principal investigator for NEOWISE at IPAC at Caltech. “With the NEOWISE archive, we can look back in time. We can find hidden treasures or learn something about an object that no other observatory can tell us.”

Launched in 2009, the WISE mission scanned the entire sky twice in infrared light, snapping pictures of three-quarters of a billion objects, including remote galaxies, stars, and asteroids. The WISE mission concluded in 2011, but two years later NASA repurposed the spacecraft to track asteroids and other near-Earth objects, or NEOs. Both the mission and the spacecraft were renamed NEOWISE.

JPL managed and operated WISE for NASA’s Astrophysics Division within the Science Mission Directorate. Edward Wright at UCLA was the principal investigator. The mission was selected competitively under NASA’s Explorers Program managed by the agency’s Goddard Space Flight Center in Greenbelt, Maryland.

JPL manages and operates the NEOWISE mission for NASA’s Planetary Defense Coordination Office within the Science Mission Directorate in Washington. The principal investigator, Amy Mainzer, is at the University of Arizona. The Space Dynamics Laboratory in Logan, Utah, built the science instrument. Ball Aerospace & Technologies Corp. of Boulder, Colorado, built the spacecraft. Science data processing takes place at IPAC at Caltech in Pasadena. Caltech manages JPL for NASA.

For more information about NEOWISE, visit:

https://www.nasa.gov/neowise

For more information about WISE, visit:

http://www.nasa.gov/wise

Calla Cofield

Jet Propulsion Laboratory, Pasadena, Calif.

626-808-2469

calla.e.cofield@jpl.nasa.gov

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Meet 8 ‘Star Wars’ Planets in Our Own Galaxy

11 min read

NASA Science Editorial Team

The fantasy creations of the "Star Wars" universe are strikingly similar to real planets in our own Milky Way galaxy. A super-Earth in deep freeze? Think ice-planet Hoth. And that distant world with double sunsets can’t help but summon thoughts of sandy Tatooine.

No indications of life have yet been detected on any of the more than 5,000 scientifically confirmed exoplanets, so we don’t know if any of them are inhabited by Wookiees or mynocks, or play host to exotic alien bar scenes (or even bacteria, for that matter).

Explore worlds similar to Star Wars in 3D

Still, a quick spin around the real exoplanet universe offers tantalizing similarities to several Star Wars counterparts:

An exoplanet possessing some Earth-like properties, Kepler-452b, might make a good stand-in for Coruscant – the high-tech world seen in several Star Wars films whose surface is encased in a single, globe-spanning city. Kepler-452b belongs to a star system 1.5 billion years older than Earth’s. That would give any technologically adept species more than a billion-year jump ahead of us. The denizens of Coruscant not only have an entirely engineered planetary surface, but an engineered climate as well. On Kepler-452b, conditions are growing markedly warmer as its star’s energy output increases, a symptom of advanced age. If this planet, 1.6 times the size of Earth, were truly Earth-like, and if technological life forms were present, some climate engineering might be needed there as well.

Mining the atmospheres of giant gas planets is a staple of science fiction. NASA too has examined the question, and found that gases such as helium-3 and hydrogen could be extracted from the atmospheres of Uranus and Neptune.

Gas giants of all stripes populate the real exoplanet universe; in “The Empire Strikes Back,” a gas giant called Bespin is home to a “Cloud City” actively involved in atmospheric mining. The toadstool-shaped city provides apparent refuge for a fleeing Princess Leia and company– at least until Darth Vader wreaks his usual havoc.

Many of the gas giants found so far by spacecraft like NASA's TESS (Transiting Exoplanet Survey Satellite) and previously by the Kepler Space Telescope are so-called “hot Jupiters”– star-hugging behemoths far too thoroughly barbecued to be proper sites for floating cities. One discovery, however, shows that gas “exogiants” can orbit their stars at distances remarkably similar to those in our solar system. An international astronomical team discovered a twin of our own Jupiter, orbiting its star at about the same distance as Jupiter is from the sun. The star, HIP 11915, is about the same age and composition as our Sun, raising the possibility that its entire planetary system might be similar to ours. This not-so-hot Jupiter, about 186 light-years away, was detected using the 11.8-foot (3.6-meter) telescope at La Silla Observatory in Chile.

Bespin’s atmospheric layers include a band of breathable air, ideal for floating cities. In our galaxy, emerging technology allows us to read out the components of real exoplanet atmospheres– including gas giants (though so far no signs of habitable bands). And tasting the atmospheres of smaller, rocky, potentially habitable exoplanets soon could be within reach. Astronomers using K2, the second planet-finding mission of the Kepler space telescope, detected three such planets orbiting a nearby dwarf star. The starlight shining through the atmospheres of these planets could reveal their composition in future observations.

The planet Mustafar, scene of an epic duel between Obi-Wan Kenobi and Anakin Skywalker in “Revenge of the Sith,” has a number of exoplanet counterparts. These molten, lava-covered worlds, such as Kepler-10b and Kepler-78b, are rocky planets in Earth’s size range whose surfaces could well be perpetual infernos. Kepler-78b, roughly 20 percent larger than Earth, weighs in at twice Earth’s mass; a comparable density means it could be composed of rock and iron. That might make it, like Mustafar, suitable for mining, although its extremely tight orbit around its Sun-like star, along with scorching temperatures, provides an unlikely arena for industrial operations– or for fencing with light-sabers.

Kepler-10b isn’t much more pleasant. The first rocky world discovered using the Kepler telescope, it also hugs its sun, some 20 times closer than Mercury orbits ours. A balmy day on Kepler-10b means daytime highs of more than 2,500 Fahrenheit (1,371 Celsius), even hotter than lava flowing on Earth. The surface, free of any kind of atmosphere, might be boiling with iron and silicates.

At 3,600 degrees Fahrenheit (1,982 Celsius), however, CoRoT-7b has Kepler-10b beat. This well-grilled planet, discovered in 2010 with France’s CoRoT satellite, lies some 480 light-years away, and has a diameter 70 percent larger than Earth’s with nearly five times the mass. Possibly the boiled-down remnant of a Saturn-sized planet, its orbit is so tight that its star looms much larger in its sky than our sun appears to us, keeping its sun-facing surface molten.

The planet OGLE-2005-BLG-390, nicknamed Hoth, is a cold super-Earth that might be a failed Jupiter. Unable to grow large enough, it had to settle for a mass five times that of Earth and a surface locked in the deepest of deep freezes, with a surface temperature estimated at minus 364 degrees Fahrenheit (minus 220 Celsius). That most likely means no Hoth-style tauntauns to ride, or even formidably fanged abominable snowmen (aka wampas). Astronomers used an extraordinary planet-finding technique known as microlensing to find this world in 2005, one of the early demonstrations of this technique’s ability to reveal exoplanets. In microlensing, back light from a distant star is used to reveal planets around a star closer to us.

The planet lies toward the heart of the Milky Way, where a greater density of stars makes microlensing events more likely. The onetime event revealing the distant Hoth was captured by the Optical Gravitational Lensing Experiment, or OGLE, and confirmed by other instruments.

We won’t have to travel 20,000 light years, however, to visit icy worlds. Saturn’s smoggy moon, Titan, where the Cassini spacecraft’s Huygens probe landed in 2005, is pocked with methane lakes and socked in permanently with thick, hydrocarbon haze. The freeze is so deep that water ice is no different from rock. Another Saturn moon, Enceladus, looks like a snowball but harbors a subsurface ocean much like Jupiter's moon Europa, also an ice ball with a possible ocean underneath. That ocean might even be warmed by tidal flexing as this little moon orbits Jupiter.

Luke Skywalker’s home planet, Tatooine, is said to possess a harsh, desert environment, swept by sandstorms as it roasts under the glare of twin suns. Real exoplanets in the thrall of two or more suns are even harsher. Kepler-16b was the Kepler telescope’s first discovery of a planet in a “circumbinary” orbit– circling two stars, as opposed to one star in a double-star system. This planet, however, is likely cold, about the size of Saturn and gaseous, though partly composed of rock. It lies outside its two stars’ “habitable zone,” where liquid water could exist. And its stars are cooler than our Sun, probably rendering the planet lifeless. Of course, we could look on the bright side (so to speak). When the discovery was announced in 2011, Bill Borucki, the now-retired NASA principal investigator for Kepler at Ames Research Center, Moffett Field, California, said finding the new planet might actually broaden the prospects for life in our galaxy. About half of all stars belong to binary systems, so the fact that planets form around these, as well as around single stars, can only increase the odds.

A more recently announced exoplanet, Kepler-453b, is also a circumbinary and a gas giant, though its orbit within the habitable zone means any moons it might have could be habitable. It was the tenth circumbinary discovered using the Kepler telescope.

Kepler-22b, analog to the Star Wars planet Kamino (home of those bug-eyed, long-necked cloners), is a super-Earth that could be covered in a super ocean. Watery, storm-drenched Kamino makes its appearance in “Attack of the Clones” when a suspicious, planet-hopping Obi-Wan Kenobi sets down there in search of answers.

The jury is still out on Kepler-22b’s true nature; at 2.4 times Earth’s radius, it might even be gaseous. But if the ocean world idea turns out to be right, we can envision a physically plausible Kamino-like planet with the help of scientists at the Massachusetts Institute of Technology in Cambridge.

An ocean world tipped on its side– a bit like our solar system’s ice giant, Uranus– turns out to be comfortably habitable based on recent computer modeling. Researchers found that an exoplanet in Earth’s size range, at a comparable distance from its sun and covered in water, could have an average surface temperature of about 60 degrees Fahrenheit (15.5 Celsius). Because of its radical tilt, its north and south poles would be alternately bathed in sunlight and darkness, for half a year each, as the planet circled its star.

Scientists previously thought such a planet would seesaw between boiling and freezing, rendering it uninhabitable. But the MIT scientists’ three-dimensional model showed that the planet, even with a relatively shallow ocean of about 160 feet (50 meters), would absorb heat during its odd polar summer and release it in winter. That would keep the overall climate mild and spring-like year round.

The shallow depth, by the way, would be ideal for Kamino-style ocean platforms, allowing construction of covered cities at the ocean surface, where armies of clones could march and drill in peace.

Endor, the forested realm of the Ewoks, orbits a gas giant and was introduced in “Return of the Jedi.” Exomoon detection is still in its infancy for scientists here on Earth. A possible exomoon– that is, a moon circling a distant planet– was observed in 2014 via microlensing. It will remain forever unconfirmed, however, since each microlensing event can be seen only once. If the exomoon is real, it orbits a rogue planet, unattached to a star and wandering freely through space. The planet might have hung on to its moon after somehow being ejected during the early history of a forgotten planetary system. A team of Japanese, New Zealand, and American astronomers analyzed data gathered in 2011 with telescopes in New Zealand and Tasmania, and suggested the possible exomoon. But they said a small star accompanied by a large planet could have caused the same lensing effect.

More exomoons might soon be popping out of the depths of space. The Harvard-based Hunt for Exomoons with Kepler, or HEK, has begun to scour data from Kepler for signs of them. In early 2015, the researchers examined about 60 Kepler planets and determined that existing technology is sufficient to capture evidence of exomoons.

The hunt could have powerful implications in the search for life beyond Earth. If exomoons are shown to be potentially habitable, it opens another avenue for biology; habitable moons might even outnumber habitable planets. Could they have bustling ecosystems, with life forms even more exotic than Endor’s living teddy bears, swinging between trees Tarzan-style? Stay tuned.

In “A New Hope,” Princess Leia’s home planet, Alderaan, is blown to smithereens by the Empire’s Death Star as she watches in horror. Real exoplanets also experience extreme destruction. A white dwarf star was caught in the act of devouring the last bits of a small planet in 2015, observed with the help of NASA’s Chandra X-ray Observatory. White dwarfs are super-dense stellar remnants about the size of Earth, but with gravity more than 10,000 times that of our sun’s surface. Tidal forces could rip a planet caught in its pull to shreds.

Observers thought at first they were seeing a black hole in the act of feeding inside a star cluster on the Milky Way's rim. X-ray observations, however, matched theoretical models of a planet being torn apart by a white dwarf.

A similar observation of a closer white dwarf was made by K2 in 2014. In this case, a tiny rocky object, probably an asteroid, was being vaporized into little more than a dusty ring as it whipped around the star every 4.5 hours.

NASA's Spitzer Space Telescope also picked up signs of debris from a likely asteroid collision in 2014. But rather than a sign of planetary destruction, the colliding asteroids could be part of a construction site. This young star, about 1,200 light years away and only 35 million years old, is surrounded by a ring of dust where such collisions are frequent. The smashed and broken bits fuse into larger and larger agglomerations, eventually forming full-sized planets.

Our own solar system might once have looked very similar, if anyone was watching.

Explore Star Wars-like worlds in 3D

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Gordon Chin Explores the Universe Through Physics and Art

5 min read

A planetary scientist, Gordon Chin also dabbles in watercolors, drawings and mix media artworks in his spare time while surrounded by a ceramic and studio art glass collection.

Name: Gordon Chin

Formal Job Classification: Planetary scientist

Organization: Solar System Exploration Division, Planetary Systems Lab; Science Directorate (Code 693)

What do you do and what is most interesting about your role here at Goddard?

I have spent my entire career formulating and developing instruments for remote observations of molecular transitions in the interstellar medium and planetary atmospheres. I focus on the submillimeter region of the electromagnetic spectrum, which is especially rich in strong spectral signatures of the most important molecules in nature, especially water.

What kept you at Goddard your entire career?

I earned a B.A. and a Ph.D. in physics from Columbia University. I then had a National Academy of Science postdoctoral fellowship in planetary exploration at Goddard after which Goddard offered me a job. I have been at Goddard for over 30 years.

Goddard has the people, facilities, expertise and colleagues for my type of work. We are very fortunate to be in this extraordinary place – a world-class institution – as our everyday workplace.

What I do is fun, interesting and challenging; I enjoy it so much it sometimes doesn't even feel like work.

What are some of the highlights of your career?

As a young scientist, I worked on the Submillimeter Wave Astronomy Satellite (SWAS), the third mission in the inaugural set of the Small Explorer Satellite (SMEX) program. Working on SWAS, I learned what makes Goddard such a unique place – the people and the facilities. Some of the people I met on SMEX, like Jim Watzin, the former SWAS project manager and current head of the Mars program at NASA Headquarters in Washington, remain important to me.

Around 2012, I became the project scientist for the Lunar Reconnaissance Obiter (LRO), thanks to Jim Watzin. I helped organize the science teams for the diverse suite of LRO instruments.

Currently, I am the project scientist for the Orbiting Astronomical Satellite Investigating Stellar Systems (OASIS). It is an astrophysics mission concept with the scientific objective to follow the water trail from galaxies, to proto-planetary disks, to oceans. We submitted the proposal in December 2021 to the NASA's Astrophysics MIDEX program. If selected, OASIS would introduce a ground-breaking technology by deploying a 14-meter telescope using an inflated metalized membrane technology as a telescope. A concept like OASIS could change how NASA can build large telescopes in space in the future. Instead of using a solid structure or an array of mirrors, like NASA's James Webb Space Telescope, we would use a thin, metalized membrane and then inflate it like a balloon to function as a large telescope and also at a much reduced cost.

What is one of your most interesting collaborations?

During the great American eclipse in 2017, I was fortunate to have my 15 minutes of fame on national TV by appearing with Al Roker on NBC's coverage of the eclipse during totality.

What inspires you?

My curiosity about how things work. Additionally, science is not just hard facts, it is also human interactions that enriches everything. You cannot do anything by yourself, you need to be able to collaborate with large teams from many different domestic and foreign institutions.

How does water coloring bring you joy?

I love to examine how our eyes see and our mind interprets things. How to depict the interplay of light and shadow that reveals the semblance of volume, texture and transparency on a flat surface like paper so that our mind reads the depiction as water rippling in the breeze or a glass holding translucent wine.

Watercolors are like expressing physics using a different part of our mind.

What art do you live with in your home?

My late significant other collected studio art glass, especially pieces made by Lino Tagliapietra and Laura Donifer. Glass is so magical with its vibrant colors, transparency and many different forms. Also, I have two major ceramic pieces by Eric Serritella, who specializes in hand crafted trompe l'oeil sculptures of charred birch disguised tea pots.

Why did you recently start writing essays?

The initial COVID isolation meant that I sometimes did not leave my home for weeks at a time. One way to cope was writing. A New York-based journal accepted one of my essays.

It was very gratifying that people like my writing and my thoughts. This type of writing is so different from my usual technical style; it was very liberating. It was something positive that came out of the isolation and is very rewarding.

Where is your spiritual home?

I was raised on the lower east side in New York, which remains my spiritual home. I return frequently for visits. NYC is exciting, full of energy. NYC is always on the cutting edge, with museums and gallery shows to see and new restaurants to try out!

By Elizabeth M. JarrellNASA's Goddard Space Flight Center, Greenbelt, Md.

Conversations With Goddard is a collection of question and answer profiles highlighting the breadth and depth of NASA's Goddard Space Flight Center's talented and diverse workforce. The Conversations have been published twice a month on average since May 2011. Read past editions on Goddard's "Our People" webpage.

NASA Continues Advancing STEM for Students Through New Partnership

NASA Invites Media to Preview its Museum Earth Information Center

NASA Seeks Innovators for Lunar Waste Competition

NASA Astronaut Tracy C. Dyson to Discuss Science, Station Mission

Mariachi and Moonshots: Melissa Moreno Orchestrates Gateway Communications

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Framework for NASA’s Roman Spacecraft Moves to Goddard Clean Room

2 min read

The primary structure that will serve as the “bones” of NASA’s Nancy Grace Roman Space Telescope has moved into the big clean room at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. The spacecraft bus, Roman’s primary support element, will now be built upon this skeletal framework. When it launches by May 2027, Roman will help unravel the secrets of dark energy and dark matter, search for and image exoplanets, and explore many topics in infrared astrophysics.

“This is a milestone several years in the making,” said Caroline Griffin, a mechanical engineer at Goddard. “The Roman team carefully assembled nearly 2,000 individual components, many of them custom-designed by Goddard engineers, to create this structure.”

It’s partly made up of a central cylinder with a top deck that will support most of the observatory. Each of its six sides has a compartment that will house key electronics and other hardware needed to operate the observatory. Major spacecraft elements, such as its power, attitude control, and propulsion systems, will be housed within the primary structure. The high-gain antenna will be installed beneath it, and the lowermost part of the primary structure will attach the spacecraft to the rocket during launch.

The structure is mainly made of a special grade of aluminum that’s strong, yet lightweight. To reduce the weight even further, most of its exterior is partly hollowed out in a triangular pattern called an isogrid. Even though it’s large – about 14 feet (4.3 meters) long, 12 feet (3.7 meters) wide, and 6.5 feet (2 meters) tall – the primary structure weighs just 3,600 pounds (1,600 kilograms). Engineers applied a protective coating to protect it from the environment on Earth and provide the right temperature profile in space. The team has also performed fit checks, ensuring all the components are precisely positioned so additional parts will connect together properly.

The primary structure has now been placed on the Pantheon – a large assembly platform built specifically for Roman. The team is lacing it with the harness, which serves as the spacecraft’s nervous system, and will connect the electronics together in June of 2023.

For more information about the Roman Space Telescope visit: roman.gsfc.nasa.gov or www.nasa.gov/roman. To virtually tour an interactive version of the telescope, visit: https://roman.gsfc.nasa.gov/interactive/.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire AndreoliNASA’s Goddard Space Flight Center301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Spots Swirling, Gritty Clouds on Remote Planet

5 min read

Researchers observing with NASA’s James Webb Space Telescope have pinpointed silicate cloud features in a distant planet’s atmosphere. The team, led by Brittany Miles of the University of Arizona, also made extraordinarily clear detections of water, methane and carbon monoxide with Webb’s data, and found evidence of carbon dioxide.

Lee esta historia en español aquí.

Researchers observing with NASA’s James Webb Space Telescope have pinpointed silicate cloud features in a distant planet’s atmosphere. The atmosphere is constantly rising, mixing, and moving during its 22-hour day, bringing hotter material up and pushing colder material down. The resulting brightness changes are so dramatic that it is the most variable planetary-mass object known to date. The team, led by Brittany Miles of the University of Arizona, also made extraordinarily clear detections of water, methane and carbon monoxide with Webb’s data, and found evidence of carbon dioxide. This is the largest number of molecules ever identified all at once on a planet outside our solar system.

Cataloged as VHS 1256 b, the planet is about 40 light-years away and orbits not one, but two stars over a 10,000-year period. “VHS 1256 b is about four times farther from its stars than Pluto is from our Sun, which makes it a great target for Webb,” Miles said. “That means the planet’s light is not mixed with light from its stars.” Higher up in its atmosphere, where the silicate clouds are churning, temperatures reach a scorching 1,500 degrees Fahrenheit (830 degrees Celsius).

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

Within those clouds, Webb detected both larger and smaller silicate dust grains, which are shown on a spectrum. “The finer silicate grains in its atmosphere may be more like tiny particles in smoke,” noted co-author Beth Biller of the University of Edinburgh in Scotland. “The larger grains might be more like very hot, very small sand particles.”

VHS 1256 b has low gravity compared to more massive brown dwarfs, which means that its silicate clouds can appear and remain higher in its atmosphere where Webb can detect them. Another reason its skies are so turbulent is the planet’s age. In astronomical terms, it’s quite young. Only 150 million years have passed since it formed – and it will continue to change and cool over billions of years.

In many ways, the team considers these findings to be the first “coins” pulled out of a spectrum that researchers view as a treasure chest of data. In many ways, they’ve only begun identifying its contents. “We’ve identified silicates, but better understanding which grain sizes and shapes match specific types of clouds is going to take a lot of additional work,” Miles said. “This is not the final word on this planet – it is the beginning of a large-scale modeling effort to fit Webb’s complex data.”

Although all of the features the team observed have been spotted on other planets elsewhere in the Milky Way by other telescopes, other research teams typically identified only one at a time. “No other telescope has identified so many features at once for a single target,” said co-author Andrew Skemer of the University of California, Santa Cruz. “We’re seeing a lot of molecules in a single spectrum from Webb that detail the planet’s dynamic cloud and weather systems.”

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

The team came to these conclusions by analyzing data known as spectra gathered by two instruments aboard Webb, the Near-Infrared Spectrograph (NIRSpec) and the Mid-Infrared Instrument (MIRI). Since the planet orbits at such a great distance from its stars, the researchers were able to observe it directly, rather than using the transit technique or a coronagraph to take this data.

There will be plenty more to learn about VHS 1256 b in the months and years to come as this team – and others – continue to sift through Webb's high-resolution infrared data. "There's a huge return on a very modest amount of telescope time," Biller added. "With only a few hours of observations, we have what feels like unending potential for additional discoveries."

What might become of this planet billions of years from now? Since it's so far from its stars, it will become colder over time, and its skies may transition from cloudy to clear.

The researchers observed VHS 1256 b as part of Webb's Early Release Science program, which is designed to help transform the astronomical community's ability to characterize planets and the disks where they form.

The team's paper, entitled "The JWST Early Release Science Program for Direct Observations of Exoplanetary Systems II: A 1 to 20 Micron Spectrum of the Planetary-Mass Companion VHS 1256-1257 b," will be published in The Astrophysical Journal Letters on March 22.

The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Media Contacts:

Laura BetzNASA's Goddard Space Flight Center, Greenbelt, Md.laura.e.betz@nasa.gov

Claire Blome / Christine PulliamSpace Telescope Science Institute, Baltimore, Md.cblome@stsci.edu / cpulliam@stsci.edu

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Celebrates Fifth Year Scanning the Sky for New Worlds

6 min read

Now in its fifth year in space, NASA’s TESS (Transiting Exoplanet Survey Satellite) remains a rousing success. TESS’s cameras have mapped more than 93% of the entire sky, discovered 329 new worlds and thousands more candidates, and provided new insights into a wide array of cosmic phenomena, from stellar pulsations and exploding stars to supermassive black holes.

Using its four cameras, TESS monitors large swaths of the sky called sectors for about a month at a time. Each sector measures 24 by 96 degrees, about as wide as a person’s hand at arm’s length and stretching from the horizon to the zenith. The cameras capture a total of 192 million pixels in each full-frame image. During its primary mission, TESS captured one of these images every 30 minutes, but this torrent of data has increased with time. The cameras now record each sector every 200 seconds.

“The volume of high-quality TESS data now available is quite impressive,” said Knicole Colón, the mission’s project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “We have more than 251 terabytes just for one of the main data products, called full-frame images. That’s the equivalent of streaming 167,000 movies in full HD.”

“TESS extracts parts of each full-frame image to make cutouts around specific cosmic objects – more than 467,000 of them at the moment – and together they create a detailed record of changing brightness for each one,” said Christina Hedges, lead for the TESS General Investigator Office and a research scientist at both the University of Maryland, Baltimore County and Goddard. “We use these files to produce light curves, a product that graphically shows how a source’s brightness alters over time.”

To find exoplanets, or worlds beyond our solar system, TESS looks for the telltale dimming of a star caused when an orbiting planet passes in front of it. But stars also change brightness for other reasons: exploding as supernovae, erupting in sudden flares, dark star spots on their rotating surfaces, and even slight changes due to oscillations driven by internal sound waves. The rapid, regular observations from TESS enable more detailed study of these phenomena.

Some stars give TESS a trifecta of brightness-changing behavior. One example is AU Microscopii, thought to be about 25 million years old – a rowdy youngster less than 1% the age of our Sun. Spotted regions on AU Mic’s surface grow and shrink, and the star’s rotation carries them into and out of sight. The stormy star also erupts with frequent flares. With all this going on, TESS, with the help of NASA’s now-retired Spitzer Space Telescope, discovered a planet about four times Earth’s size orbiting the star every 8.5 days. Then, in 2022, scientists announced that TESS data revealed the presence of another, smaller world, one almost three times Earth’s size and orbiting every 18.9 days. These discoveries have made the system a touchstone for understanding how stars and planets form and evolve.

Here are a few more of the mission’s greatest hits:

New discoveries are waiting to be made within the huge volume of data TESS has already captured. This is a library of observations astronomers will explore for years, but there’s much more to come.

“We’re celebrating TESS’s fifth anniversary at work – and wishing it many happy returns!” Colón said.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire Andreoli■NASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Measures the Temperature of a Rocky Exoplanet

6 min read

An international team of researchers has used NASA’s James Webb Space Telescope to measure the temperature of the rocky exoplanet TRAPPIST-1 b.

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

Lee esta historia en español aquí.

An international team of researchers has used NASA’s James Webb Space Telescope to measure the temperature of the rocky exoplanet TRAPPIST-1 b. The measurement is based on the planet’s thermal emission: heat energy given off in the form of infrared light detected by Webb’s Mid-Infrared Instrument (MIRI). The result indicates that the planet’s dayside has a temperature of about 500 kelvins (roughly 450 degrees Fahrenheit) and suggests that it has no significant atmosphere.

This is the first detection of any form of light emitted by an exoplanet as small and as cool as the rocky planets in our own solar system. The result marks an important step in determining whether planets orbiting small active stars like TRAPPIST-1 can sustain atmospheres needed to support life. It also bodes well for Webb’s ability to characterize temperate, Earth-sized exoplanets using MIRI.

“These observations really take advantage of Webb’s mid-infrared capability,” said Thomas Greene, an astrophysicist at NASA’s Ames Research Center and lead author on the study published today in the journal Nature. “No previous telescopes have had the sensitivity to measure such dim mid-infrared light.”

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

In early 2017, astronomers reported the discovery of seven rocky planets orbiting an ultracool red dwarf star (or M dwarf) 40 light-years from Earth. What is remarkable about the planets is their similarity in size and mass to the inner, rocky planets of our own solar system. Although they all orbit much closer to their star than any of our planets orbit the Sun – all could fit comfortably within the orbit of Mercury – they receive comparable amounts of energy from their tiny star.

TRAPPIST-1 b, the innermost planet, has an orbital distance about one hundredth that of Earth’s and receives about four times the amount of energy that Earth gets from the Sun. Although it is not within the system’s habitable zone, observations of the planet can provide important information about its sibling planets, as well as those of other M-dwarf systems.

“There are ten times as many of these stars in the Milky Way as there are stars like the Sun, and they are twice as likely to have rocky planets as stars like the Sun,” explained Greene. “But they are also very active – they are very bright when they’re young, and they give off flares and X-rays that can wipe out an atmosphere.”

Co-author Elsa Ducrot from the French Alternative Energies and Atomic Energy Commission (CEA) in France, who was on the team that conducted earlier studies of the TRAPPIST-1 system, added, “It’s easier to characterize terrestrial planets around smaller, cooler stars. If we want to understand habitability around M stars, the TRAPPIST-1 system is a great laboratory. These are the best targets we have for looking at the atmospheres of rocky planets.”

Previous observations of TRAPPIST-1 b with the Hubble and Spitzer space telescopes found no evidence for a puffy atmosphere, but were not able to rule out a dense one.

One way to reduce the uncertainty is to measure the planet's temperature. "This planet is tidally locked, with one side facing the star at all times and the other in permanent darkness," said Pierre-Olivier Lagage from CEA, a co-author on the paper. "If it has an atmosphere to circulate and redistribute the heat, the dayside will be cooler than if there is no atmosphere."

The team used a technique called secondary eclipse photometry, in which MIRI measured the change in brightness from the system as the planet moved behind the star. Although TRAPPIST-1 b is not hot enough to give off its own visible light, it does have an infrared glow. By subtracting the brightness of the star on its own (during the secondary eclipse) from the brightness of the star and planet combined, they were able to successfully calculate how much infrared light is being given off by the planet.

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute.

Webb's detection of a secondary eclipse is itself a major milestone. With the star more than 1,000 times brighter than the planet, the change in brightness is less than 0.1%.

"There was also some fear that we'd miss the eclipse. The planets all tug on each other, so the orbits are not perfect," said Taylor Bell, the post-doctoral researcher at the Bay Area Environmental Research Institute who analyzed the data. "But it was just amazing: The time of the eclipse that we saw in the data matched the predicted time within a couple of minutes."

The team analyzed data from five separate secondary eclipse observations. "We compared the results to computer models showing what the temperature should be in different scenarios," explained Ducrot. "The results are almost perfectly consistent with a blackbody made of bare rock and no atmosphere to circulate the heat. We also didn't see any signs of light being absorbed by carbon dioxide, which would be apparent in these measurements."

This research was conducted as part of Webb Guaranteed Time Observation (GTO) program 1177, which is one of eight programs from Webb's first year of science designed to help fully characterize the TRAPPIST-1 system. Additional secondary eclipse observations of TRAPPIST-1 b are currently in progress, and now that they know how good the data can be, the team hopes to eventually capture a full phase curve showing the change in brightness over the entire orbit. This will allow them to see how the temperature changes from the day to the nightside and confirm if the planet has an atmosphere or not.

"There was one target that I dreamed of having," said Lagage, who worked on the development of the MIRI instrument for more than two decades. "And it was this one. This is the first time we can detect the emission from a rocky, temperate planet. It's a really important step in the story of discovering exoplanets."

The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency), and CSA (Canadian Space Agency). MIRI was contributed by NASA and ESA, with the instrument designed and built by a consortium of nationally funded European Institutes (the MIRI European Consortium) and NASA's Jet Propulsion Laboratory, in partnership with the University of Arizona.

Media Contacts:

Laura BetzNASA's Goddard Space Flight Center, Greenbelt, Md.laura.e.betz@nasa.gov

Margaret Carruthers / Christine PulliamSpace Telescope Science Institute, Baltimore, Md.mcarruthers@stsci.edu / cpulliam@stsci.edu

NASA Continues Advancing STEM for Students Through New Partnership

NASA Invites Media to Preview its Museum Earth Information Center

NASA Seeks Innovators for Lunar Waste Competition

NASA Astronaut Tracy C. Dyson to Discuss Science, Station Mission

Mariachi and Moonshots: Melissa Moreno Orchestrates Gateway Communications

Discovery Alert: Two ‘Nearby’ Worlds Might be Habitable

4 min read

Alicia Cermak

The discovery: Two planets about as massive as Earth orbit a red-dwarf star only 16 light-years away – nearby in astronomical terms. The planets, GJ 1002 b and c, lie within the star’s habitable zone, the orbital distance that could allow liquid water to form on a planet’s surface if it has the right kind of atmosphere.

Key facts: Whether red-dwarf stars are likely to host habitable worlds is a subject of scientific debate. On the minus side, these stars – smaller, cooler, but far longer-lived than stars like our Sun – tend to flare frequently in their youth. Such flares could potentially strip the atmospheres from closely orbiting planets, and the two planets orbiting GJ 1002 are close indeed. Planet b, with a mass slightly higher than Earth’s, is the closer of the two. Its year, once around the star, lasts only 10 days. Planet c, about a third more massive than Earth, takes about 20 days to orbit the star.

On the plus side, however, GJ 1002 seems to be mature enough to have gotten over its youthful tantrums, and now appears quiet. It’s even possible that the early flaring helped build up a variety of molecules on the planets’ surfaces that could be used later, during the star’s quiet period, by any developing life forms that might be present.

Details: An international team led by Alejandro Suárez Mascareño of the University of La Laguna, Spain, discovered the two new planets using radial velocity measurements – that is, detecting the “wobbles” of the parent star caused by gravitational tugs from orbiting planets. As the planets move toward the far side of the star, they pull the star away from us, causing the star’s light to shift toward the red end of the spectrum. As the planets move toward the star’s near side, they pull the star in our direction, shifting its light toward the blue. The planetary tugs on GJ 1002 are tiny, about 4.3 feet (1.3 meters) per second – equivalent to moving at about 3 miles per hour (4.8 kilometers per hour). Such small movements are difficult to detect.

The radial velocity method, which also reveals how massive the planets are, has yielded more than 1,000 confirmed detections of exoplanets. The most detections, however, have been notched using the “transit” method – watching for a tiny dip in starlight as a planet crosses in front of its star – with nearly 4,000 confirmed detections.

To make its radial velocity measurements, the science team relied on instruments called spectrographs, which measure variations in light. The spectrographs used to discover GJ 1002 b and c were part of two collaborative observation programs: The Echelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations (ESPRESSO), and the Calar Alto high-Resolution search for M-dwarfs with Exoearths with Near-infrared and optical E■chelle Spectrographs (CARMENES).

Fun facts: The new planets join 10 others in a fairly exclusive category: small worlds in the “conservative” habitable zone that are less than 1.5 times the size of Earth or less than five times as massive. If we loosen the membership criteria a bit – slightly larger planets in the “optimistic” habitable zone – the group expands to about 40 exoplanets, or planets beyond our solar system. The conservative habitable zone is a stricter boundary for the region around a star that might allow planets to harbor water; optimistic habitable zones expand that boundary a bit. Any habitable zone estimate is a rough approximation. So far, none of these worlds’ atmospheres have been fully analyzed – and many might not possess atmospheres at all.

The discoverers: A paper on the discovery, “Two temperate Earth-mass planets orbiting the nearby star GJ 1002,” by A. Suárez Mascareño and his team, has been accepted for publication in the journal, Astronomy & Astrophysics. The planets were entered into NASA’s Exoplanet Archive on Dec. 22, 2022.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Discovers Planetary System’s Second Earth-Size World

4 min read

Using data from NASA’s Transiting Exoplanet Survey Satellite, scientists have identified an Earth-size world, called TOI 700 e, orbiting within the habitable zone of its star – the range of distances where liquid water could occur on a planet’s surface. The world is 95% Earth’s size and likely rocky.

Astronomers previously discovered three planets in this system, called TOI 700 b, c, and d. Planet d also orbits in the habitable zone. But scientists needed an additional year of TESS observations to discover TOI 700 e.

“This is one of only a few systems with multiple, small, habitable-zone planets that we know of,” said Emily Gilbert, a postdoctoral fellow at NASA’s Jet Propulsion Laboratory in Southern California who led the work. “That makes the TOI 700 system an exciting prospect for additional follow up. Planet e is about 10% smaller than planet d, so the system also shows how additional TESS observations help us find smaller and smaller worlds.”

Gilbert presented the result on behalf of her team at the 241st meeting of the American Astronomical Society in Seattle. A paper about the newly discovered planet was accepted by The Astrophysical Journal Letters.

TOI 700 is a small, cool M dwarf star located around 100 light-years away in the southern constellation Dorado. In 2020, Gilbert and others announced the discovery of the Earth-size, habitable-zone planet d, which is on a 37-day orbit, along with two other worlds.

The innermost planet, TOI 700 b, is about 90% Earth’s size and orbits the star every 10 days. TOI 700 c is over 2.5 times bigger than Earth and completes an orbit every 16 days. The planets are probably tidally locked, which means they spin only once per orbit such that one side always faces the star, just as one side of the Moon is always turned toward Earth.

TESS monitors large swaths of the sky, called sectors, for approximately 27 days at a time. These long stares allow the satellite to track changes in stellar brightness caused by a planet crossing in front of its star from our perspective, an event called a transit. The mission used this strategy to observe the southern sky starting in 2018, before turning to the northern sky. In 2020, it returned to the southern sky for additional observations. The extra year of data allowed the team to refine the original planet sizes, which are about 10% smaller than initial calculations.

“If the star was a little closer or the planet a little bigger, we might have been able to spot TOI 700 e in the first year of TESS data,” said Ben Hord, a doctoral candidate at the University of Maryland, College Park and a graduate researcher at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “But the signal was so faint that we needed the additional year of transit observations to identify it.”

TOI 700 e, which may also be tidally locked, takes 28 days to orbit its star, placing planet e between planets c and d in the so-called optimistic habitable zone.

Scientists define the optimistic habitable zone as the range of distances from a star where liquid surface water could be present at some point in a planet’s history. This area extends to either side of the conservative habitable zone, the range where researchers hypothesize liquid water could exist over most of the planet’s lifetime. TOI 700 d orbits in this region.

Finding other systems with Earth-size worlds in this region helps planetary scientists learn more about the history of our own solar system.

Follow-up study of the TOI 700 system with space- and ground-based observatories is ongoing, Gilbert said, and may yield further insights into this rare system.

“TESS just completed its second year of northern sky observations,” said Allison Youngblood, a research astrophysicist and the TESS deputy project scientist at Goddard. “We’re looking forward to the other exciting discoveries hidden in the mission’s treasure trove of data.”

TESS is a NASA Astrophysics Explorer mission led and operated by Massachusetts Institute of Technology in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

By Jeanette KazmierczakNASA’s Goddard Spaceflight Center, Greenbelt, Md.

Media Contacts:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.

Calla CofieldNASA’s Jet Propulsion Laboratory, Southern California

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Recaps Webb Telescope Findings From AAS Meeting

5 min read

Scientists shared new findings and updates from NASA’s James Webb Space Telescope, also called “Webb” or “JWST,” at press conferences during the 241st meeting of the American Astronomical Society (AAS) in Seattle, from Jan. 8 to 12.

Scientists from NASA and universities shared Webb results from multiple different scientific disciplines, ranging from the early universe and galaxy evolution to exoplanet atmospheres and young star formation.

“An Early Look at the Evolution of Galaxy Structure at z = 3-9 with JWST”

Scientists analyzed the morphologies, or visual appearance and structure, of 850 distant galaxies from observations with Webb’s Near Infrared Camera (NIRCam) instrument and compared them to their morphologies based on previous Hubble Space Telescope imaging. The term “z” denotes the redshift of the galaxies observed and is a measure of the distance of the object. As part of the Cosmic Evolution Early Release Science (CEERS) Survey, scientists conducted visual classifications of each galaxy as well as quantitative measurements of galaxy structure. Overall, the findings showed galaxies with a wide diversity of morphologies out to the highest redshifts, and many that have different morphologies than previously seen with Hubble. More here.

“Finding Peas in the Early Universe with JWST”

A new analysis of distant galaxies imaged by Webb shows that they are extremely young and share some remarkable similarities to “green peas,” a rare class of small galaxies that still exist in our cosmic backyard. Green pea galaxies appear as small, round, unresolved dots with a distinctly green shade. Researchers made connections between far-off galaxies from Webb’s First Deep Field and these nearby galaxies, which can be studied in more detail. More here.

“Zooming in on the Shocked and Turbulent Intergalactic Medium in Stephan’s Quintet with JWST and ALMA”

Shockwaves resulting from the violent collision between an intruder galaxy and Stephan’s Quintet are helping astronomers understand how turbulence influences gas in the intergalactic medium. New observations with Webb and the Atacama Large Millimeter/submillimeter Array (ALMA) revealed that a sonic boom several times the size of the Milky Way has kickstarted a recycling plant for warm and cold molecular hydrogen gas. What’s more, scientists uncovered the break-up of a giant cloud into a fog of warm gas, the possible collision of two clouds forming a splash of warm gas around them, and the formation of a new galaxy. More here.

“A Large Number of Candidate Galaxies at z ~ 11-20 Revealed by the JWST Early Release Observations”

Using data from Webb’s First Deep Field, the SMACS 0723-73 field, scientists found a total of 87 candidate galaxies at a redshift, or “z,” of greater than 11. This is the first large sample of candidate galaxies at such high redshifts. According to the researchers, such a large number of candidate objects at such high redshifts was not expected from previously favored predictions and demands further investigation. More here.

“Unveiling the Dusty Hearts of Galaxies with JWST”

Hosting an active supermassive black hole surrounded by a star-forming ring at its center, nearby Seyfert galaxy NGC 7469 presents an ideal laboratory for investigating the interplay between black hole and its host galaxy in detail. The high-resolution mid-infrared spectroscopic capability of Webb enabled not only a clear view into this phenomenon through the dusty veil, but it also, for the first time, allowed scientists to map and trace the motion of cool molecular and ionized gas species close to the active nucleus. This study revealed a highly ionized outflow driven by the central supermassive black hole in NGC 7469 that is also heating the nearby interstellar medium via shocks and destroying small dust grains, demonstrating the power of the telescope in revealing the physics of feedback processes underlying the co-evolution of black holes and galaxies. More here.

“JWST Images of a Young Planet-Hosting Debris Disk System”

Scientists shared Webb NIRCam images of the famous edge-on debris disk system AU Microscopii (or AU Mic). These images mark the first detection of the disk at these infrared wavelengths (3-4 microns), enabling new insights regarding the composition of the material in the disk. Though no planets were detected, the data is sensitive to planets as small as roughly twice Neptune’s mass – significantly constraining any yet-unseen planets that might remain. More here.

“Constraints on the Presence of a Rocky Exoplanet Atmosphere from a JWST Transmission Spectrum”

Researchers confirmed an exoplanet, a planet that orbits another star, using Webb for the first time. Formally classified as LHS 475 b, the planet is almost exactly the same size as our own, clocking in at 99% of Earth’s diameter.

The team chose to observe this target with Webb after carefully reviewing targets of interest from NASA’s Transiting Exoplanet Survey Satellite (TESS), which hinted at the planet’s existence. Webb’s Near-Infrared Spectrograph (NIRSpec) captured the planet easily and clearly with only two transit observations. More here.

“Early Imaging Results with JWST: Young Star Formation in NGC 346”

NCG 346 is located in the Small Magellanic Cloud (SMC), a dwarf galaxy close to our Milky Way. The SMC contains lower concentrations of elements heavier than hydrogen or helium, which astronomers call metals, compared to the Milky Way. Since dust grains in space are composed mostly of metals, scientists expected there would be low amounts of dust, and that it would be hard to detect. New data from Webb reveals the opposite. More here.

For more information about Webb, visit:

www.nasa.gov/webb

By Peter SooyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Wants You to Help Study Planets Around Other Stars

6 min read

The Exoplanet Watch project invites you to use your smartphone or personal telescope to help track worlds outside our solar system.

More than 5,000 planets have been confirmed to exist outside our solar system, featuring a wide array of characteristics like clouds made of glass and twin suns. Scientists estimate there could be millions more exoplanets in our home galaxy alone, which means professional astronomers could use your help tracking and studying them.

This is where Exoplanet Watch comes in. Participants in the program can use their own telescopes to detect planets outside our solar system, or they can look for exoplanets in data from other telescopes using a computer or smartphone.

Exoplanet Watch began in 2018 under NASA’s Universe of Learning, one of the agency’s Science Activation programs that enables anyone to experience how science is done and discover the universe for themselves. Until recently there were limits on how many people could help look through the data collected by other telescopes, but now this program is easily available to anyone. By following the site’s instructions, participants can download data to their device or access it via the cloud, and then assess it using a custom data analysis tool.

“With Exoplanet Watch you can learn how to observe exoplanets and do data analysis using software that actual NASA scientists use,” said Rob Zellem, the creator of Exoplanet Watch and an astrophysicist at NASA’s Jet Propulsion Laboratory in Southern California. “We’re excited to show more people how exoplanet science is really done.”

Participants without telescopes can help astronomers comb through data that’s already been taken. The project has 10 years of exoplanet observations, collected by a small ground-based telescope south of Tucson, Arizona. This year, the project will start collecting additional data from two other telescopes at the Table Mountain facility in Southern California, which JPL manages.

These telescopes look at nearby stars and search for what scientists call exoplanet transits: regular dips in a star’s brightness caused by a planet passing between the star and Earth. Essentially, a transit is an observation of a planet’s silhouette against the bright glare of its star.

Multiple NASA telescopes look for exoplanet transits as a way to discover new planets, but Exoplanet Watch participants primarily observe transits by planets that have already been discovered to gain more information about their orbits. The time between exoplanet transits reveals how long it takes an exoplanet to orbit its parent star; the more transits that are measured, the more precisely the length of the orbit is known. If the timing of the orbit isn’t measured precisely, scientists who want to study those planets in more detail with large ground-based or space-based telescopes can lose valuable observing time while they wait for the planet to appear. Having volunteers sort through the data will save significant computing and processing time.

Exoplanet Watch participants will also look for variations in the apparent brightness of stars – changes caused by features such as flares (outbursts of light) and star spots (dark spots on a star’s surface). In transit measurements, these changes make a planet appear smaller or larger than it actually is. This work will help scientists anticipate the variability of a particular star before they study its exoplanets with large, sensitive telescopes like NASA’s James Webb Space Telescope.

Want to take your own data? Although the number of targets you can see increases with the size of the telescope used, there's no minimum size requirement. For example, Exoplanet Watch can help you detect exoplanet transits for hundreds of nearby stars with just a 6-inch (15-centimeter) telescope.

Exoplanet Watch combines observations of the same target by multiple sky watchers in order to get a higher-fidelity measurement. Combining observations is also useful if the planet's transit lasts longer than the time a star is visible in the sky for a single observer: Multiple participants at different locations around the globe can collectively watch the duration of a long transit.

That was the case with a planet called HD 80606 b, which Webb will observe this year. A recent study of this planet led by Kyle Pearson, the Exoplanet Watch deputy science lead at JPL, combined observations from more than 20 Exoplanet Watch participants.

The volunteer effort on HD 80606 b will free up almost two hours of time on Webb for other observations. And on missions that aim to observe hundreds or thousands of exoplanets, the number of minutes saved by refining planet transit measurements can add up and free a significant amount of observing time, according to Zellem.

One of the program's policies requires that the first paper to make use of the observations or analysis done by volunteers will list those volunteers as co-authors, which was the case with the study led by Pearson. "I hope this program lowers barriers to science for a lot of people and inspires the next generation of astronomers to join our field," said Zellem.

Exoplanet Watch is a citizen science project managed by JPL, a division of Caltech in Pasadena, California, as part of NASA's Universe of Learning.

The ground-based data for the project was collected by the MicroObservatory Robotic Telescope Network, supported by NASA's Universe of Learning and managed by the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts. Volunteer-generated data is uploaded to the American Association of Variable Star Observers' (AAVSO) Exoplanet Database.

NASA's Universe of Learning is a competitively selected member of the NASA Science Activation program. The Science Activation program connects NASA science experts and real content and experiences with community leaders to do science in ways that activate minds and promote deeper understanding of our world and beyond.

This work is supported by NASA under award number NNX16AC65A to the Space Telescope Science Institute, in partnership with Caltech/IPAC, Center for Astrophysics | Harvard & Smithsonian, and JPL.

For more information about Exoplanet Watch, visit:

https://exoplanets.nasa.gov/exoplanet-watch/

For more information about NASA's Universe of Learning, visit:

https://www.universe-of-learning.org/

For more NASA citizen science projects, visit:

https://science.nasa.gov/citizenscience

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

2023-002

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Assembly Begins on NASA’s Next Tool to Study Exoplanets

6 min read

The Coronagraph Instrument on NASA’s Nancy Grace Roman Space Telescope will study planets around other stars. Putting it together will require a highly choreographed dance.

Scientists have discovered more than 5,000 exoplanets, or planets outside our solar system. As technologies for studying these worlds continue to advance, researchers may someday be able to search for signs of life on exoplanets that are similar in size, composition, and temperature to Earth. But to do that they’ll need new tools, like those being tested on the Coronagraph Instrument on NASA’s Nancy Grace Roman Space Telescope. The instrument will block the light from each distant star it observes so that scientists can better see the planets around the star, and it will demonstrate technologies needed to eventually study potentially habitable planets with future missions.

The Coronagraph Instrument team has already designed the cutting-edge instrument and built the components. Now they have to put the pieces together and run tests to make sure they operate as intended. “It’s like all the separate tributaries are finally coming together to form the river,” said Jeff Oseas, product delivery manager for the Coronagraph Instrument’s optical subsystem at NASA’s Jet Propulsion Laboratory in Southern California.

The process kicked off recently at JPL and will take more than a year. Once complete, the Coronagraph Instrument will be shipped to the agency’s Goddard Space Flight Center in Greenbelt, Maryland, and incorporated into the Roman observatory.

JPL engineer Gasia Bedrosian leads the assembly and testing process as the instrument’s integration and test product delivery manager. She likes to say that while integration and testing are technically the last steps in building an instrument, they’re actually part of the process from the beginning.

In 2018, Bedrosian started working on a set of assembly plans for something that’s never been built before. She and her team then spent another two years collaborating with various subject matter experts and project members to review and adjust the plan, ensuring all the pieces would come together on time and in the right order. The process will resemble a well-choreographed ballet that involves heavy duty cranes, lasers, and vacuum chambers the size of buses.

Roughly the size and shape of a baby grand piano, the Coronagraph Instrument is composed of two main sections that will stack on top of each another: the optical bench and the instrument electronics pallet.

The more delicate of the two is the optical bench, which contains 64 elements, such as mirrors and filters, designed to remove as much starlight as possible without suppressing the light from planets. This approach to finding and studying exoplanets is called direct imaging, and it is expected to be the best way to study the atmospheres and surface features of rocky worlds similar to Earth. Some of the optical components on the Coronagraph Instrument are so small they’re barely visible to the naked eye.

The pallet, or bottom layer, houses the electronics that receive instructions from the Roman spacecraft and return the Coronagraph Instrument’s scientific data. The electronics also control the mechanical components on the optical bench as well as the instrument heaters. The optical bench will be stacked by crane atop the electronics pallet. Because the two layers have to be aligned with each other to within a fraction of a millimeter, the team will use lasers to get them positioned just right over the course of four days.

Integration and testing teams will often use digital 3D models of the instrument to help make their plans, but nothing can compare to seeing the object in a real space. That's why the coronagraph team made use of an augmented reality headset that lets users see a virtual projection of a 3D object and the world around them. The headset is also used by the Mars Curiosity rover team to see in 3D the Martian terrain that the rover drives over.

"We learned a lot from that exercise," said Bedrosian. "We could get a sense of how tight the access would be at certain points of integration by literally laying on the floor and getting visuals of under the instrument. It showed us when it would be beneficial to lift the entire instrument with a crane, or if we were going to need a specialized tool to do our work at that angle. It helped make a lot of our plans safer and simpler."

Once assembled, the Coronagraph Instrument will undergo a series of tests, including almost a month of dynamical testing to simulate the rocket ride into space. It will then be put in a vacuum chamber that replicates the space environment to check that the hardware remains aligned and operating correctly.

"It's exciting to finally start putting all the pieces together," said Bedrosian. "It's definitely a delayed gratification, because we've spent so long preparing. But now that we're here and my team members are talking about the hardware arriving, I can hear the excitement in their voices."

The Nancy Grace Roman Space Telescope is managed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by JPL and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace & Technologies Corp. in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

The Roman Coronagraph Instrument was designed and is being built at JPL, which manages the instrument for NASA. Contributions were made by ESA (the European Space Agency), the Japanese Aerospace Exploration Agency (JAXA), the French space agency Centre National d'Études Spatiales (CNES), and the Max Planck Institute for Astronomy (MPIA) in Germany. Caltech, in Pasadena, California, manages JPL for NASA.

For more information about the Roman telescope, visit:

https://roman.gsfc.nasa.gov/

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Claire AndreoliGoddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

2022-205

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Help Discover Worlds With NASA

5 min read

NASA Science Editorial Team

The Exoplanet Watch project invites you to use your smartphone or personal telescope to help track worlds outside our solar system.

More than 5,000 planets have been confirmed to exist outside our solar system, featuring a wide array of characteristics like clouds made of glass and twin suns. Scientists estimate there could be millions more exoplanets in our home galaxy alone, which means professional astronomers could use your help tracking and studying them.This is where Exoplanet Watch comes in. Participants in the program can use their own telescopes to detect planets outside our solar system, or they can look for exoplanets in data from other telescopes using a computer or smartphone.

Exoplanet Watch began in 2018 under NASA’s Universe of Learning, one of the agency’s Science Activation programs that enables anyone to experience how science is done and discover the universe for themselves. Until recently there were limits on how many people could help look through the data collected by other telescopes, but now this program is easily available to anyone. By following the site’s instructions, participants can download data to their device or access it via the cloud, and then assess it using a custom data analysis tool.

“With Exoplanet Watch you can learn how to observe exoplanets and do data analysis using software that actual NASA scientists use,” said Rob Zellem, the creator of Exoplanet Watch and an astrophysicist at NASA’s Jet Propulsion Laboratory in Southern California. “We’re excited to show more people how exoplanet science is really done.”

Participants without telescopes can help astronomers comb through data that’s already been taken. The project has 10 years of exoplanet observations, collected by a small ground-based telescope south of Tucson, Arizona. This year, the project will start collecting additional data from two other telescopes at the Table Mountain facility in Southern California, which JPL manages.

These telescopes look at nearby stars and search for what scientists call exoplanet transits: regular dips in a star’s brightness caused by a planet passing between the star and Earth. Essentially, a transit is an observation of a planet’s silhouette against the bright glare of its star.

Multiple NASA telescopes look for exoplanet transits as a way to discover new planets, but Exoplanet Watch participants primarily observe transits by planets that have already been discovered to gain more information about their orbits. The time between exoplanet transits reveals how long it takes an exoplanet to orbit its parent star; the more transits that are measured, the more precisely the length of the orbit is known. If the timing of the orbit isn’t measured precisely, scientists who want to study those planets in more detail with large ground-based or space-based telescopes can lose valuable observing time while they wait for the planet to appear. Having volunteers sort through the data will save significant computing and processing time.

Exoplanet Watch participants will also look for variations in the apparent brightness of stars – changes caused by features such as flares (outbursts of light) and star spots (dark spots on a star’s surface). In transit measurements, these changes make a planet appear smaller or larger than it actually is. This work will help scientists anticipate the variability of a particular star before they study its exoplanets with large, sensitive telescopes like NASA’s James Webb Space Telescope.

Want to take your own data? Although the number of targets you can see increases with the size of the telescope used, there’s no minimum size requirement. For example, Exoplanet Watch can help you detect exoplanet transits for hundreds of nearby stars with just a 6-inch (15-centimeter) telescope.

Exoplanet Watch combines observations of the same target by multiple sky watchers in order to get a higher-fidelity measurement. Combining observations is also useful if the planet’s transit lasts longer than the time a star is visible in the sky for a single observer: Multiple participants at different locations around the globe can collectively watch the duration of a long transit.

That was the case with a planet called HD 80606 b, which Webb will observe this year. A recent study of this planet led by Kyle Pearson, the Exoplanet Watch deputy science lead at JPL, combined observations from more than 20 Exoplanet Watch participants. The volunteer effort on HD 80606 b will free up almost two hours of time on Webb for other observations. And on missions that aim to observe hundreds or thousands of exoplanets, the number of minutes saved by refining planet transit measurements can add up and free a significant amount of observing time, according to Zellem.

One of the program’s policies requires that the first paper to make use of the observations or analysis done by volunteers will list those volunteers as co-authors, which was the case with the study led by Pearson. “I hope this program lowers barriers to science for a lot of people and inspires the next generation of astronomers to join our field,” said Zellem.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: For This Familiar Planet, a Death Spiral

3 min read

Alicia Cermak

The discovery: Kepler-1658 b, a hot Jupiter with a storied history, appears to be spiraling toward its host star – and will likely crash to the star's surface in less than 3 million years.

Key facts: The deep-fried planet, about as big as our own Jupiter but nearly six times its mass, has a long history with scientists and the public. It was the first planet candidate to be identified by NASA's Kepler Space Telescope in 2009 – the same year it launched. Those were the early days of surveying exoplanets, or planets around other stars. But doubts about the detection cast Kepler-1658 b into the dustbin of "false positive" exoplanet discoveries. New software and analytical techniques rescued the planet in the years that followed, and placed it in the "confirmed" column by 2019.

Now, only a few short years after it was brought back into the fold, Kepler-1658 b has been consigned to probable oblivion by the latest observations of its orbital path.

Details: Exoplanet scientists deploy an array of techniques to study distant planets, from the "transit" method Kepler used to discover Kepler-1658 b – measuring the tiny dip in starlight as the planet crosses in front of its star – to carefully tracking the wobbles of parent stars, revealing the gravitational tugs of unseen planets. And these techniques continue to grow in refinement. By measuring subtle shifts in the timing of Kepler 1658 b's transits across the face of its swollen star, a study team determined the planet was arriving earlier than its expected transit times – a key piece of evidence that the planet's orbit is shrinking.

The team also showed that the giant planet's decaying orbit is best explained by tidal forces from its parent star, which, as it moves toward its end stage, is expanding. That expansion increases the gravitational interaction between the star and the planet; the star, in a sense, robs the planet's orbit of its energy.

Our home planet also could meet its end when the Sun grows so large it might swallow Earth, billions of years from now.

Kepler-1658 b also appears to be brighter and hotter than scientists expected, another possible result of tidal interaction with the star.

Fun facts: Hot Jupiters, although among the first exoplanets to be discovered, are strange worlds unlike any in our solar system. They are gas giants, like our own Jupiter, but in extremely tight orbits around their stars – a "year" on these planets, in fact, typically lasts less than 10 days. A year on Kepler-1658 b, once around the star, takes just under four days.

The discoverers: A team led by Shreyas Vissapragada of the Center for Astrophysics Harvard & Smithsonian published the new study of Kepler-1658 b on Dec. 19, 2022, in "The Astrophysical Journal Letters."

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Two Exoplanets May Be Mostly Water, NASA’s Hubble and Spitzer Find

6 min read

NASA Hubble Mission Team

Goddard Space Flight Center

A team led by researchers at the University of Montreal has found evidence that two exoplanets orbiting a red dwarf star are "water worlds," where water makes up a large fraction of the entire planet. These worlds, located in a planetary system 218 light-years away in the constellation Lyra, are unlike any planet found in our solar system.

The team, led by Caroline Piaulet of the Trottier Institute for Research on Exoplanets at the University of Montreal, published a detailed study of this planetary system, known as Kepler-138, in the journal Nature Astronomy today.

Piaulet and colleagues observed exoplanets Kepler-138 c and Kepler-138 d with NASA's Hubble and the retired Spitzer space telescopes and discovered that the planets could be composed largely of water. These two planets and a smaller planetary companion closer to the star, Kepler-138 b, had been discovered previously by NASA's Kepler Space Telescope. The new study found evidence for a fourth planet, too.

Water wasn't directly detected at Kepler-138 c and d, but by comparing the sizes and masses of the planets to models, astronomers conclude that a significant fraction of their volume – up to half of it – should be made of materials that are lighter than rock but heavier than hydrogen or helium (which constitute the bulk of gas giant planets like Jupiter). The most common of these candidate materials is water.

"We previously thought that planets that were a bit larger than Earth were big balls of metal and rock, like scaled-up versions of Earth, and that's why we called them super-Earths," explained Björn Benneke, study co-author and professor of astrophysics at the University of Montreal. "However, we have now shown that these two planets, Kepler-138 c and d, are quite different in nature and that a big fraction of their entire volume is likely composed of water. It is the best evidence yet for water worlds, a type of planet that was theorized by astronomers to exist for a long time."

With volumes more than three times that of Earth and masses twice as big, planets c and d have much lower densities than Earth. This is surprising because most of the planets just slightly bigger than Earth that have been studied in detail so far all seemed to be rocky worlds like ours. The closest comparison, say researchers, would be some of the icy moons in the outer solar system that are also largely composed of water surrounding a rocky core.

"Imagine larger versions of Europa or Enceladus, the water-rich moons orbiting Jupiter and Saturn, but brought much closer to their star," explained Piaulet. "Instead of an icy surface, they would harbor large water-vapor envelopes."

Researchers caution the planets may not have oceans like those on Earth directly at the planet's surface. "The temperature in Kepler-138 d's atmosphere is likely above the boiling point of water, and we expect a thick dense atmosphere made of steam on this planet. Only under that steam atmosphere there could potentially be liquid water at high pressure, or even water in another phase that occurs at high pressures, called a supercritical fluid," Piaulet said.

In 2014, data from NASA's Kepler Space Telescope allowed astronomers to announce the detection of three planets orbiting Kepler-138. This was based on a measurable dip in starlight as the planet momentarily passed in front of their star.

Benneke and his colleague Diana Dragomir, from the University of New Mexico, came up with the idea of re-observing the planetary system with the Hubble and Spitzer space telescopes between 2014 and 2016 to catch more transits of Kepler-138 d, the third planet in the system, in order to study its atmosphere.

The two possible water worlds, Kepler-138 c and d, are not located in the habitable zone, the area around a star where temperatures would allow liquid water on the surface of a rocky planet. But in the Hubble and Spitzer data, researchers additionally found evidence for a new planet in the system, Kepler-138 e, in the habitable zone.

This newly found planet is small and farther from its star than the three others, taking 38 days to complete an orbit. The nature of this additional planet, however, remains an open question because it does not seem to transit its host star. Observing the exoplanet's transit would have allowed astronomers to determine its size.

With Kepler-138 e now in the picture, the masses of the previously known planets were measured again via the transit timing-variation method, which consists of tracking small variations in the precise moments of the planets' transits in front of their star caused by the gravitational pull of other nearby planets.

The researchers had another surprise: they found that the two water worlds Kepler-138 c and d are "twin" planets, with virtually the same size and mass, while they were previously thought to be drastically different. The closer-in planet, Kepler-138 b, on the other hand, is confirmed to be a small Mars-mass planet, one of the smallest exoplanets known to date.

"As our instruments and techniques become sensitive enough to find and study planets that are farther from their stars, we might start finding a lot more of these water worlds," Benneke concluded.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, MD301-286-1940

Ray VillardSpace Telescope Science Institute, Baltimore, MD

Marie-Eve NaudTrottier Institute for Research on Exoplanets, Montreal, CanadaUniversity of Montreal, Montreal, Canada

Science Contacts:

Caroline PiauletTrottier Institute for Research on Exoplanets, Montreal, CanadaUniversity of Montreal, Montreal, Canada

Björn BennekeTrottier Institute for Research on Exoplanets, Montreal, CanadaUniversity of Montreal, Montreal, Canada

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Two Super-Earths May Be Mostly Water

5 min read

NASA Science Editorial Team

A team led by researchers at the University of Montreal has found evidence that two exoplanets orbiting a red dwarf star are "water worlds," where water makes up a large fraction of the entire planet. These worlds, located in a planetary system 218 light-years away in the constellation Lyra, are unlike any planet found in our solar system.

The team, led by Caroline Piaulet of the Trottier Institute for Research on Exoplanets at the University of Montreal, published a detailed study of this planetary system, known as Kepler-138, in the journal Nature Astronomy Dec. 15, 2022.

Piaulet and colleagues observed exoplanets Kepler-138 c and Kepler-138 d with NASA's Hubble and the retired Spitzer space telescopes and discovered that the planets could be composed largely of water. These two planets and a smaller planetary companion closer to the star, Kepler-138 b, had been discovered previously by NASA's Kepler Space Telescope. The new study found evidence for a fourth planet, too.

Water wasn't directly detected at Kepler-138 c and d, but by comparing the sizes and masses of the planets to models, astronomers conclude that a significant fraction of their volume – up to half of it – should be made of materials that are lighter than rock but heavier than hydrogen or helium (which constitute the bulk of gas giant planets like Jupiter). The most common of these candidate materials is water.

"We previously thought that planets that were a bit larger than Earth were big balls of metal and rock, like scaled-up versions of Earth, and that's why we called them super-Earths," explained Björn Benneke, study co-author and professor of astrophysics at the University of Montreal. "However, we have now shown that these two planets, Kepler-138 c and d, are quite different in nature and that a big fraction of their entire volume is likely composed of water. It is the best evidence yet for water worlds, a type of planet that was theorized by astronomers to exist for a long time."

With volumes more than three times that of Earth and masses twice as big, planets c and d have much lower densities than Earth. This is surprising because most of the planets just slightly bigger than Earth that have been studied in detail so far all seemed to be rocky worlds like ours. The closest comparison, say researchers, would be some of the icy moons in the outer solar system that are also largely composed of water surrounding a rocky core.

"Imagine larger versions of Europa or Enceladus, the water-rich moons orbiting Jupiter and Saturn, but brought much closer to their star," explained Piaulet. "Instead of an icy surface, they would harbor large water-vapor envelopes."

Researchers caution the planets may not have oceans like those on Earth directly at the planet's surface. "The temperature in Kepler-138 d's atmosphere is likely above the boiling point of water, and we expect a thick dense atmosphere made of steam on this planet. Only under that steam atmosphere there could potentially be liquid water at high pressure, or even water in another phase that occurs at high pressures, called a supercritical fluid," Piaulet said.

In 2014, data from NASA's Kepler Space Telescope allowed astronomers to announce the detection of three planets orbiting Kepler-138. This was based on a measurable dip in starlight as the planet momentarily passed in front of their star.

Benneke and his colleague Diana Dragomir, from the University of New Mexico, came up with the idea of re-observing the planetary system with the Hubble and Spitzer space telescopes between 2014 and 2016 to catch more transits of Kepler-138 d, the third planet in the system, in order to study its atmosphere.

The two possible water worlds, Kepler-138 c and d, are not located in the habitable zone, the area around a star where temperatures would allow liquid water on the surface of a rocky planet. But in the Hubble and Spitzer data, researchers additionally found evidence for a new planet in the system, Kepler-138 e, in the habitable zone.

This newly found planet is small and farther from its star than the three others, taking 38 days to complete an orbit. The nature of this additional planet, however, remains an open question because it does not seem to transit its host star. Observing the exoplanet's transit would have allowed astronomers to determine its size.

With Kepler-138 e now in the picture, the masses of the previously known planets were measured again via the transit timing-variation method, which consists of tracking small variations in the precise moments of the planets' transits in front of their star caused by the gravitational pull of other nearby planets.

The researchers had another surprise: they found that the two water worlds Kepler-138 c and d are "twin" planets, with virtually the same size and mass, while they were previously thought to be drastically different. The closer-in planet, Kepler-138 b, on the other hand, is confirmed to be a small Mars-mass planet, one of the smallest exoplanets known to date.

"As our instruments and techniques become sensitive enough to find and study planets that are farther from their stars, we might start finding a lot more of these water worlds," Benneke concluded.

Search for Life

Stars

Universe

Black Holes

NASA’s Webb Reveals an Exoplanet Atmosphere as Never Seen Before

6 min read

Lee esta historia en español aquí.

NASA’s James Webb Space Telescope just scored another first: a molecular and chemical profile of a distant world’s skies.

While Webb and other space telescopes, including NASA’s Hubble and Spitzer, previously have revealed isolated ingredients of this broiling planet’s atmosphere, the new readings from Webb provide a full menu of atoms, molecules, and even signs of active chemistry and clouds.

The latest data also gives a hint of how these clouds might look up close: broken up rather than a single, uniform blanket over the planet.

The telescope’s array of highly sensitive instruments was trained on the atmosphere of WASP-39 b, a “hot Saturn” (a planet about as massive as Saturn but in an orbit tighter than Mercury) orbiting a star some 700 light-years away.

The findings bode well for the capability of Webb’s instruments to conduct the broad range of investigations of all types of exoplanets – planets around other stars – hoped for by the science community. That includes probing the atmospheres of smaller, rocky planets like those in the TRAPPIST-1 system.

“We observed the exoplanet with multiple instruments that, together, provide a broad swath of the infrared spectrum and a panoply of chemical fingerprints inaccessible until [this mission],” said Natalie Batalha, an astronomer at the University of California, Santa Cruz, who contributed to and helped coordinate the new research. “Data like these are a game changer.”

The suite of discoveries is detailed in a set of five new scientific papers, three of which are in press and two of which are under review. Among the unprecedented revelations is the first detection in an exoplanet atmosphere of sulfur dioxide (SO_2), a molecule produced from chemical reactions triggered by high-energy light from the planet’s parent star. On Earth, the protective ozone layer in the upper atmosphere is created in a similar way.

“This is the first time we see concrete evidence of photochemistry – chemical reactions initiated by energetic stellar light – on exoplanets,” said Shang-Min Tsai, a researcher at the University of Oxford in the United Kingdom and lead author of the paper explaining the origin of sulfur dioxide in WASP-39 b’s atmosphere. “I see this as a really promising outlook for advancing our understanding of exoplanet atmospheres with [this mission].”

This led to another first: scientists applying computer models of photochemistry to data that requires such physics to be fully explained. The resulting improvements in modeling will help build the technological know-how to interpret potential signs of habitability in the future.

“Planets are sculpted and transformed by orbiting within the radiation bath of the host star,” Batalha said. “On Earth, those transformations allow life to thrive.”

The planet’s proximity to its host star – eight times closer than Mercury is to our Sun – also makes it a laboratory for studying the effects of radiation from host stars on exoplanets. Better knowledge of the star-planet connection should bring a deeper understanding of how these processes affect the diversity of planets observed in the galaxy.

To see light from WASP-39 b, Webb tracked the planet as it passed in front of its star, allowing some of the star's light to filter through the planet's atmosphere. Different types of chemicals in the atmosphere absorb different colors of the starlight spectrum, so the colors that are missing tell astronomers which molecules are present. By viewing the universe in infrared light, Webb can pick up chemical fingerprints that can't be detected in visible light.

Other atmospheric constituents detected by the Webb telescope include sodium (Na), potassium (K), and water vapor (H2O), confirming previous space and ground-based telescope observations as well as finding additional fingerprints of water, at these longer wavelengths, that haven't been seen before.

Webb also saw carbon dioxide (CO2) at higher resolution, providing twice as much data as reported from its previous observations. Meanwhile, carbon monoxide (CO) was detected, but obvious signatures of both methane (CH4) and hydrogen sulfide (H2S) were absent from the Webb data. If present, these molecules occur at very low levels.

To capture this broad spectrum of WASP-39 b's atmosphere, an international team numbering in the hundreds independently analyzed data from four of the Webb telescope's finely calibrated instrument modes.

Download the full-resolution image from the Space Telescope Science Institute.

“We had predicted what [the telescope] would show us, but it was more precise, more diverse, and more beautiful than I actually believed it would be,” said Hannah Wakeford, an astrophysicist at the University of Bristol in the United Kingdom who investigates exoplanet atmospheres.

Having such a complete roster of chemical ingredients in an exoplanet atmosphere also gives scientists a glimpse of the abundance of different elements in relation to each other, such as carbon-to-oxygen or potassium-to-oxygen ratios. That, in turn, provides insight into how this planet – and perhaps others – formed out of the disk of gas and dust surrounding the parent star in its younger years.

WASP-39 b's chemical inventory suggests a history of smashups and mergers of smaller bodies called planetesimals to create an eventual goliath of a planet.

“The abundance of sulfur [relative to] hydrogen indicated that the planet presumably experienced significant accretion of planetesimals that can deliver [these ingredients] to the atmosphere,” said Kazumasa Ohno, a UC Santa Cruz exoplanet researcher who worked on Webb data. “The data also indicates that the oxygen is a lot more abundant than the carbon in the atmosphere. This potentially indicates that WASP-39 b originally formed far away from the central star.”

In so precisely parsing an exoplanet atmosphere, the Webb telescope's instruments performed well beyond scientists' expectations – and promise a new phase of exploration among the broad variety of exoplanets in the galaxy.

“We are going to be able to see the big picture of exoplanet atmospheres,” said Laura Flagg, a researcher at Cornell University and a member of the international team. “It is incredibly exciting to know that everything is going to be rewritten. That is one of the best parts of being a scientist.”

The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

Media Contacts:

Rob GutroNASA’s Goddard Space Flight Center, Greenbelt, Md.robert.j.gutro@nasa.gov

Christine PulliamSpace Telescope Science Institute, Baltimore, Md.cpulliam@stsci.edu

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Wonderland of Science Awaits

3 min read

NASA Science Editorial Team

NASA's James Webb Space Telescope launched on Christmas Day, Dec. 25, 2021. In its first year in space, it's delivered amazing images and exoplanet science, and promises more. Each of the seven planets orbiting the TRAPPIST-1 star will continued to be studied by the telescope, but we should have initial science in 2023.

In September 2022, astronomers used NASA’s the Webb telescope to take a direct image of a planet outside our solar system. The exoplanet is a gas giant, meaning it has no rocky surface and could not be habitable.

The image, as seen through four different light filters, shows how Webb’s powerful infrared gaze can easily capture worlds beyond our solar system, pointing the way to future observations that will reveal more information than ever before about exoplanets.

Meanwhile, we are sharing some of our favorite direct images of exoplanets:

One of our best views of an exoplanet moving in its orbit around a distant star. Beta Pictoris b is a massive planet about 63 light-years away, orbiting the second-brightest star in the constellation Pictoris. This gas giant is about 10 times more massive than Jupiter, and passes through a bright ring of dust and debris as it circles its star. A series of images captured between November 2013 to April 2015 shows the exoplanet as it moves through 1.5 years of its 22-year orbital period. The planet is nearly 100,000 times fainter than its star; a device inside the telescope called a coronagraph blocks the light of star Beta Pictoris so the planet is visible.

Four giants twirl around their star in a slow dance over eight years of observation. Each moving dot is a gas giant planet more massive than Jupiter; the innermost planet takes 40 years to orbit its star, and the furthest takes 400 years! The wonder of seeing another star system 129 light-years away hasn’t faded since the images were first taken. The black circle in the center of the image is from a coronagraph, which purposely blocks the light of the young star to reveal the much fainter light from the planets. The HR 8799 system can be found in the constellation Pegasus.

Like a baby photo, the brightly colored lights show infant planets in the making. There are 450 light-years between Earth and LkCa15, a young star with a doughnut-shaped protoplanetary disk around it, also known as a birthplace for planets. This composite image of the young star system LkCa15 is the first photo of several planets being formed. Protoplanetary disks form around young stars using the debris left over from the star’s formation. Though scientists don’t know for certain, it’s theorized that planets then form from this spinning disk of gas and dust around the young star. The color in this image has been added afterward.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Confirm the Existence of Newly Discovered Worlds Right from Your Backyard with UNITE!

2 min read

NASA Science Editorial Team

Jupiter-like planets play important roles in arranging planetary systems, and can influence the abilities of planets to host life. But detecting them requires coordinated observations across multiple hours or days by astronomers worldwide. That's why out of the more than 5,200 known exoplanets, we only have a few dozen examples of these Jupiter-like objects.

Enter the Unistellar Network Investigating TESS Exoplanets project, or UNITE, a new NASA citizen science project. UNITE brings together telescope users from around the world to make their own observations of transiting exoplanets to find these Jupiter-like objects.

UNITE volunteers observe planet candidates found by NASA's Transiting Exoplanet Survey Satellite (TESS) mission. Transiting exoplanets are planets that orbit their stars at just the right angle for us to see these stars dim as the planet passes, or transits, in front of it. When UNITE volunteers detect multiple dimmings, or transits, that tells us how long an exoplanet takes to orbit its star, which then tells us

where and when we should look if we want to study that exoplanet in detail later (say, with the James Webb Space Telescope).

There are already 10,000 amateur astronomers from around the world collaborating as part of the Unistellar network, with daily, open communication

between participants and organizers at the SETI Institute on a dedicated digital collaboration platform. The project has already succeeded in confirming two new TESS exoplanet candidates and measuring their orbits!

Learn more

Project home: https://science.unistellaroptics.com Recent project results: https://science.unistellaroptics.com/exoplanets/results/

NASA's Citizen Science Program:Learn about NASA citizen science projectsFollow on TwitterFollow on Facebook

How NASA’s Roman Telescope Will Scan for Showstopping Explosions

6 min read

What happens when the densest, most massive stars – that are also super small – collide? They send out brilliant explosions known as kilonovae. Think of these events as the universe’s natural fireworks. Theorists suspect they periodically occur all across the cosmos – both near and far. Scientists will soon have an additional observatory to help follow up on and even scout these remarkable events: NASA’s Nancy Grace Roman Space Telescope, which is set to launch by May 2027.

The key actors in kilonovae are neutron stars, the central cores of stars that collapsed under gravity during supernova explosions. They each have a mass similar to the Sun, but are only about 6 miles (10 kilometers) in diameter. And when they collide, they send out debris moving near the speed of light. These explosions are also thought to forge heavy elements, like gold, platinum, and strontium (which gives actual fireworks their stunning reds). Kilonovae shoot those elements across space, potentially allowing them to end up in rocks forming the crust of terrestrial planets like Earth.

The astronomical community captured one of these remarkable kilonova events in 2017. Scientists at the National Science Foundation’s Laser Interferometer Gravitational-Wave Observatory (LIGO) detected the collision of two neutron stars first with gravitational waves – ripples in space-time. Almost simultaneously, NASA’s Fermi Gamma-ray Space Telescope detected high-energy light. NASA quickly pivoted to observe the event with a broader fleet of telescopes, and captured the fading glow of the blast’s expanding debris in a series of images.

But the players in this example collided practically in our “backyard,” at least in astronomical terms. They lie only 130 million light-years away. There must be more kilonovae – and many that are farther flung – dotting our ever-active universe.

“We don’t yet know the rate of these events,” said Daniel M. Scolnic, an assistant professor of physics at Duke University in Durham, North Carolina. Scolnic led a study that estimates the number of kilonovae that could be discovered by past, present, and future observatories including Roman. “Is the single kilonova we identified typical? How bright are these explosions? What types of galaxies do they occur in?” Existing telescopes can’t cover wide enough areas or observe deeply enough to find more distant examples, but that will change with Roman.

At this stage, LIGO leads the pack in identifying neutron star mergers. It can detect gravitational waves in all areas of the sky, but some of the most distant collisions may be too weak to be identified. Roman is set to join LIGO’s search, offering complementary qualities that help “fill out” the team. Roman is a survey telescope that will repeatedly scan the same areas of the sky. Plus, Roman’s field of view is 200 times larger than the Hubble Space Telescope’s infrared view – not as vast as LIGO’s, but huge for a telescope that takes images. Its cadence will allow researchers to spot when objects on the sky brighten or dim, whether nearby or very far away.

Roman will provide researchers a powerful tool for observing extremely distant kilonovae. This is due to the expansion of space. Light that left stars billions of years ago is stretched into longer, redder wavelengths, known as infrared light, over time. Since Roman specializes in capturing near-infrared light, it will detect light from very distant objects. How distant? “Roman will be able to see some kilonovae whose light has traveled about 7 billion years to reach Earth,” explained Eve Chase, a postdoctoral researcher at Los Alamos National Laboratory in Los Alamos, New Mexico. Chase led a more recent study that simulated how differences in kilonovae ejecta can vary what we expect to observe from observatories including Roman.

There’s a second benefit to near-infrared light: It provides more time to observe these short-lived bursts. Shorter wavelengths of light, like ultraviolet and visible, disappear from view in a day or two. Near-infrared light can be gathered for a week or more. Researchers have been simulating the data to see how this will work. “For a subset of simulated kilonovae, Roman would be able to observe some more than two weeks after the neutron star merger occurred,” Chase added. “It will be an excellent tool for looking at kilonovae that are very far away.”

Soon, researchers will know far more about where kilonovae occur, and how often these explosions occur in the history of the universe. Were those that occurred earlier different in some way? “Roman will allow the astronomy community to begin conducting population studies along with a slew of new analyses on the physics of these explosions,” Scolnic said.

A survey telescope offers enormous possibility – and also a ton of data that will require precise machine learning. Astronomers are meeting this challenge by writing code to automate these searches. Ultimately, Roman’s massive data sets will help researchers unravel perhaps the greatest mysteries about kilonovae to date: What happens after two neutron stars collide? Does it produce a single neutron star, a black hole, or something else entirely? With Roman, we will gather the statistics researchers need to make substantial breakthroughs.

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Claire Blome, Space Telescope Science Institute

Media contact:

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

Related Links and Documents:

Science paper by E. Chase et al

Science paper by Daniel Scolnic et al

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Massive Planet is a ‘Hulk’ among Super-Earths

3 min read

Alicia Cermak

The discovery: New data shows that TOI-1075 b is one of the most massive super-Earths discovered so far.

Key facts: The planet, nearly 10 times Earth’s mass, orbits a small, red-orange star about 200 light-years away. Its year, once around the star, takes only 14 ½ hours. This “ultra-short” orbit makes the planet extremely hot, with an estimated temperature of 1,922 degrees Fahrenheit (1,050 Celsius).

Details: Planets in the super-Earth category – up to twice as large as Earth – are shrouded in mystery, because we have nothing like them in our own solar system. Yet they are among the most common in the galaxy. They appear to be rocky planets, like Earth, and some lie within the habitable zones of their stars, a distance that could allow liquid water to form on the surface.

That clearly isn’t the case for TOI-1075 b. Its surface, in fact, could be molten lava. But studies of this bulky planet could yield new insight into the formation of rocky planets like our own. Based on patterns seen among the thousands of exoplanets – planets around other stars – confirmed in the galaxy so far, scientists create computer models of how various planet types form, what they are composed of, and what kinds of atmospheres they might possess. Super-Earths the size of TOI-1075 b, models suggest, normally would be expected to have a fairly thick atmosphere of hydrogen and helium. But this planet’s dense composition and scorchingly tight orbit make such an atmosphere unlikely. That makes TOI-1075 b a “keystone planet” – among only a few others so far with precise enough measurements of size and mass to help scientists fine-tune their models of planet formation. That, in turn, will help them predict just what kinds of atmospheres super-Earths and other planet types possess, or whether they have atmospheres at all.

Fun facts: Astronomers discovered the planet using the Transiting Exoplanet Survey Satellite (TESS), revealing its diameter; more recent, follow-up observations with ground-based instruments determined the planet’s mass. The discovery that TOI-1075 b is nearly 10 times more massive than Earth makes it a true Hulk. Stand on its higher-gravity surface and you, too, would experience significant weight gain. You’d be about three times your weight on Earth.

The discoverers: The discovery of TOI-1075 b’s hefty mass was announced by an international science team led by Zahra Essack of the Massachusetts Institute of Technology. The planet had been added previously to the NASA Exoplanet Archive.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Reveals an Exoplanet Atmosphere as Never Seen Before

6 min read

NASA Science Editorial Team

The exoplanet WASP-39 b is also known as Bocaprins, a name bestowed by the International Astronomical Union for a scenic beach in Aruba. NASA's James Webb Space Telescope provided the most detailed analysis of an exoplanet atmosphere ever with WASP-39 b analysis released in November 2022.Among the 'firsts':Identifying sulfur dioxide in an exoplanet atmosphereObserving photocemistry (reactions triggered by starlight) at work on an exoplanet

NASA’s James Webb Space Telescope just scored another first: a molecular and chemical profile of a distant world’s skies.

While Webb and other space telescopes, including NASA's Hubble and Spitzer, previously have revealed isolated ingredients of this broiling planet’s atmosphere, the new readings from Webb provide a full menu of atoms, molecules, and even signs of active chemistry and clouds.

The latest data also give a hint of how these clouds might look up close: broken up rather than a single, uniform blanket over the planet.

The telescope’s array of highly sensitive instruments was trained on the atmosphere of WASP-39 b, a “hot Saturn” (a planet about as massive as Saturn but in an orbit tighter than Mercury) orbiting a star some 700 light-years away.

The findings bode well for the capability of Webb’s instruments to conduct the broad range of investigations of all types of exoplanets – planets around other stars – hoped for by the science community. That includes probing the atmospheres of smaller, rocky planets like those in the TRAPPIST-1 system.

“We observed the exoplanet with multiple instruments that, together, provide a broad swath of the infrared spectrum and a panoply of chemical fingerprints inaccessible until [this mission],” said Natalie Batalha, an astronomer at the University of California, Santa Cruz, who contributed to and helped coordinate the new research. “Data like these are a game changer.”

The suite of discoveries is detailed in a set of five new scientific papers, three of which are in press and two of which are under review.

Among the unprecedented revelations is the first detection in an exoplanet atmosphere of sulfur dioxide (SO_2), a molecule produced from chemical reactions triggered by high-energy light from the planet’s parent star. On Earth, the protective ozone layer in the upper atmosphere is created in a similar way.

“This is the first time we see concrete evidence of photochemistry – chemical reactions initiated by energetic stellar light – on exoplanets,” said Shang-Min Tsai, a researcher at the University of Oxford in the United Kingdom and lead author of the paper explaining the origin of sulfur dioxide in WASP-39 b’s atmosphere. “I see this as a really promising outlook for advancing our understanding of exoplanet atmospheres with [this mission].”

This led to another first: scientists applying computer models of photochemistry to data that requires such physics to be fully explained. The resulting improvements in modeling will help build the technological know-how to interpret potential signs of habitability in the future.

“Planets are sculpted and transformed by orbiting within the radiation bath of the host star,” Batalha said. “On Earth, those transformations allow life to thrive.”

The planet’s proximity to its host star – eight times closer than Mercury is to our Sun – also makes it a laboratory for studying the effects of radiation from host stars on exoplanets. Better knowledge of the star-planet connection should bring a deeper understanding of how these processes affect the diversity of planets observed in the galaxy.

To see light from WASP-39 b, Webb tracked the planet as it passed in front of its star, allowing some of the star’s light to filter through the planet’s atmosphere. Different types of chemicals in the atmosphere absorb different colors of the starlight spectrum, so the colors that are missing tell astronomers which molecules are present. By viewing the universe in infrared light, Webb can pick up chemical fingerprints that can’t be detected in visible light.

Other atmospheric constituents detected by the Webb telescope include sodium (Na), potassium (K), and water vapor (H2O), confirming previous space- and ground-based telescope observations as well as finding additional fingerprints of water, at these longer wavelengths, that haven’t been seen before.

Webb also saw carbon dioxide (CO2) at higher resolution, providing twice as much data as reported from its previous observations. Meanwhile, carbon monoxide (CO) was detected, but obvious signatures of both methane (CH4) and hydrogen sulfide (H2S) were absent from the Webb data. If present, these molecules occur at very low levels.

To capture this broad spectrum of WASP-39 b’s atmosphere, an international team numbering in the hundreds independently analyzed data from four of the Webb telescope’s finely calibrated instrument modes.

"We had predicted what [the telescope] would show us, but it was more precise, more diverse and more beautiful than I actually believed it would be,” said Hannah Wakeford, an astrophysicist at the University of Bristol in the United Kingdom who investigates exoplanet atmospheres.

Having such a complete roster of chemical ingredients in an exoplanet atmosphere also gives scientists a glimpse of the abundance of different elements in relation to each other, such as carbon-to-oxygen or potassium-to-oxygen ratios. That, in turn, provides insight into how this planet – and perhaps others – formed out of the disk of gas and dust surrounding the parent star in its younger years.

WASP-39 b’s chemical inventory suggests a history of smashups and mergers of smaller bodies called planetesimals to create an eventual goliath of a planet.

“The abundance of sulfur [relative to] hydrogen indicated that the planet presumably experienced significant accretion of planetesimals that can deliver [these ingredients] to the atmosphere,” said Kazumasa Ohno, a UC Santa Cruz exoplanet researcher who worked on Webb data. “The data also indicates that the oxygen is a lot more abundant than the carbon in the atmosphere. This potentially indicates that WASP-39 b originally formed far away from the central star.”

In so precisely parsing an exoplanet atmosphere, the Webb telescope’s instruments performed well beyond scientists’ expectations – and promise a new phase of exploration among the broad variety of exoplanets in the galaxy.

“We are going to be able to see the big picture of exoplanet atmospheres,” said Laura Flagg, a researcher at Cornell University and a member of the international team. “It is incredibly exciting to know that everything is going to be rewritten. That is one of the best parts of being a scientist.”

The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

Read the papers:

The science paper by L. Alderson et al.The science paper by Z. Rustamkulov et al.The science paper by E. Ahrer et al.The science paper by A. Feinstein et al.The science paper by S. Tsai et al.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: A Rocky ‘Super-Earth’ in the Habitable Zone

3 min read

Pat Brennan

The discovery: LP 890-9 c, a “super-Earth” in the habitable zone of its star.

Key facts: The planet, likely rocky but 40% larger than Earth, came to light during follow-up observations of its sister planet, LP 890-9 b. Both fall into the super-Earth category – exoplanets, or planets around other stars, that are up to 75% larger than our own but believed to be rocky worlds, like Earth. Surface conditions might or might not be similar.

Details: Both planets orbit a comparatively cool, red-dwarf star, LP 890-9, about 98 light-years away. The inner planet, discovered using the Transiting Exoplanet Survey Satellite (TESS), is about 30% larger than Earth and, with an estimated temperature of 253 degrees Fahrenheit (123 Celsius), probably too hot to be habitable. The outer planet, though possibly chilly by human standards at an estimated 30 Fahrenheit (minus 1.1 Celsius), sits within its star’s habitable zone, the orbital distance where liquid water might be present on the surface. This planet was detected using a ground-based telescope survey, the Search for habitable Planets EClipsing Ultra-cOOl Stars (SPECULOOS). The observations not only met their original goal – confirming the existence of the innermost planet – but unexpectedly discovered a second planet in the system.

Plenty of caveats come with the temperature estimates. The planets’ actual temperatures depend on their atmospheres, about which nothing is yet known. It’s possible that the outermost planet’s atmosphere has given rise to a runaway greenhouse effect, which would make it more like Venus than Earth – much too hot for habitability. Both planets orbit their stars tightly: a “year” on planet b, once around the star, takes only 2.7 days, planet c 8.5 days. But the star is far smaller and cooler than our Sun, placing closely orbiting planet c near the inner edge of this star’s habitable zone.

Fun facts: The new planet, LP 890-9 c, adds to the list of worlds discovery teams suggest might be examined by the James Webb Space Telescope. Launched in December 2021, the telescope has settled into its orbit a million miles from Earth and already has begun reading out the gases present in exoplanet atmospheres. The telescope’s instruments include spectrographs, which can capture light shining from a parent star through the atmospheres of exoplanets, providing a spectrum and a fingerprint of the types of gases present. That, and other methods the telescope uses to analyze atmospheres, potentially could reveal which of these planets might be habitable worlds.

The study authors say the new planet is especially promising for potential atmospheric studies; in fact, the study says, it is “the second-most favorable habitable-zone terrestrial planet” after the TRAPPIST-1 planetary system – seven roughly Earth-sized planets about 40 light-years away, including three in the habitable zone of their red-dwarf star.

The discoverers: The new planet is detailed in a paper published by an international team of scientists led by Laetitia Delrez, an astrophysicist at the University of Liège, Belgium. It was entered into NASA’s Exoplanet Archive on Sept. 16, 2022.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

TESS Status Update

2 min read

NASA's Transiting Exoplanet Survey (TESS) began its return to normal operations on Thursday, Oct. 13, at around 6:30 p.m. EDT. Engineers successfully powered up the instrument, and the spacecraft resumed its regular fine-pointing mode. The team expects that TESS will resume science observations later today, and all science data stored on the spacecraft will be downlinked at the next opportunity.

TESS entered into safe mode on Oct. 10 following a reset of its flight computer. The team will spend the next several days analyzing data to determine the cause.

Launched in 2018, TESS has been scanning almost the entire sky looking for planets beyond our solar system, known as exoplanets. TESS has also uncovered other cosmic phenomena, including star-shredding black holes and stellar oscillations. Read more about TESS discoveries at www.nasa.gov/tess.

Media contact: Alise Fisher, NASA Headquarters / Claire Andreoli, NASA Goddard

NASA's Transiting Exoplanet Survey Satellite (TESS) entered into safe mode on Monday, Oct. 10. The spacecraft is in a stable configuration that suspends science observations. Preliminary investigation revealed that the TESS flight computer experienced a reset.

The TESS operations team reported that science data not yet sent to the ground appears to be safely stored on the satellite. Recovery procedures and investigations are underway to resume normal operations, which could take several days.

TESS launched in April 2018 and has since discovered more than 250 exoplanets – worlds beyond our solar system – and thousands of additional candidates. The agency will provide additional updates at www.nasa.gov/tess.

Media contact: Alise Fisher, NASA Headquarters / Claire Andreoli, NASA Goddard

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Ultra-hot ‘Super-Earth’ Could Have No Atmosphere

5 min read

Chelsea Gohd

The planet: GJ 1252 b

The discovery: GJ 1252 b, a rocky, terrestrial "super-Earth" discovered in 2020, has been given a closer look and astronomers have found that the exoplanet could have a very minimal atmosphere or possibly no atmosphere at all.

The planet, which orbits an M-type star, is "the smallest exoplanet yet for which we have such tight constraints on its atmosphere,” said lead author Ian Crossfield, an astronomer and assistant professor at the University of Kansas.

Key facts: Astronomers often discover and study exoplanets by observing how much light the planets block out as they pass in front of their host stars, a technique known as the "transit method." GJ 1252 b, an exoplanet about 65 light-years away with a radius 1.18 times larger than Earth, was discovered with this method by NASA's Transiting Exoplanet Survey Satellite (TESS) in 2020. Astronomers in this new study observed the exoplanet with the Spitzer Space Telescope before it retired and were able to get a closer look at the planet and its atmosphere.

With Spitzer, the team detected a secondary eclipse, which occurs when a planet passes behind a star and the planet's light, which comes from its own infrared radiation (or heat), as well as light reflected from the star, is blocked.

Details: Astronomers searching for signs of life in the cosmos focus on a number of different details in exoplanets. Many of these details serve as a comparison between the exoplanet and Earth, as Earth remains the only planet where we have confirmed the presence of life.

GJ 1252 b isn’t much larger than Earth, but it is much hotter as it is closer to its star and, as astronomers have found in this study, is lacking much of an atmosphere.

“We’re just beginning to learn how often, and under what circumstances, rocky planets can keep their atmospheres,” said astronomer and study co-author Laura Kreidberg, the director of the Atmospheric Physics of Exoplanets (APEx Department at the Max Planck Institute for Astronomy. “This measurement is an indication that for the hottest planets, it’s unlikely that thick atmospheres typically survive.”

To determine what the exoplanet's atmosphere (if there is one) could be like, astronomers measured infrared radiation from GJ 1252 b as its light was obscured during a secondary eclipse. These observations revealed the planet’s scorching day-side temperature, which is estimated to reach as high as 2,242 degrees Fahrenheit (1228 degrees Celsius). In fact, GJ 1252 b is so hot that gold, silver, and copper would all melt on the planet.

The exoplanet's expected temperatures, when compared to atmospheric models, suggest that it likely has a surface pressure of less than 10 bar (for reference, Earth’s surface pressure is approximately 1 bar.) While the planet’s sizzling hot temperatures would make it difficult for an atmosphere to be stable for long, it is possible that this exoplanet could have an atmosphere with a density like Earth’s, an atmosphere up to 10 times denser than Earth's, or even no atmosphere whatsoever.

Given its extreme temperatures and low surface pressure, the astronomers on this team have predicted that GJ 1252 b likely has no atmosphere at all. This is currently the smallest exoplanet for which scientists have such a clear idea of its atmosphere.

Fun facts: GJ 1252b is an exoplanet that was first detected with TESS and then investigated more thoroughly with Spitzer before the telescope's mission ended in 2020. With further exploration with the James Webb Space Telescope (JWST), the team could put even tighter constraints on this planet's atmosphere, an exciting possibility.

“At the time, Spitzer was the only facility in the known universe that could make these sorts of measurements. Now, Spitzer has been turned off, but JWST is there and at these wavelengths it's much more sensitive than Spitzer was. So, what we did with difficulty with Spitzer we can now start to do easily and for larger numbers of rocky planets with JWST,” Crossfield said.

“JWST observations in the infrared have the potential to reveal the surface properties of hot, rocky planets like this. Different types of rock have different spectral signatures, so we could potentially learn what type of rock GJ 1252b is made of,” Kreidberg added.

Studying GJ 1252 b further with JWST poses an exciting possibility for scientists, as it would be interesting to confirm an atmosphere on such a small and hot exoplanet as it would also be fascinating to explore the composition of a planet like this with no atmosphere at all.

The discoverers: A team at the University of Kansas, led by Crossfield, led this study which discovered strange new details about the atmosphere of GJ 1252b. Additionally involved in this paper were researchers from the University of California, Riverside, NASA’s Jet Propulsion Laboratory, the Caltech/IPAC-NASA Exoplanet Science Institute, the University of Maryland, the Earth and Planets Laboratory at the Carnegie Institution for Science, the Max Planck Institute for Astronomy, McGill University, the University of New Mexico, Albuquerque, NM, and the Institute for Research on Exoplanets at the University of Montreal. The study, published in the Astrophysical Journal Letters, can be found here.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb Detects Carbon Dioxide in Exoplanet Atmosphere

6 min read

NASA’s James Webb Space Telescope has captured the first clear evidence for carbon dioxide in the atmosphere of a planet outside the solar system. This observation of a gas giant planet orbiting a Sun-like star 700 light-years away provides important insights into the composition and formation of the planet. The finding, accepted for publication in Nature, offers evidence that in the future Webb may be able to detect and measure carbon dioxide in the thinner atmospheres of smaller rocky planets.

Lee esta historia en español aquí.

NASA’s James Webb Space Telescope has captured the first clear evidence for carbon dioxide in the atmosphere of a planet outside the solar system. This observation of a gas giant planet orbiting a Sun-like star 700 light-years away provides important insights into the composition and formation of the planet. The finding, accepted for publication in Nature, offers evidence that in the future Webb may be able to detect and measure carbon dioxide in the thinner atmospheres of smaller rocky planets.

WASP-39 b is a hot gas giant with a mass roughly one-quarter that of Jupiter (about the same as Saturn) and a diameter 1.3 times greater than Jupiter. Its extreme puffiness is related in part to its high temperature (about 1,600 degrees Fahrenheit or 900 degrees Celsius). Unlike the cooler, more compact gas giants in our solar system, WASP-39 b orbits very close to its star – only about one-eighth the distance between the Sun and Mercury – completing one circuit in just over four Earth-days. The planet’s discovery, reported in 2011, was made based on ground-based detections of the subtle, periodic dimming of light from its host star as the planet transits, or passes in front of the star.

Previous observations from other telescopes, including NASA’s Hubble and Spitzer space telescopes, revealed the presence of water vapor, sodium, and potassium in the planet’s atmosphere. Webb’s unmatched infrared sensitivity has now confirmed the presence of carbon dioxide on this planet as well.

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute

Transiting planets like WASP-39 b, whose orbits we observe edge-on rather than from above, can provide researchers with ideal opportunities to probe planetary atmospheres.

During a transit, some of the starlight is eclipsed by the planet completely (causing the overall dimming) and some is transmitted through the planet’s atmosphere.

Because different gases absorb different combinations of colors, researchers can analyze small differences in brightness of the transmitted light across a spectrum of wavelengths to determine exactly what an atmosphere is made of. With its combination of inflated atmosphere and frequent transits, WASP-39 b is an ideal target for transmission spectroscopy.

The research team used Webb’s Near-Infrared Spectrograph (NIRSpec) for its observations of WASP-39b. In the resulting spectrum of the exoplanet’s atmosphere, a small hill between 4.1 and 4.6 microns presents the first clear, detailed evidence for carbon dioxide ever detected in a planet outside the solar system.

“As soon as the data appeared on my screen, the whopping carbon dioxide feature grabbed me,” said Zafar Rustamkulov, a graduate student at Johns Hopkins University and member of the JWST Transiting Exoplanet Community Early Release Science team, which undertook this investigation. “It was a special moment, crossing an important threshold in exoplanet sciences.”

No observatory has ever measured such subtle differences in brightness of so many individual colors across the 3 to 5.5-micron range in an exoplanet transmission spectrum before. Access to this part of the spectrum is crucial for measuring abundances of gases like water and methane, as well as carbon dioxide, which are thought to exist in many different types of exoplanets.

“Detecting such a clear signal of carbon dioxide on WASP-39 b bodes well for the detection of atmospheres on smaller, terrestrial-sized planets,” said Natalie Batalha of the University of California at Santa Cruz, who leads the team.

Understanding the composition of a planet’s atmosphere is important because it tells us something about the origin of the planet and how it evolved. “Carbon dioxide molecules are sensitive tracers of the story of planet formation,” said Mike Line of Arizona State University, another member of this research team. “By measuring this carbon dioxide feature, we can determine how much solid versus how much gaseous material was used to form this gas giant planet. In the coming decade, JWST will make this measurement for a variety of planets, providing insight into the details of how planets form and the uniqueness of our own solar system.”

Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute

This NIRSpec prism observation of WASP-39 b is just one part of a larger investigation that includes observations of the planet using multiple Webb instruments, as well as observations of two other transiting planets. The investigation, which is part of the Early Release Science program, was designed to provide the exoplanet research community with robust Webb data as soon as possible.

“The goal is to analyze the Early Release Science observations quickly and develop open-source tools for the science community to use,” explained Vivien Parmentier, a co-investigator from Oxford University. “This enables contributions from all over the world and ensures that the best possible science will come out of the coming decades of observations.”

Natasha Batalha, co-author on the paper from NASA’s Ames Research Center, adds that “NASA’s open science guiding principles are centered in our Early Release Science work, supporting an inclusive, transparent, and collaborative scientific process.”

The James Webb Space Telescope is the world’s premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Banner Image: This illustration shows what exoplanet WASP-39 b could look like, based on current understanding of the planet. WASP-39 b is a hot, puffy gas-giant planet with a mass 0.28 times Jupiter (0.94 times Saturn) and a diameter 1.3 times greater than Jupiter, orbiting just 0.0486 astronomical units (4,500,000 miles) from its star. The star, WASP-39, is fractionally smaller and less massive than the Sun. Because it is so close to its star, WASP-39 b is very hot and is likely to be tidally locked, with one side facing the star at all times. Illustration Credit: NASA, ESA, CSA, and J. Olmsted (STScI) Download the full-resolution, uncompressed version and supporting visuals from the Space Telescope Science Institute

Laura Betz Goddard Space Flight Center, Greenbelt, Md.301-286-9030laura.e.betz@nasa.gov

Christine PulliamSpace Telescope Science Institute, Baltimore, Md.410-338-4366cpulliam@stsci.edu

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Intriguing New ‘Super-Earth’ Could Get a Closer Look

3 min read

Alicia Cermak

The discovery: Planet TOI-1452 b.

Key facts: Using observations from NASA’s Transiting Exoplanet Survey Satellite (TESS), backed up by ground-based telescopes, an international team led by the University of Montreal announced the discovery of a “super-Earth” – a planet that is potentially rocky like ours, but larger – orbiting a red-dwarf star about 100 light-years away. Further investigation could shed light on an intriguing possibility: that the planet might be a “water world.”

Details: Ocean planets are long imagined but difficult to confirm, and TOI-1452 b is no different. About 70% larger than Earth, and roughly five times as massive, its density could be consistent with having a very deep ocean. But more follow-up will be needed. The planet also might be a huge rock, with little or no atmosphere. It could even be a rocky planet with an atmosphere of hydrogen and helium.

If TOI-1452 b were shown to be an ocean world, that ocean could be quite deep indeed. While Earth’s surface is 70% water, our sea of blue makes up less than 1% of Earth’s mass. One simulation of TOI-1452 b, created by computer modeling specialists on the discovery team, showed that water could make up as much as 30% of its mass. That proportion is comparable to watery moons in our solar system – Jupiter’s Ganymede and Callisto, or Saturn’s Titan and Enceladus – believed to hide deep oceans under shells of ice.

TOI-1452 b makes a complete orbit of its star every 11 days – a “year” on TOI-1452 b. But because the red-dwarf star is smaller and cooler than our Sun, the planet receives a similar amount of light from its star as Venus does from our Sun. Liquid water might exist on the planet’s surface, despite its close orbit. The star, by the way, is one of a pair; its gravitational partner also is a red dwarf, estimated to be in a 1,400-year orbit.

Fun facts: Planet TOI-1452 b seems perfectly positioned for further investigation by the James Webb Space Telescope, now delivering science observations from its perch about a million miles (1.6 million kilometers) from Earth. The planet’s distance of 100 light-years is, in astronomical terms, fairly close. Its relatively bright star should allow Webb to capture a spectrum of starlight shining through its atmosphere, a kind of fingerprint of atmospheric components. It also appears in a part of the sky, in the constellation Draco, that Webb can observe almost any time of year. Researchers on the discovery team say they will seek to schedule time on Webb to take a closer look.

The discoverers: The international team that found the planet was led by Charles Cadieux, a Ph.D. student at the University of Montreal. Read the University’s press release.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Webb’s First Full-Color Images, Data Are Set to Sound

9 min read

There’s a new, immersive way to explore some of the first full-color infrared images and data from NASA’s James Webb Space Telescope – through sound. Listeners can enter the complex soundscape of the Cosmic Cliffs in the Carina Nebula, explore the contrasting tones of two images that depict the Southern Ring Nebula, and identify the individual data points in a transmission spectrum of hot gas giant exoplanet WASP-96 b. “Music taps into our emotional centers,” said Matt Russo, a musician and physics professor at the University of Toronto. “Our goal is to make Webb’s images and data understandable through sound – helping listeners create their own mental images.”

There’s a new, immersive way to explore some of the first full-color infrared images and data from NASA’s James Webb Space Telescope – through sound. Listeners can enter the complex soundscape of the Cosmic Cliffs in the Carina Nebula, explore the contrasting tones of two images that depict the Southern Ring Nebula, and identify the individual data points in a transmission spectrum of hot gas giant exoplanet WASP-96 b. “Music taps into our emotional centers,” said Matt Russo, a musician and physics professor at the University of Toronto. “Our goal is to make Webb’s images and data understandable through sound – helping listeners create their own mental images.”

A team of scientists, musicians, and a member of the blind and visually impaired community worked to adapt Webb’s data, with support from the Webb mission and NASA’s Universe of Learning.

A near-infrared image of the Cosmic Cliffs in the Carina Nebula, captured by NASA’s Webb Telescope, has been mapped to a symphony of sounds. Musicians assigned unique notes to the semi-transparent, gauzy regions and very dense areas of gas and dust in the nebula, culminating in a buzzing soundscape.

The sonification scans the image from left to right. The soundtrack is vibrant and full, representing the detail in this gigantic, gaseous cavity that has the appearance of a mountain range. The gas and dust in the top half of the image are represented in blue hues and windy, drone-like sounds. The bottom half of the image, represented in ruddy shades of orange and red, has a clearer, more melodic composition.

Brighter light in the image is louder. The vertical position of light also dictates the frequency of sound. For example, bright light near the top of the image sounds loud and high, but bright light near the middle is loud and lower pitched. Dimmer, dust-obscured areas that appear lower in the image are represented by lower frequencies and clearer, undistorted notes.

NASA’s Webb Telescope uncovered two views of the Southern Ring Nebula – in near-infrared light (at left) and mid-infrared light (at right) – and each has been adapted to sound.

In this sonification, the colors in the images were mapped to pitches of sound – frequencies of light converted directly to frequencies of sound. Near-infrared light is represented by a higher range of frequencies at the beginning of the track. Mid-way through, the notes change, becoming lower overall to reflect that mid-infrared includes longer wavelengths of light.

Listen carefully at 15 seconds and 44 seconds. These notes align with the centers of the near- and mid-infrared images, where the stars at the center of the “action” appear. In the near-infrared image that begins the track, only one star is heard clearly, with a louder clang. In the second half of the track, listeners will hear a low note just before a higher note, which denotes that two stars were detected in mid-infrared light. The lower note represents the redder star that created this nebula, and the second is the star that appears brighter and larger.

NASA's Webb Telescope observed the atmospheric characteristics of the hot gas giant exoplanet WASP-96 b – which contains clear signatures of water – and the resulting transmission spectrum's individual data points were translated into sound.

The sonification scans the spectrum from left to right. From bottom to top, the y-axis ranges from less to more light blocked. The x-axis ranges from 0.6 microns on the left to 2.8 microns on the right. The pitches of each data point correspond to the frequencies of light each point represents. Longer wavelengths of light have lower frequencies and are heard as lower pitches. The volume indicates the amount of light detected in each data point.

The four water signatures are represented by the sound of water droplets falling. These sounds simplify the data – water is detected as a signature that has multiple data points. The sounds align only to the highest points in the data.

These audio tracks support blind and low-vision listeners first, but are designed to be captivating to anyone who tunes in. "These compositions provide a different way to experience the detailed information in Webb's first data. Similar to how written descriptions are unique translations of visual images, sonifications also translate the visual images by encoding information, like color, brightness, star locations, or water absorption signatures, as sounds," said Quyen Hart, a senior education and outreach scientist at the Space Telescope Science Institute in Baltimore, Maryland. "Our teams are committed to ensuring astronomy is accessible to all."

This project has parallels to the "curb-cut effect," an accessibility requirement that supports a wide range of pedestrians. "When curbs are cut, they benefit people who use wheelchairs first, but also people who walk with a cane and parents pushing strollers," explained Kimberly Arcand, a visualization scientist at the Chandra X-ray Center in Cambridge, Massachusetts, who led the initial data sonification project for NASA and now works on it on behalf of NASA's Universe of Learning. "We hope these sonifications reach an equally broad audience."

Preliminary results from a survey Arcand led showed that people who are blind or low vision, and people who are sighted, all reported that they learned something about astronomical images by listening. Participants also shared that auditory experiences deeply resonated with them. "Respondents' reactions varied – from experiencing awe to feeling a bit jumpy," Arcand continued. "One significant finding was from people who are sighted. They reported that the experience helped them understand how people who are blind or low vision access information differently."

These tracks are not actual sounds recorded in space. Instead, Russo and his collaborator, musician Andrew Santaguida, mapped Webb's data to sound, carefully composing music to accurately represent details the team would like listeners to focus on. In a way, these sonifications are like modern dance or abstract painting – they convert Webb's images and data to a new medium to engage and inspire listeners.

Christine Malec, a member of the blind and low vision community who also supports this project, said she experiences the audio tracks with multiple senses. "When I first heard a sonification, it struck me in a visceral, emotional way that I imagine sighted people experience when they look up at the night sky."

There are other profound benefits to these adaptations. "I want to understand every nuance of sound and every instrument choice, because this is primarily how I'm experiencing the image or data," Malec continued. Overall, the team hopes that sonifications of Webb's data help more listeners feel a stronger connection to the universe – and inspire everyone to follow the observatory's upcoming astronomical discoveries.

The James Webb Space Telescope is the world’s premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and CSA (Canadian Space Agency).

These sonifications are a result of a collaboration between the NASA’s Universe of Learning program and the James Webb Space Telescope. The Chandra X-ray Center (CXC) leads data sonification as a NASA’s Universe of Learning partner. Science experts affiliated with the Webb mission provide their expertise on Webb observations, data, and targets.

NASA’s Universe of Learning is part of the NASA Science Activation program, from the Science Mission Directorate at NASA Headquarters. The Science Activation program connects NASA science experts, real content and experiences, and community leaders in a way that activates minds and promotes deeper understanding of our world and beyond. Using its direct connection to the science and the experts behind the science, NASA’s Universe of Learning provides resources and experiences that enable youth, families, and lifelong learners to explore fundamental questions in science, experience how science is done, and discover the universe for themselves.

NASA’s Universe of Learning materials are based upon work supported by NASA under cooperative agreement award number NNX16AC65A to the Space Telescope Science Institute, working in partnership with Caltech/IPAC, Center for Astrophysics | Harvard & Smithsonian, and Jet Propulsion Laboratory.

Laura Betz Goddard Space Flight Center, Greenbelt, Md.301-286-9030laura.e.betz@nasa.gov

Christine PulliamSpace Telescope Science Institute, Baltimore, Md.410-338-4366cpulliam@stsci.edu

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Test Chamber for NASA’s New Cosmic Mapmaker Makes Dramatic Entrance

5 min read

The SPHEREx mission will create a 3D map of the entire sky. Its cutting-edge instruments require a custom-built chamber to make sure they’ll be ready to operate in space.

After three years of design and construction, a monthlong boat ride across the Pacific Ocean, and a lift from a 30-ton crane, the customized test chamber for NASA’s upcoming SPHEREx mission has finally reached its destination at Caltech’s Cahill Center for Astronomy and Astrophysics in Pasadena.

Set to launch no earlier than June 2024, SPHEREx (short for Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer) will make a unique map of the cosmos that will contain hundreds of millions of objects, including stars, galaxies, star-forming regions, and other cosmic wonders. Unlike any previous map, it will provide images of individual objects, as well as a spectrum for every point in the sky. Spectra can contain a treasure trove of information about cosmic objects, including their composition, age, and the distance to faraway galaxies.

With this dynamic chart, scientists will be able to answer questions about what happened shortly after the big bang, the prevalence of life-sustaining molecules like water ice in our galaxy’s planet-forming regions, and how galaxies began and evolved over the universe’s lifetime.

But for SPHEREx to make that possible, the telescope must be able not only to withstand the rigors of space but also to thrive there. That’s where the custom test chamber comes in. About the size of a small SUV and made of stainless steel, the cylindrical chamber was built by the Korean Astronomy and Space Science Institute (KASI), a partner in the SPHEREx mission. It will be used to test SPHEREx’s detectors (essentially its cameras) and optics (the system that collects light from the cosmos).

Managed by NASA’s Jet Propulsion Laboratory, SPHEREx will detect infrared light, which human eyes can’t detect. Sometimes called heat radiation, it is emitted by warm objects, including stars and galaxies, as well as the telescope’s instruments. So the chamber is designed to cool the detectors to about minus 350 degrees Fahrenheit (about minus 200 degrees Celsius) to make sure their own heat won’t overwhelm the light from the objects they’re built to observe.

But first, the SPHEREx team needs to test whether the detectors are in focus. This is determined by their distance from the optics, similar to how moving a magnifying glass closer to or farther away from your eye brings objects into or out of focus. The team will have to get the distance between the detectors and the optics correct to within 0.0003 inches (7.5 micrometers), or about one-tenth the width of a human hair. To do this, they’ll point the optics and detectors at a projected source of infrared light located outside the chamber’s window, which is made of sapphire because glass blocks infrared. The source will serve as a stand-in for the objects that SPHEREx will observe in space, and the resulting image will tell engineers if the spacing is correct.

“A number of factors can influence the focus position of our instrument as it gets down to its operating temperature,” said Phil Korngut, the SPHEREx instrument scientist and a researcher at Caltech. “It’s absolutely essential that we get this thing sharply into focus before we fly, and the only way to accomplish that is through specific cryogenic optical testing in the environment provided by the KASI chamber.”

The chamber is also customized to calibrate the SPHEREx spectrometer, which will provide a spectrum of every point on the sky.

In 2018, KASI launched a mission called the Near-infrared Imaging Spectrometer for Star formation history (NISS), which has similarities to SPHEREx. Working on NISS gave the KASI team the right experience to build the custom chamber.

After traveling by ship from Korea to Long Beach, California, the chamber was transported north to Caltech. Too large to fit through the main entrance of its new home, it had to travel under the building: A 30-ton crane lifted off a removable section of an adjacent road and then lowered the test chamber, along with its components, into a high-ceilinged, windowless receiving room unofficially known as “the crypt.” The chamber was then wheeled into the SPHEREx test lab, where it will stay for about 18 months until the hardware tests are complete.

“Not only the SPHEREx team at KASI, but the whole Korean astronomical community are very interested in the SPHEREx data and its science objectives,” said Woong-Soeb Jeong, the principal investigator for SPHEREx for KASI. “So KASI’s participation in the SPHEREx mission is expected to have a great impact on the research in our astronomical community. That heritage will be of great help in developing our own medium- or large-class space telescope in the future.”

SPHEREx is managed by JPL for NASA’s Astrophysics Division within the Science Mission Directorate in Washington. The mission’s principal investigator, James Bock, has a joint position between Caltech and JPL. Ball Aerospace in Boulder, Colorado, will supply the spacecraft. The science analysis of the SPHEREx data will be conducted by a team of scientists located at 10 institutions across the U.S. and in South Korea. Data will be processed and archived at IPAC at Caltech. The SPHEREx dataset will be publicly available.

For more information about the SPHEREx mission visit:

https://www.jpl.nasa.gov/missions/spherex/

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

2022-122

NASA Scientists Study How to Remove Planetary ‘Photobombers’

4 min read

Imagine you go to a theme park with your family and you ask a park employee to take a group photo. A celebrity walks by in the background and waves at the camera, stealing the focus of the photo. Surprisingly, this concept of “photobombing” is relevant to astronomers looking for habitable planets, too.

When scientists point a telescope at an exoplanet, the light the telescope receives could effectively be “contaminated” by light from other planets in the same star system, according to a new NASA study. The research, published in the Astrophysical Journal Letters on Aug. 11, modeled how this “photobombing” effect would impact an advanced space telescope designed to observe potentially habitable exoplanets and suggested potential ways to overcome this challenge.

“If you looked at Earth sitting next to Mars or Venus from a distant vantage point, then depending on when you observed them, you might think they’re both the same object,” explains Dr. Prabal Saxena, a scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, who led the research.

Saxena uses our own solar system as an analog to explain this photobombing effect.

“For example, depending on the observation, an exo-Earth could be hiding in [light from] what we mistakenly believe is a large exo-Venus,” said Dr. Saxena. Earth’s neighbor Venus is generally thought to be hostile to habitability, with surface temperatures hot enough to melt lead – so this mixing could lead scientists to miss out on a potentially habitable planet.

Astronomers use telescopes to analyze light from distant worlds to gather information that may reveal whether they could support life. One light-year, the distance light travels in a year, is almost six trillion miles (over nine trillion kilometers), and there are about 30 stars similar to our Sun within roughly 30 light-years of our solar system.

This photobombing phenomenon, in which observations of one planet are contaminated by light from other planets in a system, stems from the “point-spread function” (PSF) of the target planet. The PSF is an image created due to diffraction of light (the bending or spreading of light waves around an opening) coming from a source and is larger than the source for something very far away (such as an exoplanet). The size of the PSF of an object depends on the size of the telescope aperture (the light-collecting area) and wavelength at which the observation is taken. For worlds around a distant star, a PSF may resolve in such a way that two nearby planets or a planet and a moon could seem to morph into one.

If that is the case, the data that scientists can gather about such an Earth analog would be skewed or affected by whatever world or worlds were photobombing the planet in question, which could complicate or outright prevent the detection and confirmation of an exo-Earth, a potential planet like Earth beyond our solar system.

Saxena examined an analogous scenario in which otherworldly astronomers might be looking at Earth from more than 30 light-years away, using a telescope similar to that recommended in the 2020 Astrophysics Decadal Survey. “We found that such a telescope would sometimes see potential exo-Earths beyond 30 light-years distance blended with additional planets in their systems, including those that are outside of the habitable zone, for a range of different wavelengths of interest,” Saxena said.

The habitable zone is that region of space around a star where the amount of starlight would allow liquid water on a planet’s surface, which may enable the existence of life.

There are multiple strategies to deal with the photobombing problem. These include developing new methods of processing data gathered by telescopes to mitigate the potential that photobombing will skew the results of a study. Another method would be to study systems over time, to avoid the possibility that planets with close orbits would appear in each other’s PSFs. Saxena’s study also discusses how using observations from multiple telescopes or increasing the size of the telescope could reduce the photobombing effect at similar distances.

Discovering exoplanets and determining if any can support life is part of NASA’s mission to explore and understand the unknown, to inspire and benefit humanity.

The research was funded by NASA under award number 80GSFC21M0002 and was also funded in part by the Goddard Sellers Exoplanet Environments Collaboration (SEEC).

By Nick Oakes

Media Contact:

Bill SteigerwaldNASA’s Goddard Space Flight Center, Greenbelt, Md.william.a.steigerwald@nasa.gov

Exoplanet Clouds: ‘Jewels’ of New Knowledge

3 min read

Alicia Cermak

Clouds of vaporized rock, and perhaps even glittering gems, could fill the skies of some distant worlds. Add howling winds and broiling temperatures, and you begin to catch the first glimpse of wildly different environments on one of the many varieties of exoplanets – planets around other stars.

Exoplanet scientists are on the edge of their seats. NASA’s James Webb Space Telescope has begun to deliver its first science images and data. The targets for observations to come include the atmospheres of some of the strangest exoplanets found so far.

Among the best ways to understand these atmospheres, and even the planets themselves, will be the first-ever direct observations of clouds, however weird and exotic they might be.

“On Earth, a lot of these minerals are jewels,” said Tiffany Kataria, an exoplanet scientist at NASA’s Jet Propulsion Laboratory in Southern California. “A geologist would study them as rocks on Earth. But they can form clouds on exoplanets. That’s pretty wild.”

These planets – hot gas giants – are among many exoplanet types confirmed in the galaxy. They could have clouds of vaporized rock because they orbit so close to their stars, making their atmospheres ferociously hot.

And while clouds of rock, rubies, or sapphires might sound enchanting, actually detecting such minerals in an exoplanet atmosphere also would be a giant step forward in scientific knowledge.

“Clouds tell us a lot about the chemistry in the atmosphere,” Kataria said. “It then becomes a question of how the clouds formed, and the formation and evolution of the system as a whole.”

The Webb telescope's many capabilities include “spectroscopy” – splitting the light Webb receives from distant stars and planets into a spectrum, a bit like a rainbow. That would allow scientists to read the types of molecules present in an exoplanet atmosphere.

And that means Webb could detect specific types of minerals in clouds.

Detailed study of exoplanet clouds might even yield evidence of a habitable, potentially life-bearing planet – say on a small, rocky world like Earth.

“Clouds are an important feature on Earth, to regulate temperature,” Kataria said. “They’re an important consideration for Earth’s climate. It stands to reason that clouds could also be a vital component in the atmosphere of a habitable exoplanet. The more we understand how clouds form in general – as they have on Earth and other solar system planets – the more we understand how clouds evolved in more exotic environments.”

Probing the hearts of exoplanet clouds could bring together experts from many scientific fields as they seek to understand the origin, evolution, and environments of other planets in our galaxy.

“This further illustrates that exoplanets as a field really is interdisciplinary, borrowing lessons learned from astronomy, planetary science, geology, chemistry, and other areas of science,” Kataria said. “It’s so important to build these connections with scientists in all these different fields to better understand the many exotic worlds out there.”

The James Webb Space Telescope is the world's premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

For more information about Webb, visit www.nasa.gov/webb.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanets: What NASA Will See with the Webb Telescope

Alicia Cermak

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Helps Decipher How Some Distant Planets Have Clouds of Sand

5 min read

A new study using archival observations by the now-retired Spitzer Space Telescope found a common trait among distant worlds where the exotic clouds form.

Most clouds on Earth are made of water, but beyond our planet they come in many chemical varieties. The top of Jupiter's atmosphere, for example, is blanketed in yellow-hued clouds made of ammonia and ammonium hydrosulfide. And on worlds outside our solar system, there are clouds composed of silicates, the family of rock-forming minerals that make up over 90% of Earth's crust. But researchers haven't been able to observe the conditions under which these clouds of small dust grains form.

A new study appearing in the Monthly Notices of the Royal Astronomical Society provides some insight: The research reveals the temperature range at which silicate clouds can form and are visible at the top of a distant planet's atmosphere. The finding was derived from observations by NASA's retired Spitzer Space Telescope of brown dwarfs – celestial bodies that fall in between planets and stars – but it fits into a more general understanding of how planetary atmospheres work.

"Understanding the atmospheres of brown dwarfs and planets where silicate clouds can form can also help us understand what we would see in the atmosphere of a planet that's closer in size and temperature to Earth," said Stanimir Metchev, a professor of exoplanet studies at Western University in London, Ontario, and co-author of the study.

The steps to make any type of cloud are the same. First, heat the key ingredient until it becomes a vapor. Under the right conditions, that ingredient could be a variety of things, including water, ammonia, salt, or sulfur. Trap it, cool it just enough for it to condense, and voilà – clouds! Of course, rock vaporizes at a much higher temperature than water, so silicate clouds are visible only on hot worlds, such as the brown dwarfs used for this study and some planets outside our solar system.

Although they form like stars, brown dwarfs aren't massive enough to kick-start fusion, the process that causes stars to shine. Many brown dwarfs have atmospheres almost indistinguishable from those of gas-dominated planets, such as Jupiter, so they can be used as a proxy for those planets.

Before this study, data from Spitzer already suggested the presence of silicate clouds in a handful of brown dwarf atmospheres. (NASA's James Webb Space Telescope will be able to confirm these types of clouds on distant worlds.) This work was done during the first six years of the Spitzer mission (which launched in 2003), when the telescope was operating three cryogenically cooled instruments. In many cases, though, the evidence of silicate clouds on brown dwarfs observed by Spitzer was too weak to stand on its own.

For this latest research, astronomers gathered more than 100 of those marginal detections and grouped them by the temperature of the brown dwarf. All of them fell within the predicted temperature range for where silicate clouds should form: between about 1,900 degrees Fahrenheit (about 1,000 degrees Celsius) and 3,100 F (1,700 C). While the individual detections are marginal, together they reveal a definitive trait of silicate clouds.

"We had to dig through the Spitzer data to find these brown dwarfs where there was some indication of silicate clouds, and we really didn't know what we would find," said Genaro Suárez, a postdoctoral researcher at Western University and lead author of the new study. "We were very surprised at how strong the conclusion was once we had the right data to analyze."

In atmospheres hotter than the top end of the range identified in the study, silicates remain a vapor. Below the bottom end, the clouds will turn into rain or sink lower in the atmosphere, where the temperature is higher.

In fact, researchers think that silicate clouds exist deep in Jupiter's atmosphere, where the temperature is much higher than it is at the top, owing to atmospheric pressure. The silicate clouds can't rise higher, because at lower temperatures the silicates will solidify and won't remain in cloud form. If the top of the atmosphere were thousands of degrees hotter, the planet's ammonia and ammonium hydrosulfide clouds would vaporize and the silicate clouds could potentially rise to the top.

Scientists are finding an increasingly varied menagerie of planetary environments in our galaxy. For example, they have found planets with one side permanently facing their star and the other permanently in shadow – a planet where clouds of different compositions might be visible, depending on the side observed. To understand those worlds, astronomers will first need to understand the common mechanisms that shape them.

The entire body of scientific data collected by Spitzer during its lifetime is available to the public via the Spitzer data archive, housed at the Infrared Science Archive at IPAC at Caltech in Pasadena, California. NASA's Jet Propulsion Laboratory, a division of Caltech, managed Spitzer mission operations for the agency's Science Mission Directorate in Washington. Science operations were conducted at the Spitzer Science Center at IPAC at Caltech. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado.

For more information about NASA's Spitzer mission, go to:

https://www.jpl.nasa.gov/missions/spitzer-space-telescope

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

2022-098

NASA’s New Hubble E-Book Takes Readers on a Journey to Curious Worlds

5 min read

NASA’s Hubble Space Telescope team has released a new edition in the Hubble Focus e-book series, called “Hubble Focus: Strange New Worlds.” This e-book highlights the mission’s recent discoveries about worlds outside our solar system, known as exoplanets.

Download:

ePub format (120 MB)

PDF format (5 MB)

“The Hubble Space Telescope is once again opening our eyes to an incredible universe, this time to the nature of alien worlds,” said Jennifer Wiseman, NASA’s Hubble senior project scientist. “These are impressive achievements when we consider that when Hubble was designed and launched, no exoplanets had yet been discovered.”

For thousands of years, people believed Earth was fixed at the center of the universe and that every other celestial object revolved around our planet. But over time, it became clear that Earth did not occupy such a special position. People began to see that perhaps Earth was not as unique as they thought. Some even wondered if there might be planets circling other stars.

To date, astronomers have found more than 5,000 exoplanets. While astronomers initially expected to find systems similar to ours, most of the first exoplanets they discovered were wild and exotic compared to our solar system. Hubble’s exoplanet studies continue to help broaden our view of planetary systems by revealing even more oddballs, often by investigating the chemistry of their atmospheres via spectroscopy – the study of the information coded in light.

Hubble’s spectroscopic observations have unveiled withering worlds that dwindle as they lose their atmospheres to space, and planets in bizarre orbits. But the observatory has also revealed worlds that are more similar to our own. Hubble has studied exoplanets’ atmospheres and found several that contain water vapor – an essential ingredient for life as we know it. Some of these worlds even orbit within their star’s habitable zone, which is the range of orbital distances where temperatures are mild enough that liquid water could pool on planetary surfaces. “Hubble has provided us with a wealth of information on the variety that exists among exoplanets, probing the composition of their atmospheres and discovering exotic weather seen nowhere on Earth or even elsewhere in our solar system,” said Ken Carpenter, Hubble’s operations project scientist based at NASA Goddard Space Flight Center. “It has also carried out an extremely critical exploration of relationship between these exoplanets and their host stars and how it drives conditions on the planetary surfaces that influence their habitability. Hubble has shown us that even stars unlike our Sun may harbor habitable worlds and thus broadened our search for life elsewhere in the galaxy.”

Earth exhibits a wide range of weather, from rolling thunderstorms to sunny skies to blizzards. Thanks to Hubble, astronomers have learned about the weather some exoplanets experience, including molten iron rain, amber skies, and even sunscreen-like snow flurries. Future observations could reveal more information about what drives exoplanets’ weather, including their relationships with their host stars.

If our own host star, the Sun, were just a little hotter or colder, or if it were much older or younger, Earth might not be habitable. Hubble has helped astronomers explore other planet-star relationships, offering clues to how they may evolve and informing our search for habitable worlds.

The observatory has even revealed a world with two suns and studied different types of stars to explore which are most conducive to life.

While Sun-like stars may be the most obvious targets to search for habitable planets, Hubble revealed that orange dwarfs – smaller and cooler than our yellow-white Sun, but larger and hotter than red dwarfs – could offer better chances. These stars are not too hot, too cool, or too violent to host life-friendly planets over vast stretches of cosmic time. Hubble's future observations will continue to help us focus our search for habitable worlds, bringing us ever closer to the possibility of finding life on other planets.

New stars form in the Milky Way from swirling clouds of gas and dust that are peppered throughout our galaxy. Vestiges of those clouds remain, surrounding each star in a disk that grows ever more diffuse as debris clumps together to form objects like planets. Hubble's exoplanet studies have largely focused on the planets themselves, but occasionally surprises pop up in the disks in which these planets are embedded.

Hubble has seen an eerie shadow sweep across a star's surrounding disk, studied comets a planet's gravity is hurling into its star, and watched a growing planet gobble up material. The observatory has even offered clues about the mystery of why so few planets between the sizes of Earth and Neptune exist. Hubble will continue to reveal new information about the worlds that grace our galaxy for years to come, providing hints about our own solar system's formation and evolution along the way.

As the fourth edition of the series, this e-book builds on the wealth of information shared in previous renditions, which focused on the solar system, stars, and galaxies. Upcoming editions will zoom in on other cosmic topics, such as dark matter and dark energy – two invisible cosmic mysteries that make up the majority of our universe.

The new e-book is compatible with most electronic devices and can be downloaded in multiple formats for free from:

https://science.nasa.gov/mission/hubble/multimedia/e-books

For more information about Hubble, visit:

www.nasa.gov/hubble

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Geology from 50 Light-Years: Webb Gets Ready to Study Rocky Worlds

5 min read

With its mirror segments beautifully aligned and its scientific instruments undergoing calibration, NASA’s James Webb Space Telescope is just weeks away from full operation. Soon after the first observations are revealed this summer, Webb’s in-depth science will begin.

Among the investigations planned for the first year are studies of two hot exoplanets classified as “super-Earths” for their size and rocky composition: the lava-covered 55 Cancri e and the airless LHS 3844 b. Researchers will train Webb’s high-precision spectrographs on these planets with a view to understanding the geologic diversity of planets across the galaxy, and the evolution of rocky planets like Earth.

55 Cancri e orbits less than 1.5 million miles from its Sun-like star (one twenty-fifth of the distance between Mercury and the Sun), completing one circuit in less than 18 hours. With surface temperatures far above the melting point of typical rock-forming minerals, the day side of the planet is thought to be covered in oceans of lava.

Planets that orbit this close to their star are assumed to be tidally locked, with one side facing the star at all times. As a result, the hottest spot on the planet should be the one that faces the star most directly, and the amount of heat coming from the day side should not change much over time.

But this doesn’t seem to be the case. Observations of 55 Cancri e from NASA’s Spitzer Space Telescope suggest that the hottest region is offset from the part that faces the star most directly, while the total amount of heat detected from the day side does vary.

One explanation for these observations is that the planet has a dynamic atmosphere that moves heat around. “55 Cancri e could have a thick atmosphere dominated by oxygen or nitrogen,” explained Renyu Hu of NASA’s Jet Propulsion Laboratory in Southern California, who leads a team that will use Webb’s Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI) to capture the thermal emission spectrum of the day side of the planet. “If it has an atmosphere, [Webb] has the sensitivity and wavelength range to detect it and determine what it is made of,” Hu added.

Another intriguing possibility, however, is that 55 Cancri e is not tidally locked. Instead, it may be like Mercury, rotating three times for every two orbits (what’s known as a 3:2 resonance). As a result, the planet would have a day-night cycle.

“That could explain why the hottest part of the planet is shifted,” explained Alexis Brandeker, a researcher from Stockholm University who leads another team studying the planet. “Just like on Earth, it would take time for the surface to heat up. The hottest time of the day would be in the afternoon, not right at noon.”

Brandeker’s team plans to test this hypothesis using NIRCam to measure the heat emitted from the lit side of 55 Cancri e during four different orbits. If the planet has a 3:2 resonance, they will observe each hemisphere twice and should be able to detect any difference between the hemispheres.

In this scenario, the surface would heat up, melt, and even vaporize during the day, forming a very thin atmosphere that Webb could detect. In the evening, the vapor would cool and condense to form droplets of lava that would rain back to the surface, turning solid again as night falls.

While 55 Cancri e will provide insight into the exotic geology of a world covered in lava, LHS 3844 b affords a unique opportunity to analyze the solid rock on an exoplanet surface.

Like 55 Cancri e, LHS 3844 b orbits extremely close to its star, completing one revolution in 11 hours. However, because its star is relatively small and cool, the planet is not hot enough for the surface to be molten. Additionally, Spitzer observations indicate that the planet is very unlikely to have a substantial atmosphere.

While we won’t be able to image the surface of LHS 3844 b directly with Webb, the lack of an obscuring atmosphere makes it possible to study the surface with spectroscopy.

“It turns out that different types of rock have different spectra,” explained Laura Kreidberg at the Max Planck Institute for Astronomy. “You can see with your eyes that granite is lighter in color than basalt. There are similar differences in the infrared light that rocks give off.”

Kreidberg’s team will use MIRI to capture the thermal emission spectrum of the day side of LHS 3844 b, and then compare it to spectra of known rocks, like basalt and granite, to determine its composition. If the planet is volcanically active, the spectrum could also reveal the presence of trace amounts of volcanic gases.

The importance of these observations goes far beyond just two of the more than 5,000 confirmed exoplanets in the galaxy. “They will give us fantastic new perspectives on Earth-like planets in general, helping us learn what the early Earth might have been like when it was hot like these planets are today,” said Kreidberg.

These observations of 55 Cancri e and LHS 3844 b will be conducted as part of Webb’s Cycle 1 General Observers program. General Observers programs were competitively selected using a dual-anonymous review system, the same system used to allocate time on Hubble.

The James Webb Space Telescope is the world’s premier space science observatory. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Margaret W. CarruthersSpace Telescope Science Institute, Baltimore, Maryland410-338-4366mcarruthers@stsci.edu

Discovery Alert: 30 ‘Exocomets’ Orbit a Familiar Star

2 min read

Alicia Cermak

The discovery: An international science team has detected 30 comets in orbit around the star Beta Pictoris – the first time the size distribution of small bodies has been measured in a planetary system other than our own. They are called “exocomets” because they are found outside our solar system.

Key facts: The team used NASA’s Transiting Exoplanet Survey Satellite (TESS) to determine the various sizes of the comets. The nuclei of the comets, or their solid, central portions, ranged between 1.8 and 8.6 miles (3 to 14 kilometers) across. The scientists were able to detect such small bodies at such a great distance by spotting their long tails as they crossed the face of their star.

Details: The range of comet sizes around Beta Pictoris, a star some 64 light-years away from our Sun, is quite similar to those in our own solar system. This might suggest a similar formation history for our system of planets and this not-so-distant neighbor. Both likely involved plenty of collisions and smash-ups as the systems sorted themselves into large and small bodies orbiting their respective stars. The study of the Beta Pictoris comets could yield insights into the early days of our solar system.

Fun facts: Beta Pictoris is probably already familiar to anyone who likes to keep tabs on exoplanets – planets outside our solar system. It is known to play host to at least two planets: Beta Pictoris b, a giant about 11 times the mass of Jupiter, and Beta Pictoris c, only a little less hefty at 9 times Jupiter’s mass. The first was discovered in 2008, the second in 2019.

The discoverers: The exocomet discovery team was led by Alain Lecavelier des Etangs of the Paris Institute of Astrophysics, part of the National Center for Scientific Research (CNRS) in France. The team of astronomers from France, Brazil, and the Netherlands published its findings April 28 in the journal, Scientific Reports.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Discovery Alert: Two New, Rocky Planets in the Solar Neighborhood

3 min read

Alicia Cermak

The discovery: NASA's TESS mission has found two rocky worlds orbiting the relatively bright, red dwarf star HD 260655, only 33 light-years away. The new planets, HD 260655 b and HD 260655 c, are among the closest-known rocky planets yet found outside our solar system that astronomers can observe crossing the faces of their stars.

Key facts: Using NASA's orbiting planet hunter, the Transiting Exoplanet Survey Satellite (TESS), scientists discovered sibling planets in Earth's size-range that are prime candidates for atmospheric investigation. And the discovery comes at an ideal moment: The giant James Webb Space Telescope, soon to deliver its first science images, can examine the atmospheres of exoplanets – planets beyond our solar system – to search for water, carbon molecules and other components. Learning more about the atmospheres of rocky planets will help scientists understand the formation and development of worlds like our own.

Details: Both planets are "super-Earths" – terrestrial worlds like ours, only bigger. Planet b is about 1.2 times as big around as Earth, planet c 1.5 times. In this case, however, neither world is likely to support life. The temperature on planet b, nearest to the star, is estimated at 816 degrees Fahrenheit (435 Celsius), planet c 543 Fahrenheit (284 Celsius), though actual temperature depends on the presence and nature of possible atmospheres.

Still, the science team that discovered the planets says they are well worth further investigation. At 33 light-years, they are relatively close to us, and their star, though smaller than ours, is among the brightest in its class. These and other factors raise the likelihood that the Webb telescope, and perhaps even the Hubble Space Telescope, could capture data from the star's light shining through these planets' atmospheres. Such light can be spread into a spectrum, revealing the fingerprints of molecules within the atmosphere itself.

Both planets rate in the top 10 candidates for atmospheric characterization among all terrestrial exoplanets so far discovered, the team says. That places them in the same category as one of the most famous planetary systems: the seven roughly Earth-sized planets around a star called TRAPPIST-1. The TRAPPIST-1 worlds and several other rocky exoplanets are already on the list of observation targets for the Webb telescope.

Fun facts: The jury is out on whether either newly discovered planet possesses an atmosphere, and if so, what it's made of. But the science team's analysis already has produced some intriguing clues. TESS finds exoplanets by watching for "transits" – the tiny drop in starlight when a planet passes in front of its star – which can reveal the planet's diameter. But the scientists also used data from ground-based telescopes to confirm the existence of the two new planets. These telescopes measured the "wobble" of the star, caused by the gravitational tugs from orbiting planets, which yields the planets' mass. Combine these measurements, and you can determine the density of the planets – in this case confirming they are rocky worlds. The measurements also suggest that if the planets do have atmospheres, they are not extended, hydrogen atmospheres.

The discoverers: An international team of astronomers led by Rafael Luque of the Institute of Astrophysics of Andalusia, Spain, and also of the University of Chicago, used TESS data to make the discovery. The team's paper has been accepted for publication in the science journal, "Astronomy & Astrophysics," with presentation of its results at the American Astronomical Society meeting in Pasadena in June 2022.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: A Flood of New Planets, Plus Hint of an ‘Exomoon’

4 min read

Alicia Cermak

The Discovery: An international team of astronomers confirms 60 new exoplanets, or planets orbiting other stars; a separate study finds tentative evidence of an “exomoon.”

Key facts: Data from NASA’s now-retired Kepler Space Telescope reveals an eclectic assortment of new planets and planetary systems that promises to deepen understanding of how exoplanets form. Some of the newly-discovered planets might make tempting targets for the James Webb Space Telescope, now being fine-tuned for its first observations this summer. The Webb telescope is expected to search for signs of atmospheres around some exoplanets, and potentially determine some of the gases and molecules present. This raft of new planets also helped push NASA’s tally of confirmed exoplanets past the 5,000 mark in March 2022.

Details: The study highlights several standouts in the new planetary menagerie:

Fun facts: The Kepler Space Telescope, deactivated in 2018 after running out of fuel, continues to yield new exoplanet discoveries.

Data from Kepler’s nine years of observations is still being analyzed by scientific teams around the world. The latest crop of 60 planets comes from Kepler’s second mission, called K2. Despite more limited observations due to mechanical issues, the K2 campaign found nearly 500 new planets and more than 1,000 candidate exoplanets.

Combing through Kepler data also revealed another potentially significant find: a possible exomoon. Planets around other stars are expected to have moons, just as planets in our solar system do, but gathering clear evidence of exomoons is a difficult business. Their typically small size and immense distance make them far harder to detect than exoplanets. The new possible exomoon, Kepler-1708 b-i, would be very large for a moon, about 2.6 times as big around as Earth. It would be orbiting a confirmed Jupiter-sized planet, itself in orbit around a Sun-like star more than 5,400 light-years away from Earth. It’s the second “unexpectedly large” exomoon candidate identified by astronomers; the first, Kepler-1625 b-i, was revealed in 2018 – a possible Uranus-sized moon also orbiting a Jupiter-sized planet. Despite data hinting at these exomoons’ presence, scientists involved in both discoveries say they will require more observations before they can be considered validated.

The discoverers: The international science team that confirmed 60 new planets was led by Jessie Christiansen, science lead for NASA’s Exoplanet Archive and a research scientist with the NASA Exoplanet Science Institute at Caltech in Pasadena. Christiansen also was a co-author of the study announcing the possible detection of a new exomoon candidate.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Finds a Planet Forming in an Unconventional Way

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA's Hubble Space Telescope has directly photographed evidence of a Jupiter-like protoplanet forming through what researchers describe as an "intense and violent process." This discovery supports a long-debated theory for how planets like Jupiter form, called "disk instability."

Thayne Currie

Lead Researcher on the Study

The new world under construction is embedded in a protoplanetary disk of dust and gas with distinct spiral structure swirling around surrounding a young star that’s estimated to be around 2 million years old. That's about the age of our solar system when planet formation was underway. (The solar system's age is currently 4.6 billion years.)

"Nature is clever; it can produce planets in a range of different ways," said Thayne Currie of the Subaru Telescope and Eureka Scientific, lead researcher on the study.

All planets are made from material that originated in a circumstellar disk. The dominant theory for jovian planet formation is called "core accretion," a bottom-up approach where planets embedded in the disk grow from small objects – with sizes ranging from dust grains to boulders – colliding and sticking together as they orbit a star. This core then slowly accumulates gas from the disk. In contrast, the disk instability approach is a top-down model where as a massive disk around a star cools, gravity causes the disk to rapidly break up into one or more planet-mass fragments.

The newly forming planet, called AB Aurigae b, is probably about nine times more massive than Jupiter and orbits its host star at a whopping distance of 8.6 billion miles – over two times farther than Pluto is from our Sun. At that distance it would take a very long time, if ever, for a Jupiter-sized planet to form by core accretion. This leads researchers to conclude that the disk instability has enabled this planet to form at such a great distance. And, it is in a striking contrast to expectations of planet formation by the widely accepted core accretion model.

The new analysis combines data from two Hubble instruments: the Space Telescope Imaging Spectrograph and the Near Infrared Camera and Multi-Object Spectrograph. These data were compared to those from a state-of-the-art planet imaging instrument called SCExAO on Japan's 8.2-meter Subaru Telescope located at the summit of Mauna Kea, Hawaii. The wealth of data from space and ground-based telescopes proved critical, because distinguishing between infant planets and complex disk features unrelated to planets is very difficult.

"Interpreting this system is extremely challenging," Currie said. "This is one of the reasons why we needed Hubble for this project – a clean image to better separate the light from the disk and any planet."

Nature itself also provided a helping hand: the vast disk of dust and gas swirling around the star AB Aurigae is tilted nearly face-on to our view from Earth.

Currie emphasized that Hubble's longevity played a particular role in helping researchers measure the protoplanet's orbit. He was originally very skeptical that AB Aurigae b was a planet. The archival data from Hubble, combined with imaging from Subaru, proved to be a turning point in changing his mind.

"We could not detect this motion on the order of a year or two years," Currie said. "Hubble provided a time baseline, combined with Subaru data, of 13 years, which was sufficient to be able to detect orbital motion."

"This result leverages ground and space observations and we get to go back in time with Hubble archival observations," Olivier Guyon of the University of Arizona, Tucson, and Subaru Telescope, Hawaii added. "AB Aurigae b has now been looked at in multiple wavelengths, and a consistent picture has emerged – one that's very solid."

The team's results are published in the April 4 issue of Nature Astronomy.

"This new discovery is strong evidence that some gas giant planets can form by the disk instability mechanism," Alan Boss of the Carnegie Institution of Science in Washington, D.C. emphasized. "In the end, gravity is all that counts, as the leftovers of the star-formation process will end up being pulled together by gravity to form planets, one way or the other."

Understanding the early days of the formation of Jupiter-like planets provides astronomers with more context into the history of our own solar system. This discovery paves the way for future studies of the chemical make-up of protoplanetary disks like AB Aurigae, including with NASA's James Webb Space Telescope.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center301-286-1940

Hannah BraunSpace Telescope Science Institute, Baltimore, Maryland

Ray VillardSpace Telescope Science Institute, Baltimore, Maryland

Science Contacts:

Thayne CurrieSubaru Telescope, Hilo, HawaiiEureka Scientific Inc., Oakland, California

Olivier GuyonSubaru Telescope, Hilo, HawaiiUniversity of Arizona, Tucson, Arizona

Kellen LawsonUniversity of Oklahoma, Norman, Oklahoma

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Probes Extreme Weather on Ultra-Hot Jupiters

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

In studying a unique class of ultra-hot exoplanets, NASA Hubble Space Telescope astronomers may be in the mood for dancing to the Calypso party song "Hot, Hot, Hot." That's because these bloated Jupiter-sized worlds are so precariously close to their parent star they are being roasted at seething temperatures above 3,000 degrees Fahrenheit. That's hot enough to vaporize most metals, including titanium. They have the hottest planetary atmospheres ever seen.

In two new papers, teams of Hubble astronomers are reporting on bizarre weather conditions on these sizzling worlds. It's raining vaporized rock on one planet, and another one has its upper atmosphere getting hotter rather than cooler because it is being "sunburned" by intense ultraviolet (UV) radiation from its star.

This research goes beyond simply finding weird and quirky planet atmospheres. Studying extreme weather gives astronomers better insights into the diversity, complexity, and exotic chemistry taking place in far-flung worlds across our galaxy.

Learn More about Hot Jupiters

"We still don't have a good understanding of weather in different planetary environments," said David Sing of the Johns Hopkins University in Baltimore, Maryland, co-author on two studies being reported. "When you look at Earth, all our weather predictions are still finely tuned to what we can measure. But when you go to a distant exoplanet, you have limited predictive powers because you haven't built a general theory about how everything in an atmosphere goes together and responds to extreme conditions. Even though you know the basic chemistry and physics, you don't know how it's going to manifest in complex ways."

In a paper in the April 7 journal Nature, astronomers describe Hubble observations of WASP-178b, located about 1,300 light-years away. On the daytime side the atmosphere is cloudless, and is enriched in silicon monoxide gas. Because one side of the planet permanently faces its star, the torrid atmosphere whips around to the nighttime side at super-hurricane speeds exceeding 2,000 miles per hour. On the dark side, the silicon monoxide may cool enough to condense into rock that rains out of clouds, but even at dawn and dusk, the planet is hot enough to vaporize rock. "We knew we had seen something really interesting with this silicon monoxide feature," said Josh Lothringer of the Utah Valley University in Orem, Utah.

In a paper published in the January 24 issue of Astrophysical Journal Letters, Guangwei Fu of the University of Maryland, College Park, reported on a super-hot Jupiter, KELT-20b, located about 400 light-years away. On this planet a blast of ultraviolet light from its parent star is creating a thermal layer in the atmosphere, much like Earth's stratosphere. "Until now we never knew how the host star affected a planet's atmosphere directly. There have been lots of theories, but now we have the first observational data," Fu said.

By comparison, on Earth, ozone in the atmosphere absorbs UV light and raises temperatures in a layer between 7 to 31 miles above Earth's surface. On KELT-20b the UV radiation from the star is heating metals in the atmosphere which makes for a very strong thermal inversion layer.

Evidence came from Hubble's detection of water in near-infrared observations, and from NASA's Spitzer Space Telescope's detection of carbon monoxide. They radiate through the hot, transparent upper atmosphere that is produced by the inversion layer. This signature is unique from what astronomers see in the atmospheres of hot-Jupiters orbiting cooler stars, like our Sun. "The emission spectrum for KELT-20b is quite different from other hot-Jupiters," said Fu. "This is compelling evidence that planets don't live in isolation but are affected by their host star."

Though super-hot Jupiters are uninhabitable, this kind of research helps pave the way to better understanding the atmospheres of potentially inhabitable terrestrial planets. "If we can't figure out what's happening on super-hot Jupiters where we have reliable solid observational data, we're not going to have a chance to figure out what's happening in weaker spectra from observing terrestrial exoplanets," said Lothringer. "This is a test of our techniques that allows us to build a general understanding of physical properties such as cloud formation and atmospheric structure."

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center301-286-1940

Ray VillardSpace Telescope Science Institute, Baltimore, Maryland

Science Contacts:

David SingJohns Hopkins University, Baltimore, Maryland

Joshua LothringerUtah Valley University, Orem, Utah

Guangwei FuUniversity of Maryland, College Park, Maryland

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cosmic Milestone: NASA Confirms 5,000 Exoplanets

5 min read

Pat Brennan

The count of confirmed exoplanets just ticked past the 5,000 mark, representing a 30-year journey of discovery led by NASA space telescopes.

Not so long ago, we lived in a universe with only a small number of known planets, all of them orbiting our Sun. But a new raft of discoveries marks a scientific high point: More than 5,000 planets are now confirmed to exist beyond our solar system.

The planetary odometer turned on March 21, 2022, with a large batch of 65 exoplanets – planets outside our immediate solar family – added to the NASA Exoplanet Archive. The archive records exoplanet discoveries that appear in peer-reviewed, scientific papers, and that have been confirmed using multiple detection methods or by analytical techniques.

The 5,000-plus planets found so far include small, rocky worlds like Earth, gas giants many times larger than Jupiter, and “hot Jupiters” in scorchingly close orbits around their stars. There are “super-Earths,” which are possible rocky worlds bigger than our own, and “mini-Neptunes,” smaller versions of our system’s Neptune. Add to the mix planets orbiting two stars at once and planets stubbornly orbiting the collapsed remnants of dead stars.

“It’s not just a number,” said Jessie Christiansen, science lead for the archive and a research scientist with the NASA Exoplanet Science Institute at Caltech in Pasadena. “Each one of them is a new world, a brand-new planet. I get excited about every one because we don’t know anything about them.”

We do know this: Our galaxy likely holds hundreds of billions of such planets. The steady drumbeat of discovery began in 1992 with strange new worlds orbiting an even stranger star. It was a type of neutron star known as a pulsar, a rapidly spinning stellar corpse that pulses with millisecond bursts of searing radiation. Measuring slight changes in the timing of the pulses allowed scientists to reveal planets in orbit around the pulsar.

Finding just three planets around this spinning star essentially opened the floodgates, said Alexander Wolszczan, the lead author on the paper that, 30 years ago, unveiled the first planets to be confirmed outside our solar system.

“If you can find planets around a neutron star, planets have to be basically everywhere,” Wolszczan said. “The planet production process has to be very robust.”

Wolszczan, who still searches for exoplanets as a professor at Penn State, says we’re opening an era of discovery that will go beyond simply adding new planets to the list. The Transiting Exoplanet Survey Satellite (TESS), launched in 2018, continues to make new exoplanet discoveries. But soon powerful next-generation telescopes and their highly sensitive instruments, starting with the recently launched James Webb Space Telescope, will capture light from the atmospheres of exoplanets, reading which gases are present to potentially identify tell-tale signs of habitable conditions.

Alexander Wolszczan

The Nancy Grace Roman Space Telescope, expected to launch in 2027, will make new exoplanet discoveries using a variety of methods. The ESA (European Space Agency) mission ARIEL, launching in 2029, will observe exoplanet atmospheres; a piece of NASA technology aboard, called CASE, will help zero in on exoplanet clouds and hazes.

“To my thinking, it is inevitable that we’ll find some kind of life somewhere – most likely of some primitive kind,” Wolszczan said. The close connection between the chemistry of life on Earth and chemistry found throughout the universe, as well as the detection of widespread organic molecules, suggests detection of life itself is only a matter of time, he added.

The picture didn’t always look so bright. The first planet detected around a Sun-like star, in 1995, turned out to be a hot Jupiter: a gas giant about half the mass of our own Jupiter in an extremely close, four-day orbit around its star. A year on this planet, in other words, lasts only four days.

More such planets appeared in the data from ground-based telescopes once astronomers learned to recognize them – first dozens, then hundreds. They were found using the “wobble” method: tracking slight back-and-forth motions of a star, caused by gravitational tugs from orbiting planets. But still, nothing looked likely to be habitable.

Finding small, rocky worlds more like our own required the next big leap in exoplanet-hunting technology: the “transit” method. Astronomer William Borucki came up with the idea of attaching extremely sensitive light detectors to a telescope, then launching it into space. The telescope would stare for years at a field of more than 170,000 stars, searching for tiny dips in starlight when a planet crossed a star’s face.

That idea was realized in the Kepler Space Telescope.

Borucki, principal investigator of the now-retired Kepler mission, says its launch in 2009 opened a new window on the universe.

“I get a real feeling of satisfaction, and really of awe at what’s out there,” he said. “None of us expected this enormous variety of planetary systems and stars. It’s just amazing.”

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Finalizes Plans for Its Next Cosmic Mapmaker

6 min read

The SPHEREx mission will have some similarities with the James Webb Space Telescope. But the two observatories will take dramatically different approaches to studying the sky.

NASA’s upcoming SPHEREx mission will be able to scan the entire sky every six months and create a map of the cosmos unlike any before. Scheduled to launch no later than April 2025, it will probe what happened within the first second after the big bang, how galaxies form and evolve, and the prevalence of molecules critical to the formation of life, like water, locked away as ice in our galaxy. Achieving these goals will require cutting-edge technology, and NASA has this month approved final plans for all the observatory’s components.

“We’re at the transition from doing things with computer models to doing things with real hardware,” said Allen Farrington, SPHEREx project manager at NASA’s Jet Propulsion Laboratory in Southern California, which manages the mission. “The design for the spacecraft, as it stands, is confirmed. We have shown that it’s doable down to the smallest details. So now we can really start building and putting things together.”

To answer big questions about the universe, scientists need to look at the sky in different ways. Many telescopes, like NASA’s Hubble Space Telescope, are built to focus on individual stars, galaxies, or other cosmic objects, and to study them in detail. But SPHEREx (which stands for Spectro-Photometer for the History of the Universe, Epoch of Reionization and Ices Explorer) belongs to another class of space telescopes that quickly observe large portions of the sky, surveying many objects in a short period of time. SPHEREx will scan over 99% of the sky every six months; by contrast, Hubble has observed about 0.1% of the sky in more than 30 years of operations. Although survey telescopes like SPHEREx can’t see objects with the same level of detail as targeted observatories, they can answer questions about the typical properties of those objects throughout the universe.

For example, NASA’s recently launched James Webb Space Telescope will target individual exoplanets (planets outside our solar system), measuring their size, temperature, weather patterns, and makeup. But do exoplanets, on average, form in environments that are conducive to life as we know it? With SPHEREx, scientists will measure the prevalence of life-sustaining materials like water that reside in icy dust grains in the galactic clouds from which new stars and their planetary systems are born. Astronomers believe the water in Earth’s oceans, thought to be essential to life starting on Earth, originally came from such interstellar material.

“It’s the difference between getting to know a few individual people, and doing a census and learning about the population as a whole,” said Beth Fabinsky, deputy project manager for SPHEREx at JPL. “Both types of studies are important, and they complement each other. But there are some questions that can only be answered through that census.”

SPHEREx and Webb differ not only in their approach to studying the sky but in their physical parameters. Webb is the largest telescope to ever fly in space, with a 21.3-foot (6.5-meter) primary mirror to capture the highest-resolution images of any space telescope in history. The observatory protects its sensitive instruments from the Sun’s blinding light with a sunshield that’s as big as a tennis court. SPHEREx, on the other hand, has an 8-inch primary mirror and a sunshield that is just 10.5 feet (3.2 meters) across.

But both observatories will collect infrared light – wavelengths outside the range that human eyes can detect. Infrared is sometimes called heat radiation because it is emitted by warm objects, which is why it’s used in night vision equipment. The two telescopes will also both use a technique called spectroscopy to break infrared light into its individual wavelengths, or colors, just like a prism breaks sunlight into its component colors. Spectroscopy is what enables both SPHEREx and Webb to reveal what an object is made of, because individual chemical elements absorb and radiate specific wavelengths of light.

In order to pursue big-picture questions, the SPHEREx team first had to answer more practical ones, such as whether the instrument on board could survive the environment in space, and if all its components could be packed together and operate as a system. Last month, the team’s final plans were approved by NASA, a step that the agency calls critical design review or CDR. This marks a major milestone for the mission on the way to launch.

“COVID continues to be a big challenge for us in developing new space projects. Everything the country went through over the past year, from supply chain disruptions to working at home with kids, we’ve gone through as well,” said SPHEREx Principal Investigator James Bock, who is a scientist at JPL and Caltech in Pasadena, California. “It’s really incredible to be part of a team that has handled these difficulties with enthusiasm and a seemingly unlimited supply of determination.”

SPHEREx is managed by JPL for NASA’s Science Mission Directorate in Washington. The mission’s principal investigator is based at Caltech, which manages JPL for NASA and will also develop the payload in collaboration with JPL. Ball Aerospace in Boulder, Colorado, will supply the spacecraft. The Korea Astronomy and Space Science Institute (KASI) is an instrument and science partner for the mission. Data will be processed and archived at IPAC at Caltech. The SPHEREx science team includes members from 10 institutions across the U.S. and South Korea.

For more information about the SPHEREx mission, visit:

https://www.jpl.nasa.gov/missions/spherex/

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

2022-041

Cosmic Milestone: NASA Confirms 5,000 Exoplanets

5 min read

The count of confirmed exoplanets just ticked past the 5,000 mark, representing a 30-year journey of discovery led by NASA space telescopes.

Not so long ago, we lived in a universe with only a small number of known planets, all of them orbiting our Sun. But a new raft of discoveries marks a scientific high point: More than 5,000 planets are now confirmed to exist beyond our solar system.

The planetary odometer turned on March 21, with the latest batch of 65 exoplanets – planets outside our immediate solar family – added to the NASA Exoplanet Archive. The archive records exoplanet discoveries that appear in peer-reviewed, scientific papers, and that have been confirmed using multiple detection methods or by analytical techniques.

The 5,000-plus planets found so far include small, rocky worlds like Earth, gas giants many times larger than Jupiter, and “hot Jupiters” in scorchingly close orbits around their stars. There are “super-Earths,” which are possible rocky worlds bigger than our own, and “mini-Neptunes,” smaller versions of our system’s Neptune. Add to the mix planets orbiting two stars at once and planets stubbornly orbiting the collapsed remnants of dead stars.

“It’s not just a number,” said Jessie Christiansen, science lead for the archive and a research scientist with the NASA Exoplanet Science Institute at Caltech in Pasadena. “Each one of them is a new world, a brand-new planet. I get excited about every one because we don’t know anything about them.”

We do know this: Our galaxy likely holds hundreds of billions of such planets. The steady drumbeat of discovery began in 1992 with strange new worlds orbiting an even stranger star. It was a type of neutron star known as a pulsar, a rapidly spinning stellar corpse that pulses with millisecond bursts of searing radiation. Measuring slight changes in the timing of the pulses allowed scientists to reveal planets in orbit around the pulsar.

Finding just three planets around this spinning star essentially opened the floodgates, said Alexander Wolszczan, the lead author on the paper that, 30 years ago, unveiled the first planets to be confirmed outside our solar system.

“If you can find planets around a neutron star, planets have to be basically everywhere,” Wolszczan said. “The planet production process has to be very robust.”

Wolszczan, who still searches for exoplanets as a professor at Penn State, says we’re opening an era of discovery that will go beyond simply adding new planets to the list. The Transiting Exoplanet Survey Satellite (TESS), launched in 2018, continues to make new exoplanet discoveries. But soon powerful next-generation telescopes and their highly sensitive instruments, starting with the recently launched James Webb Space Telescope, will capture light from the atmospheres of exoplanets, reading which gases are present to potentially identify tell-tale signs of habitable conditions.

The Nancy Grace Roman Space Telescope, expected to launch in 2027, will make new exoplanet discoveries using a variety of methods. The ESA (European Space Agency) mission ARIEL, launching in 2029, will observe exoplanet atmospheres; a piece of NASA technology aboard, called CASE, will help zero in on exoplanet clouds and hazes.

“To my thinking, it is inevitable that we’ll find some kind of life somewhere – most likely of some primitive kind,” Wolszczan said. The close connection between the chemistry of life on Earth and chemistry found throughout the universe, as well as the detection of widespread organic molecules, suggests detection of life itself is only a matter of time, he added.

The picture didn’t always look so bright. The first planet detected around a Sun-like star, in 1995, turned out to be a hot Jupiter: a gas giant about half the mass of our own Jupiter in an extremely close, four-day orbit around its star. A year on this planet, in other words, lasts only four days.

More such planets appeared in the data from ground-based telescopes once astronomers learned to recognize them – first dozens, then hundreds. They were found using the “wobble” method: tracking slight back-and-forth motions of a star, caused by gravitational tugs from orbiting planets. But still, nothing looked likely to be habitable.

Finding small, rocky worlds more like our own required the next big leap in exoplanet-hunting technology: the “transit” method. Astronomer William Borucki came up with the idea of attaching extremely sensitive light detectors to a telescope, then launching it into space. The telescope would stare for years at a field of more than 170,000 stars, searching for tiny dips in starlight when a planet crossed a star’s face.

That idea was realized in the Kepler Space Telescope.

Borucki, principal investigator of the now-retired Kepler mission, says its launch in 2009 opened a new window on the universe.

“I get a real feeling of satisfaction, and really of awe at what’s out there,” he said. “None of us expected this enormous variety of planetary systems and stars. It’s just amazing.”

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

Written by Pat Brennan

2022-037

‘Heroic’ Space Telescopes See Skies Packed With Planets

3 min read

NASA Science Editorial Team

Searching for planets beyond our solar system takes us out of this world – in fact, high above it.

While the first exoplanets – planets around other stars – were discovered using ground-based telescopes, the view was blurry at best. Clouds, moisture, and jittering air molecules all got in the way, limiting what we could learn about these distant worlds.

To capture finer details – detecting atmospheres on small, rocky planets like Earth, for instance, to seek potential signs of habitability – astronomers knew they needed what we might call “superhero” telescopes, capable of blasting off the surface into orbit.

“While ground-based telescopes showed us that it is indeed possible to discover new planets, it’s often space-based facilities that allow us to advance from initial detections to well-understood worlds,” said Jennifer Burt, an exoplanet scientist at NASA’s Jet Propulsion Laboratory in Southern California.

Over the past few decades, a team of now-legendary space telescopes answered the call: Hubble, Chandra, Spitzer, Kepler, TESS, and now, the Webb telescope.

Many of their “superpowers,” of course, go far beyond detecting exoplanets. The Hubble Space Telescope can look deep into the cosmic past, seeing light from the early universe and some of the most distant stars and galaxies ever observed. The Chandra X-ray Observatory, like Hubble one of NASA’s “Great Observatories,” examines the universe in X-rays. That has allowed it to peer into the tatters of exploded stars and the edges of our galaxy’s central, supermassive black hole.

Another Great Observatory, the now-retired Spitzer Space Telescope, viewed the cosmos in infrared light, observing structural details of disks around stars and the faint glow of distant galaxies.

All three of these telescopes also have made ground-breaking exoplanet observations.

Meanwhile, Kepler, also retired, and TESS took on exoplanets as their main mission, both employing the transit method – searching for tiny dips in starlight as a planet crosses, or “transits,” the face of its star.

The result of all this teamwork: thousands of exoplanets confirmed in our galaxy, and the opening chapter in a new era of discovery – not only finding exoplanets, but understanding what they are like.

Hubble, Spitzer, and Chandra, for example, each helped open the door to analyzing exoplanet atmospheres.

One very strange world, the “hot Jupiter” HD 189733 b, has been observed by all three. Hubble found that the atmosphere of the planet is a deep blue. Spitzer estimated its temperature at 1,700 degrees Fahrenheit (935 degrees Celsius). Chandra, measuring the planet’s transit using X-rays from its star, showed that HD 189733 b’s atmosphere is distended by evaporation.

The James Webb Space Telescope delivered its first images in July 2022, and will also examine the planet, perhaps revealing further details about the composition of its atmosphere.

And Webb will open the door to atmospheric characterization even farther, probing the seven Earth-sized worlds orbiting a star called TRAPPIST-1 and seeking evidence of atmospheric gases.

If Webb succeeds, it will mark the first detection of an atmosphere around a rocky, Earth-sized planet.

Call it epic, or even heroic: The space telescope adventure continues.

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

How NASA’s Roman Could Help Find Other Earths by Surveying Space Dust

5 min read

A team of scientists found NASA’s Nancy Grace Roman Space Telescope will be able to measure a specific kind of space dust littered throughout dozens of nearby planetary systems’ habitable zones, or the regions around stars where temperatures are mild enough that liquid water could pool on worlds’ surfaces. Finding out how much of this material these systems contain would help astronomers learn more about how rocky planets form and guide the search for habitable worlds by future missions.

In our own solar system, zodiacal dust – small rocky grains largely left behind by colliding asteroids and crumbling comets – spans from near the Sun to the asteroid belt between Mars and Jupiter. Seen from a distance, it’s the brightest thing in the solar system after the Sun. In other planetary systems it’s called exozodiacal dust and creates a haze that obscures our view of planets because it scatters light from the host star.

“If we don’t find much of this dust around a particular star, that means future missions will be able to see potential planets relatively easily,” said Ewan Douglas, an assistant professor of astronomy at the University of Arizona in Tucson and the lead author of a paper describing the results. “But if we do find this kind of dust, we can study it and learn all kinds of interesting things about its sources, like comets and asteroids in these systems, and the influence of unseen planets on its brightness and distribution. It’s a win-win for science!”

Searching for exozodiacal dust is just one example of the promising potential scientific uses from Roman’s Coronagraph Instrument that could follow its 18-month technology demonstration phase. The team’s results are published in the Publications of the Astronomical Society of the Pacific.

By studying exozodiacal dust, astronomers can find clues to what other planetary systems are like. The amount of debris hints at comet activity, since a greater number of comets should produce more dust. Seeing the dust’s distribution pattern could offer hints about orbiting planets, which could sculpt the debris with their gravity and carve paths through the material.

“No one knows much about exozodiacal dust because it’s so close to its host star that it’s usually lost in the glare, making it notoriously difficult to observe,” said Bertrand Mennesson, Roman’s deputy project scientist at NASA’s Jet Propulsion Laboratory in Southern California and a co-author of the paper. “We’re not sure what Roman will find in these other planetary systems, but we’re excited to finally have an observatory that’s equipped to explore this aspect of their habitable zones.”

Roman could use its Coronagraph Instrument to block out a host star’s light and make sensitive measurements of the light reflected by the system’s dust in the same kind of light our eyes can see. Ground-based telescopes struggle with such observations because they must look through Earth’s turbulent atmosphere. “It’s very hard to block a twinkling star,” Douglas said.

“The Roman Coronagraph is equipped with special sensors and deformable mirrors that will actively measure and subtract starlight in real time,” said John Debes, an astronomer at the Space Telescope Science Institute in Baltimore and a co-author of the paper. “This will help provide a very high level of contrast, a hundred times better than Hubble’s passive coronagraph offers, which we need to spot warm dust that orbits close to the host star.”

While other observatories, such as the Hubble Space Telescope, have observed cold debris disks far from their host stars – farther from their stars than Neptune is from the Sun – no one has been able to photograph warm dust in the habitable zone region. While previous NASA projects have made preliminary measurements of exozodiacal dust in habitable zones, Roman's images will be much more sensitive, thanks to its advanced high-contrast Coronagraph Instrument and its stable location in space. Orbiting a million miles from Earth around the Lagrange Point 2 (L2), instead of in low-Earth orbit like Hubble, means our planet won't present such a challenging environment from which to make these observations.

Imaging warm debris closer to host stars is important because it's made up of different material than outer dust disks. Closer to the host star, rocky grains dominate the dust; farther away, it is largely composed of icy grains. The debris in each region is created by different processes, so studying the chemistry of exozodiacal dust offers information astronomers can't get by observing the outer regions around other stars.

"By prospecting for this dust, we could learn about the processes that shape planetary systems while providing important information for future missions that aim to image habitable-zone planets," Debes said. "By finding out how much exozodiacal dust is in the way of possible planets in nearby systems, we can tell how large future telescopes will need to be to see through it. Observations from the Roman Coronagraph could offer a crucial steppingstone in the search for Earth analogs."

The Nancy Grace Roman Space Telescope is managed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Ashley BalzerNASA's Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Coffee Chat with Planet Hunters

1 min read

NASA Science Editorial Team

Do you want to help discover new planets? How about having your name included on a scientific publication? Watch the Planet Hunters Coffee Chat video tutorials and learn how you can join and become a citizen scientist, be part of the hunt for undiscovered worlds! Planet Hunters Coffee Chat (PHCC) is an opportunity to grab some coffee and hear from astronomers about discovering planets, star variability, light curves with flares, eclipsing binaries, and more! A new video is released every week and you can join online discussions with astronomers: https://www.planethunters.coffee/tutorials. After watching the video series, bring your questions to PHCC's Live Office Hours and join roundtable discussions on exoplanet discoveries, be introduced to the astronomers who find them, and learn why these discoveries are important to NASA.

NASA's Citizen Science Program:Learn about NASA citizen science projectsFollow on TwitterFollow on Facebook

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Day of Discovery: 7 Earth-Size Planets

5 min read

Five years ago, astronomers revealed a spectacular collection of other worlds: the TRAPPIST-1 system.

Newspapers around the world printed the discovery on their front pages: Astronomers had found that a red dwarf star called TRAPPIST-1 was home to a close-knit family of seven Earth-size planets. NASA announced the system Feb. 22, 2017.

Using telescopes on the ground and in space, scientists revealed one of the most unusual planetary systems yet found beyond our Sun and opened the tantalizing question: Are any of these worlds habitable – a suitable home for life?

Five years later, the planets are still enigmatic. Since the first announcement, subsequent studies have revealed that the TRAPPIST-1 planets are rocky, that they could be almost twice as old as our solar system, and that they are located 41 light-years from Earth.

But a real game-changer will be the recently launched James Webb Space Telescope. Larger and more powerful than any previous space telescope, Webb will look for signs of atmospheres on the TRAPPIST-1 planets.

“That folks are even able to ask the question about whether a planet around another star is habitable – that just boggles my mind,” said Sean Carey, manager of the Exoplanet Science Institute at NASA’s Jet Propulsion Laboratory in Southern California. Carey was part of the team that helped discover some of the TRAPPIST-1 planets using data from the now-retired Spitzer Space Telescope.

Explore the TRAPPIST-1 system using NASA’s Eyes on Exoplanets interactive visualization, where you can view each planet illustration up close. Credit: NASA/JPL-Caltech

A prime target for Webb is the fourth planet from the star, called TRAPPIST-1e. It’s right smack in the middle of what scientists call the habitable zone, also known as the Goldilocks zone. This is the orbital distance from a star where the amount of heating is right to allow liquid water on the surface of a planet.

Though the planets are tightly packed around TRAPPIST-1, the red dwarf star is not only far cooler than our Sun, it is less than 10% its size. (In fact, if the entire system were placed in our own solar system, it would fit within the orbit of our innermost planet, Mercury.)

The habitable zone is just a first cut. A potentially habitable planet also would require a suitable atmosphere, and Webb, especially in its early observations, is likely to gain only a partial indication of whether an atmosphere is present.

“What is at stake here is the first atmosphere characterization of a terrestrial Earth-size planet in the habitable zone,” said Michaël Gillon, an astronomer at the University of Liege in Belgium and the lead author of the study that revealed the seven sibling planets in 2017.

Measurements with the Hubble Space Telescope added more information about habitability. While Hubble does not have the power to determine whether the planets possess potentially habitable atmospheres, it did find that at least three of the planets – d, e, and f – do not appear to have the puffy, hydrogen-dominated atmospheres of gas giants, such as Neptune, in our solar system. Such planets are thought to be less likely to support life.

That leaves open the possibility of “the atmospheres’ potential to support liquid water on the surface,” said Nikole Lewis, a planetary scientist at Cornell University.

Lewis is part of a science team that will use the Webb telescope, which will view the heavens in infrared light, to hunt for signs of an atmosphere on TRAPPIST-1e, the one with the Goldilocks perch in the habitable zone.

“The hope is that we see carbon dioxide, a really strong feature, right at the wavelengths [detectable by] Webb,” she said. “Once we know where there are little things peaking up above the noise, we can go back and do a much higher resolution look in that area.”

The size of the TRAPPIST-1 planets also might help to strengthen the case for habitability, though the research is far from conclusive.

They’re comparable to Earth not just in diameter but mass. Narrowing down the mass of the planets was possible, thanks to their tight bunching around TRAPPIST-1: Packed shoulder to shoulder, they jostle one another, enabling scientists to compute their likely range of mass from those gravitational effects.

“We have gotten some really good information about their size – mass and radius,” said Cornell’s Lewis. “That means we know about their densities.”

The densities suggest the planets might be composed of materials found in terrestrial planets like Earth.

Scientists use computer models of possible planetary atmosphere formation and evolution to try to narrow down their possible composition, and these will be critical for the TRAPPIST-1 planets, Lewis said.

“The great thing about the TRAPPIST system is that it is going to allow us to refine those models either way – whether they will end up being just barren rock or end up being potentially habitable worlds,” she said.

For Gillon, another great thing about the system is the reach of the TRAPPIST-1 system. “I’ve seen TRAPPIST-1 included in some artistic works; I’ve seen it in music, sci-fi novels, comics,” he said. “That’s really something we have enjoyed during these five years. It’s like this system has a life of its own.”

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

Written by Pat Brennan

Day of Discovery: 7 Earth-Size Planets

5 min read

Alicia Cermak

Newspapers around the world printed the discovery on their front pages: Astronomers had found that a red dwarf star called TRAPPIST-1 was home to a close-knit family of seven Earth-size planets. NASA announced the system Feb. 22, 2017.

Using telescopes on the ground and in space, scientists revealed one of the most unusual planetary systems yet found beyond our Sun and opened the tantalizing question: Are any of these worlds habitable – a suitable home for life?

Five years later, the planets are still enigmatic. Since the first announcement, subsequent studies have revealed that the TRAPPIST-1 planets are rocky, that they could be almost twice as old as our solar system, and that they are located 41 light-years from Earth.

But a real game-changer will be the recently launched James Webb Space Telescope. Larger and more powerful than any previous space telescope, Webb will look for signs of atmospheres on the TRAPPIST-1 planets.

“That folks are even able to ask the question about whether a planet around another star is habitable – that just boggles my mind,” said Sean Carey, manager of the Exoplanet Science Institute at NASA’s Jet Propulsion Laboratory in Southern California. Carey was part of the team that helped discover some of the TRAPPIST-1 planets using data from the now-retired Spitzer Space Telescope.

A prime target for Webb is the fourth planet from the star, called TRAPPIST-1e. It’s right smack in the middle of what scientists call the habitable zone, also known as the Goldilocks zone. This is the orbital distance from a star where the amount of heating is right to allow liquid water on the surface of a planet.

Though the planets are tightly packed around TRAPPIST-1, the red dwarf star is not only far cooler than our Sun, it is less than 10% its size. (In fact, if the entire system were placed in our own solar system, it would fit within the orbit of our innermost planet, Mercury.)

Searching for Atmospheres

The habitable zone is just a first cut. A potentially habitable planet also would require a suitable atmosphere, and Webb, especially in its early observations, is likely to gain only a partial indication of whether an atmosphere is present.

“What is at stake here is the first atmosphere characterization of a terrestrial Earth-size planet in the habitable zone,” said Michaël Gillon, an astronomer at the University of Liege in Belgium and the lead author of the study that revealed the seven sibling planets in 2017.

Measurements with the Hubble Space Telescope added more information about habitability. While Hubble does not have the power to determine whether the planets possess potentially habitable atmospheres, it did find that at least three of the planets – d, e, and f – do not appear to have the puffy, hydrogen-dominated atmospheres of gas giants, such as Neptune, in our solar system. Such planets are thought to be less likely to support life.

That leaves open the possibility of “the atmospheres’ potential to support liquid water on the surface,” said Nikole Lewis, a planetary scientist at Cornell University.

More on TRAPPIST-1

Lewis is part of a science team that will use the Webb telescope, which will view the heavens in infrared light, to hunt for signs of an atmosphere on TRAPPIST-1e, the one with the Goldilocks perch in the habitable zone.

“The hope is that we see carbon dioxide, a really strong feature, right at the wavelengths [detectable by] Webb,” she said. “Once we know where there are little things peaking up above the noise, we can go back and do a much higher resolution look in that area.”

The size of the TRAPPIST-1 planets also might help to strengthen the case for habitability, though the research is far from conclusive.

They’re comparable to Earth not just in diameter but mass. Narrowing down the mass of the planets was possible, thanks to their tight bunching around TRAPPIST-1: Packed shoulder to shoulder, they jostle one another, enabling scientists to compute their likely range of mass from those gravitational effects.

“We have gotten some really good information about their size – mass and radius,” said Cornell’s Lewis. “That means we know about their densities.”

The densities suggest the planets might be composed of materials found in terrestrial planets like Earth.

Scientists use computer models of possible planetary atmosphere formation and evolution to try to narrow down their possible composition, and these will be critical for the TRAPPIST-1 planets, Lewis said.

“The great thing about the TRAPPIST system is that it is going to allow us to refine those models either way – whether they will end up being just barren rock or end up being potentially habitable worlds,” she said.

For Gillon, another great thing about the system is the reach of the TRAPPIST-1 system. “I’ve seen TRAPPIST-1 included in some artistic works; I’ve seen it in music, sci-fi novels, comics,” he said. “That’s really something we have enjoyed during these five years. It’s like this system has a life of its own.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Roman Mission Could Snap First Image of a Jupiter-Like World

6 min read

NASA’s Nancy Grace Roman Space Telescope, now under construction, will test new technologies for space-based planet hunting. The mission aims to photograph worlds and dusty disks around nearby stars with detail up to a thousand times better than possible with other observatories.

Roman will use its Coronagraph Instrument – a system of masks, prisms, detectors, and even self-flexing mirrors built to block out the glare from distant stars and reveal the planets in orbit around them – to demonstrate that direct imaging technologies can perform even better in space than they have with ground-based telescopes.

“We will be able to image worlds in visible light using the Roman Coronagraph,” said Rob Zellem, an astronomer at NASA’s Jet Propulsion Laboratory (JPL) in Southern California who is co-leading the observation calibration plan for the instrument. JPL is building Roman’s Coronagraph Instrument. “Doing so from space will help us see smaller, older, and colder planets than direct imaging usually reveals, bringing us a giant leap closer to imaging planets like Earth.”

Exoplanets – planets beyond our solar system – are so distant and dim relative to their host stars that they’re practically invisible, even to powerful telescopes. That’s why nearly all of the worlds discovered so far have been found indirectly through effects they have on their host stars. However, recent advancements in technology allow astronomers to actually take images of the reflected light from the planets themselves.

Analyzing the colors of planetary atmospheres helps astronomers discover what the atmospheres are made of. This, in turn, can offer clues about the processes occurring on the imaged worlds that may affect their habitability. Since living things modify their environment in ways we might be able to detect, such as by producing oxygen or methane, scientists hope this research will pave the way for future missions that could reveal signs of life.

If Roman’s Coronagraph Instrument successfully completes its technology demonstration phase, its polarimetry mode will allow astronomers to image the disks around stars in polarized light, familiar to many as the reflected glare blocked by polarized sunglasses. Astronomers will use polarized images to study the dust grains that make up the disks around stars, including their sizes, shapes, and possibly mineral properties. Roman may even be able to reveal structures in the disks, such as gaps created by unseen planets. These measurements will complement existing data by probing fainter dust disks orbiting nearer to their host stars than other telescopes can see.

Current direct imaging efforts are limited to enormous, bright planets. These worlds are typically super-Jupiters that are less than 100 million years old – so young that they glow brightly thanks to heat left over from their formation, which makes them detectable in infrared light. They also tend to be very far away from their host stars because it’s easier to block the star’s light and see planets in more distant orbits. The Roman Coronagraph could complement other telescopes’ infrared observations by imaging young super-Jupiters in visible light for the first time, according to a study by a team of scientists.

But astronomers would also like to directly image planets that are similar to our own one day – rocky, Earth-sized planets orbiting Sun-like stars within their habitable zones, the range of orbital distances where temperatures allow liquid water to exist on a planet’s surface. To do so, astronomers need to be able to see smaller, cooler, dimmer planets orbiting much closer to their host stars than current telescopes can. By photographing worlds in visible light, Roman will be able to image mature planets spanning ages up to several billion years – something that has never been done before.

“To image Earth-like planets, we’ll need 10,000 times better performance than today’s instruments provide,” said Vanessa Bailey, an astronomer at JPL and the instrument technologist for the Roman Coronagraph. “The Coronagraph Instrument will perform several hundred times better than current instruments, so we will be able to see Jupiter-like planets that are more than 100 million times fainter than their host stars.”

A team of scientists recently simulated a promising target for Roman to image, called Upsilon Andromedae d. “This gas giant exoplanet is slightly larger than Jupiter, orbits within a Sun-like star’s habitable zone, and is relatively close to Earth – just 44 light-years away,” said Prabal Saxena, an assistant research scientist at the University of Maryland, College Park and NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and the lead author of a paper describing the results. “What’s really exciting is that Roman may be able to help us explore hazes and clouds in Upsilon Andromedae d’s atmosphere and may even be able to act as a planetary thermometer by putting constraints on the planet’s internal temperature!”

The Coronagraph Instrument will contain several state-of-the-art components that have never flown aboard a space-based observatory before. For example, it will use specially designed coronagraph masks to block the glare from host stars but allow the light from dimmer, orbiting planets to filter through. These masks have innovative, complex shapes that block starlight more effectively than traditional masks.

The Roman Coronagraph will also be equipped with deformable mirrors, which help counteract small imperfections that reduce image quality. These special mirrors will measure and subtract starlight in real time, and technicians on the ground can also send commands to the spacecraft to adjust them. This will help counteract effects like temperature changes, which can slightly alter the shape of the optics.

Using this technology, Roman will observe planets so faint that special detectors will count individual photons of light as they arrive, seconds or even minutes apart. No other observatory has done this kind of imaging in visible light before, providing a vital step toward discovering habitable planets and possibly learning whether we are alone in the universe.

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

Download high-resolution video and images from NASA’s Scientific Visualization Studio

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Spitzer Illuminates Exoplanets in Astronomical Society Briefing

5 min read

The infrared observatory may help answer questions about planets outside our solar system, or exoplanets, including how they form and what drives weather in their atmospheres.

Two new studies using data from NASA’s retired Spitzer Space Telescope shed light on giant exoplanets and brown dwarfs, objects that aren’t quite stars but aren’t quite planets either. Both studies will be the focus of virtual news conferences hosted by the American Astronomical Society on Jan. 13.

One investigation shows that the weather on brown dwarfs – which form like stars but don’t have sufficient mass to start burning hydrogen in their cores as stars do – varies with age. Brown dwarfs and giant exoplanets are similar in diameter, mass, and composition, so understanding the atmospheric properties of one can provide insights about those of the other.

The second study belongs to a body of work looking at hot Jupiters – gas exoplanets that orbit extremely close to their parent stars. How do these massive planets come to be, and could there be subclasses of hot Jupiters with different formation stories? To look for answers, the study authors looked at exoplanet XO-3b, a rare example of a hot Jupiter observed while migrating closer to its host star.

Age often brings stability in humans, and that appears to be true for cosmic objects as well. Johanna Vos, an astrophysicist at the American Museum of Natural History in New York, will discuss a Spitzer survey published in the Astrophysical Journal that found higher variability in the weather on young brown dwarfs compared to old ones.

With regard to brown dwarfs, the word variability refers to short-term changes in the intensity of different wavelengths of infrared light coming from the object’s atmosphere. Astronomers think these variations are caused by clouds, which reflect and absorb light in the atmosphere.

High variability might indicate a major atmospheric feature, perhaps like Jupiter’s Great Red Spot – a storm larger than Earth that’s been swirling for hundreds of years. It can also indicate a rapidly changing atmosphere, which can have multiple causes such as major temperature differences in the atmosphere or turbulence (sometimes caused by powerful winds).

Comparing the young brown dwarfs to previous Spitzer observations of older brown dwarfs, the authors found that the young objects are more likely to show atmospheric variation. They also found that variations are larger and more dramatic in younger brown dwarfs. Vos and her colleagues attribute the difference to the fact that brown dwarfs are puffier when they’re young but become more compact as they age, which likely makes the atmosphere appear more uniform.

Young brown dwarfs are similar in diameter, mass, and composition to giant exoplanets primarily made of gas. But studying large exoplanets is complicated by the close presence of their parent stars: The companion irradiates the planet’s atmosphere, which changes the temperature, or even the chemistry, and affects the weather. The bright light from the star also makes seeing the much fainter planet more difficult.

Brown dwarfs, on the other hand, can act as a sort of control group and be observed in isolation in space. The study’s authors plan to incorporate the new finding into models of how brown dwarf and giant exoplanet atmospheres evolve with age.

Though hot Jupiters are the most studied type of exoplanet, major questions remain about how they form. For example, do these planets take shape far from their parent stars – at a distance where it's cold enough for molecules such as water to become solid – or closer? The first scenario fits better with theories about how planets in our own solar system are born, but what would drive these types of planets to migrate so close to their parent stars remains unclear.

Lisa Dang, an exoplanet scientist at McGill University in Montreal, and her colleagues used Spitzer data to study an exoplanet named XO-3b, which has an eccentric (oval) orbit rather than the circular orbit of almost all other known hot Jupiters. The eccentric orbit indicates XO-3b may have recently migrated toward its parent star; if that's the case, it will eventually settle into a more circular orbit.

Observations by Gaia, an ESA (European Space Agency) space observatory, and Spitzer both suggest the planet produces some of its own heat, but scientists don't know why. The Spitzer data also provides a map of the placessnet's climate patterns. It's possible that the excess warmth is coming from the planet's interior, through a pro called tidal heating. The star's gravitational squeeze on the planet oscillates as the irregular orbit takes the planet farther and then closer to the star. The resulting changes in interior pressure produce heat.

For Dang, an unusual hot Jupiter provides an opportunity to test ideas about which formation processes may produce certain characteristics in these exoplanets. For example, could tidal heating in other hot Jupiters also be a sign of recent migration? XO-3b alone won't solve the mystery, but it serves as an important test for emerging ideas about these scorching giants.

The entire body of scientific data collected by Spitzer during its lifetime is available to the public via the Spitzer data archive, housed at the Infrared Science Archive at IPAC at Caltech in Pasadena, California. NASA's Jet Propulsion Laboratory in Southern California managed the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington.

Science operations were conducted at the Spitzer Science Center at IPAC. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado.

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

2022-003

How NASA in Silicon Valley Will Use Webb to Study Distant Worlds

6 min read

NASA’s James Webb Space Telescope gives scientists new tools to search for the building blocks of life on distant planets

NASA’s James Webb Space Telescope is getting ready to give us the best view yet of worlds beyond our own solar system, commonly known as exoplanets. Scientists at NASA’s Ames Research Center in California’s Silicon Valley will be among the first to observe the cosmos with Webb, and they’re looking for clues about how exoplanets form, what they’re made of, and whether any could be potentially habitable.

On Jan. 24, 2022, the telescope reached its destination, an orbit about one million miles from Earth around a location called Sun-Earth Lagrange point 2, also known as L2. Now, Webb is one step closer to launching its scientific mission to transform our understanding of the universe.

Filling a Planetary Knowledge Gap

When we look for exoplanets, scientists often use the worlds we know best as reference – our own, and our neighbors in the solar system. But most planets out there aren’t quite like any of our neighbors.

“The diversity of planets we’ve discovered within the galaxy far exceeds the diversity of planets within our own solar system,” said Natasha Batalha, a research scientist at Ames who is a co-investigator on several Webb programs. “In our solar system, we have the inner rocky worlds and outer gas planets – but the most common exoplanets we see are actually in between.”

NASA’s James Webb Space Telescope Primed to Lift the Haze Surrounding Sub-Neptunes

Batalha’s team will use Webb to study 11 of those “in between” planets, larger than the Earth but smaller than Neptune, to learn more about how they formed and have evolved through time. Getting a basic sense of what this planetary population looks like – are they rocky, or made of gas? – is the start. Much of Ames’ exoplanet research enabled by Webb will be focused on that kind of basic knowledge-building, giving scientists more pieces to puzzle together what the population of planets beyond our solar system looks like and if such worlds could harbor potential life.

Thomas Greene, an astrophysicist at Ames who has contributed to the development of Webb’s instrumentation and analysis techniques for over 20 years, is leading a study on nine planets that are less massive and cooler than many studied by previous telescopes. His study will focus on the chemical makeup of the atmospheres surrounding those worlds, the abundances of heavier elements in their composition compared to their host stars, temperatures across each planet’s surface, and more.

Searching for Atmospheres and Potential Habitability

Another type of planet that is in need of further study are small rocky worlds in orbit around cool dwarf stars. These planets are often very close to their suns, but because their suns are small and cool, they lie within the habitable zone. However, very little is known about these worlds – including whether they are capable of maintaining atmospheres at all, let alone whether they could harbor life.

Largest batch of Earth-size, habitable zone planets

Though most of the worlds in Greene's study are made of gas, one is rocky – TRAPPIST-1b. It is the innermost planet in the TRAPPIST-1 system, a group of seven rocky, roughly Earth-sized planets that orbit close to a small, cool dwarf star. With so little known about the makeup of the planet, including if it has an atmosphere or not, the data gathered by Webb could reveal it to be a dead and barren world, or even one with the potential for hosting life.

"A planet's atmosphere is essential for the possibility of life as we know it," said Greene. "We've developed Webb's instruments to be able to give us the data we need to not only detect atmospheres, but to determine what they are made of."

Greene's team will be taking a close look at the spectrum of the planet – to see what kind of light it emits, which gives a view into its chemical composition. The study will focus on the planet's infrared emissions and search for signs of carbon dioxide. If there are signs an atmosphere is present, and especially carbon dioxide, then TRAPPIST-1b could have formed and evolved like the rocky planets in our own solar system that also have carbon dioxide – Venus, Earth, and Mars.

Batalha is also contributing to two Webb programs focused on characterizing five similar rocky worlds, including two in the same system – TRAPPIST-1h and TRAPPIST-1e, the latter of which is in the habitable zone. Those programs will determine how many of those worlds have atmospheres, and if they do, what they are made of. Many of Webb's targets are hundreds or even billions of light-years away, but some of the exoplanets closest to us are these same small, rocky worlds. Proxima Centauri, the star closest to us at just over four light-years away, is an M dwarf and potentially home to two such worlds. Learning about distant worlds could help us understand the prospects for habitability closer to home.

The Webb telescope is the largest astrophysical space observatory and the most technically complex science mission NASA has ever built.

"It's a humbling experience to be part of such a massive endeavor," said Batalha. "About 10,000 people have contributed to this telescope, and thousands more across over 400 institutions will be analyzing data from its first cycle. It's an amazing opportunity to get to do science on this scale."

The James Webb Space Telescope is the world's largest, most powerful, and most complex space science telescope ever built. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Learn more about Webb at: webb.nasa.gov nasa.gov/webb webbtelescope.org

Read more:

NASA's James Webb Space Telescope Primed to Lift the Haze Surrounding Sub-Neptunes

Largest batch of Earth-size, habitable zone planets

For news media:

Members of the news media interested in covering these topics should reach out to the NASA Ames newsroom.

Author: Frank Tavares, NASA's Ames Research Center

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Puffy Planets Lose Atmospheres, Become Super Earths

6 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Exoplanets come in shapes and sizes that are not found in our solar system. These include small gaseous planets called mini-Neptunes and rocky planets several times Earth's mass called super-Earths.

Now, astronomers have identified two different cases of "mini-Neptune" planets that are losing their puffy atmospheres and likely transforming into super-Earths. Radiation from the planets' stars is stripping away their atmospheres, driving the hot gas to escape like steam from a pot of boiling water. The new findings help paint a picture of how exotic worlds like these form and evolve, and help explain a curious gap in the size distribution of planets found around other stars.

Mini-Neptunes are smaller, denser versions of the planet Neptune in our solar system, and are thought to consist of large rocky cores surrounded by thick blankets of gas. In the new studies, a team of astronomers used NASA's Hubble Space Telescope to look at two mini-Neptunes orbiting HD 63433, a star located 73 light-years away. And they used the W. M. Keck Observatory in Hawaii to study one of two mini-Neptune planets in the star system called TOI 560, located 103 light-years away.

Their results show that atmospheric gas is escaping from the innermost mini-Neptune in TOI 560, called TOI 560.01 (also known as HD 73583b), and from the outermost mini-Neptune in HD 63433, called HD 63433c. This suggests that they could be turning into super-Earths.

"Most astronomers suspected that young, mini-Neptunes must have evaporating atmospheres," said Michael Zhang, lead author of both studies and a graduate student at Caltech. "But nobody had ever caught one in the process of doing so until now."

The study also found, surprisingly, that the gas around TOI 560.01 was escaping predominantly toward the star.

"This was unexpected, as most models predict that the gas should flow away from the star," said professor of planetary science Heather Knutson of Caltech, Zhang's advisor and a co-author of the study. "We still have a lot to learn about how these outflows work in practice."

Since the first exoplanets orbiting sun-like stars were discovered in the mid-1990s, thousands of other exoplanets have been found. Many of these orbit close to their stars, and the smaller, rocky ones generally fall into two groups: the mini-Neptunes and super-Earths. The super-Earths are as large as 1.6 times the size of Earth (and occasionally as large as 1.75 times the size of Earth), while the mini-Neptunes are between 2 and 4 times the size of Earth. Planets of these types are not found in our solar system. In fact, few planets with sizes between these two ranges have been detected around other stars.

One possible explanation for this size-gap is that the mini-Neptunes are transforming into the super-Earths. The mini-Neptunes are theorized to be cocooned by primordial atmospheres made of hydrogen and helium. The hydrogen and helium are left over from the formation of the central star, which is born out of clouds of gas. If a mini-Neptune is small enough and close enough to its star, stellar X-rays and ultraviolet radiation can strip away its primordial atmosphere over a period of hundreds of millions of years, scientists theorize. This would then leave behind a rocky super-Earth with a substantially smaller diameter (which could, in theory, still retain a relatively thin atmosphere similar to that surrounding our planet Earth).

"A planet in the size-gap would have enough atmosphere to puff up its radius, making it intercept more stellar radiation and thereby enabling fast mass loss," said Zhang. "But the atmosphere is thin enough that it gets lost quickly. This is why a planet wouldn't stay in the gap for long."

Other scenarios could explain the size-gap, according to the astronomers. For instance, the smaller rocky planets might have never gathered gas envelopes in the first place, and mini-Neptunes could be water worlds and not enveloped in hydrogen gas. This latest discovery of two mini-Neptunes with escaping atmospheres represents the first direct evidence to support the theory that mini-Neptunes are indeed turning into super-Earths.

The astronomers were able to detect the escaping atmospheres by watching the mini-Neptunes cross in front of, or transit, their host stars. The planets cannot be seen directly but when they pass in front of their stars as seen from our point of view on Earth, telescopes can look for absorption of starlight by atoms in the planets' atmospheres. In the case of the mini-Neptune TOI 560.01, the researchers found signatures of helium. For the star system HD 63433, the team found signatures of hydrogen in the outermost planet they studied, called HD 63433c, but not the inner planet, HD 63433b.

"The inner planet may have already lost its atmosphere," explained Zhang.

"The speed of the gases provides the evidence that the atmospheres are escaping. The observed helium around TOI 560.01 is moving as fast as 20 kilometers per second, while the hydrogen around HD 63433c is moving as fast as 50 kilometers per second. The gravity of these mini-Neptunes is not strong enough to hold on to such fast-moving gas. The extent of the outflows around the planets also indicates escaping atmospheres; the cocoon of gas around TOI 560.01 is at least 3.5 times as large as the radius of the planet, and the cocoon around HD 63433c is at least 12 times the radius of the planet."

The observations also revealed that the gas lost from TOI 560.01 was flowing toward the star. Future observations of other mini-Neptunes should reveal if TOI 560.01 is an anomaly or whether an inward-moving atmospheric outflow is more common.

"As exoplanet scientists, we've learned to expect the unexpected," Knutson said. "These exotic worlds are constantly surprising us with new physics that goes beyond what we observe in our solar system."

The findings are being published in two separate papers in The Astronomical Journal.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Release Credit: NASA, ESA, STScI, Caltech, Keck Observatory

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center301-286-1940

Ray VillardSpace Telescope Science Institute, Baltimore, Maryland

Whitney ClavinCalifornia Institute of Technology, Pasadena, California

Mari-Ela ChockW. M. Keck Observatory, Mauna Kea, Hawaii

Science Contacts:

Michael ZhangCalifornia Institute of Technology, Pasadena, California

Heather A. KnutsonCalifornia Institute of Technology, Pasadena, California

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Water Vapor Detected on a ‘Super Neptune’

3 min read

Alicia Cermak

The discovery: Water vapor in the atmosphere of planet TOI-674 b.

Key facts: This recently discovered planet, a bit bigger than Neptune and orbiting a red-dwarf star about 150 light-years away, places it in an exclusive club: exoplanets, or planets around other stars, known to have water vapor in their atmospheres. Many questions remain, such as how much water vapor its atmosphere holds. But TOI-674 b’s atmosphere is far easier to observe than those of many exoplanets, making it a prime target for deeper investigation.

Details: The planet’s distance, size and relationship to its star make it especially accessible to spaceborne telescopes. At 150 light-years, it’s considered “nearby” in astronomical terms. The star itself, relatively cool and less than half as big around as our Sun, can’t be seen from Earth with the naked eye, but this too translates into an advantage for astronomers. As the comparatively large planet – in a size-class known as “super Neptune” – crosses the face of its smallish star, starlight shining through its atmosphere can be more easily analyzed by our telescopes. Those equipped with special instruments called spectrographs – including the just-launched James Webb Space Telescope – can spread this light into a spectrum, revealing which gases are present in the planet’s atmosphere.

The discovery grew from a partnership between the tried-and-true Hubble Space Telescope and TESS, NASA’s Transiting Exoplanet Survey Satellite, launched in 2018. The planet was first found by TESS, then its light spectrum was measured by Hubble. Data from the now-retired Spitzer Space Telescope also helped astronomers tease out some of the planet’s atmospheric components. If the Webb telescope, once it’s up and running, is turned on TOI-674 b, it should be able to examine the planet’s atmosphere in far more detail.

Only three other Neptune-sized exoplanets have had aspects of their atmospheres revealed so far, though the advent of telescopes like Webb promises a golden age in the study of exoplanet atmospheres.

Fun facts: The new planet can claim membership in another exclusive group: inhabitants of the so-called “Neptune Desert.” TOI-674 b orbits its small star so tightly that a “year” on this planet, once around the star, takes less than two days. But among the thousands of exoplanets confirmed in our galaxy so far, a strange pattern has emerged: Planets in the size-class between Neptune and Jupiter are extremely rare in orbits of three days or less. The rarity of such planets, and the analysis of those that do turn up, could provide important clues to the formation of planetary systems in general – including our own.

The discoverers: An international team of scientists, led by Jonathan Brande of the University of Kansas, contributed to the new study of water vapor on TOI-674 b, which has been submitted to an academic journal. They included researchers from the NASA Ames Research Center and from IPAC and other research centers at Caltech.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: 172 Possible Planets? A New Roadmap to Distant Worlds

4 min read

Alicia Cermak

The discovery: A new catalog of exoplanets – planets around other stars – includes 172 previously unknown planet candidates, as well as 18 possible multi-planet systems that also are newly identified. A fully automated exoplanet-detection system sifted through years of data from NASA's retired Kepler Space Telescope, yielding a torrent of discoveries; scientists will use the resulting catalog to reveal secrets of exoplanet formation and to sharpen our picture of their many varieties.

Key facts: The Kepler Space Telescope, which was shut down in 2018 after running dry of fuel, explored the galaxy for nine years and found thousands of exoplanets. More than 2,800 have been confirmed; and more than 3,250 candidate planets await confirmation, including the latest batch of 172 candidates. Hundreds of these candidates were detected during Kepler's second mission, known as K2, after mechanical failure ended the first mission and sharply limited observing capability for the second. Even with those limits, Kepler continued to rack up exoplanet discoveries.

Details: The new catalog, drawn from Kepler's K2 observations, includes some truly bizarre planets and planetary systems. In one system (EPIC 249559552) about 650 light-years away, two "sub-Neptunes" – smaller versions of our own Neptune – orbit a yellow-white, Sun-like star. The planets are locked in a kind of gravitational dance, known as orbital resonance, with the inner planet making five orbits for every two by the outer planet.

In another system some 3,500 light-years distant, EPIC 249731291, a star not unlike our Sun hosts two gas giants, a bit smaller than Saturn, orbiting their star so closely that their atmospheres are perpetual infernos. Placed in our solar system, these two giants would be inside the orbit of Mercury, the closest planet to our Sun. Two giant planets in such a tight orbit around their star could reveal important clues about how planets form, and possibly how they migrate from one orbit to another during the long lives of planetary systems.

Fun facts: The new catalog, which includes a total of 747 planet candidates and 57 possible multi-planet systems, will allow scientists to conduct "demographic" studies – identifying populations of exoplanets with shared characteristics, how frequently they occur in the galaxy, and the relations of these many planet types to one other. Such an exoplanet "census" could reveal patterns in how planetary systems form, and how they change over time, including giant gas planets migrating from distant orbits into closer orbits around their stars. Some planet types might be found more frequently around certain types of stars, such as red-dwarfs, or yellow stars like our Sun.

The new catalog also might reveal formation patterns for the galaxy as a whole. Kepler's first mission focused on a single patch of sky above the galactic plane – the narrow, disk-like region where a greater abundance of stars orbits the center of the galaxy. The second mission, K2, was confined to the ecliptic plane, where the planets in our system orbit the Sun, but was able to observe a series of sections around the plane instead of a single patch. Does the distribution of planets look different above the galactic plane than in a different direction? That could tell us whether certain planet types, say small, rocky worlds like our own, are more plentiful or more rare in different parts of the galaxy.

The discoverers: The new exoplanet catalog was compiled by a team of astronomers led by Jon K. Zink of the University of California, Los Angeles, and including Kevin K. Hardegree-Ullman, Jessie L. Christiansen, and Sakhee Bhure of the Caltech/IPAC-NASA Exoplanet Science Institute in Pasadena, California. The other co-authors were Britt Duffy Adkins of the University of Southern

California, Los Angeles, Erik A. Petigura of UCLA, Courtney D. Dressing of the University of California, Berkeley, Ian J. M. Crossfield of the University of Kansas, and Joshua E. Schlieder of the NASA Goddard Space Flight Center in Greenbelt, Maryland.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New Deep Learning Method Adds 301 Planets to Kepler’s Total Count

4 min read

Scientists recently added a whopping 301 newly validated exoplanets to the total exoplanet tally. The throng of planets is the latest to join the 4,569 already validated planets orbiting a multitude of distant stars. How did scientists discover such a huge number of planets, seemingly all at once? The answer lies with a new deep neural network called ExoMiner.

Deep neural networks are machine learning methods that automatically learn a task when provided with enough data. ExoMiner is a new deep neural network that leverages NASA’s Pleiades supercomputer, and can distinguish real exoplanets from different types of imposters, or “false positives.” Its design is inspired by various tests and properties human experts use to confirm new exoplanets. And it learns by using past confirmed exoplanets and false positive cases.

ExoMiner supplements people who are pros at combing through data and deciphering what is and isn’t a planet. Specifically, data gathered by NASA’s Kepler spacecraft and K2, its follow-on mission. For missions like Kepler, with thousands of stars in its field of view, each holding the possibility to host multiple potential exoplanets, it’s a hugely time-consuming task to pore over massive datasets. ExoMiner solves this dilemma.

“Unlike other exoplanet-detecting machine learning programs, ExoMiner isn’t a black box – there is no mystery as to why it decides something is a planet or not,” said Jon Jenkins, exoplanet scientist at NASA’s Ames Research Center in California’s Silicon Valley. “We can easily explain which features in the data lead ExoMiner to reject or confirm a planet.”

What is the difference between a confirmed and validated exoplanet? A planet is “confirmed,” when different observation techniques reveal features that can only be explained by a planet. A planet is “validated” using statistics – meaning how likely or unlikely it is to be a planet based on the data.

In a paper accepted for publication in The Astrophysical Journal, the team at Ames shows how ExoMiner discovered the 301 planets using data from the remaining set of possible planets – or candidates – in the Kepler Archive. All 301 machine-validated planets were originally detected by the Kepler Science Operations Center pipeline and promoted to planet candidate status by the Kepler Science Office. But until ExoMiner, no one was able to validate them as planets.

The paper also demonstrates how ExoMiner is more precise and consistent in ruling out false positives and better able to reveal the genuine signatures of planets orbiting their parent stars – all while giving scientists the ability to see in detail what led ExoMiner to its conclusion.

“When ExoMiner says something is a planet, you can be sure it’s a planet,” added Hamed Valizadegan, ExoMiner project lead and machine learning manager with the Universities Space Research Association at Ames. “ExoMiner is highly accurate and in some ways more reliable than both existing machine classifiers and the human experts it’s meant to emulate because of the biases that come with human labeling.”

None of the newly confirmed planets are believed to be Earth-like or in the habitable zone of their parent stars. But they do share similar characteristics to the overall population of confirmed exoplanets in our galactic neighborhood.

“These 301 discoveries help us better understand planets and solar systems beyond our own, and what makes ours so unique,” said Jenkins.

As the search for more exoplanets continues – with missions using transit photometry such as NASA’s Transiting Exoplanet Survey Satellite, or TESS, and the European Space Agency’s upcoming PLAnetary Transits and Oscillations of stars, or PLATO, mission – ExoMiner will have more opportunities to prove it’s up to the task.

“Now that we’ve trained ExoMiner using Kepler data, with a little fine-tuning, we can transfer that learning to other missions, including TESS, which we’re currently working on,” said Valizadegan. “There’s room to grow.”

NASA’s Ames Research Center in California’s Silicon Valley managed the Kepler and K2 missions for NASA’s Science Mission Directorate. NASA’s Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation in Boulder, Colorado, operated the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New Deep Learning Method Adds 301 Planets to Kepler's Total Count

4 min read

NASA Science Editorial Team

Rachel Hoover

Scientists recently added a whopping 301 newly validated exoplanets to the total exoplanet tally. The throng of planets is the latest to join the 4,569 already validated planets orbiting a multitude of distant stars. How did scientists discover such a huge number of planets, seemingly all at once? The answer lies with a new deep neural network called ExoMiner.

Deep neural networks are machine learning methods that automatically learn a task when provided with enough data. ExoMiner is a new deep neural network that leverages NASA's supercomputer, Pleiades, and can distinguish real exoplanets from different types of imposters, or "false positives." Its design is inspired by various tests and properties human experts use to confirm new exoplanets. And it learns by using past confirmed exoplanets and false positive cases.

ExoMiner supplements people who are pros at combing through data and deciphering what is and isn't a planet. Specifically, data gathered by NASA's Kepler spacecraft and K2, its follow-on mission. For missions like Kepler, with thousands of stars in its field of view, each holding the possibility to host multiple potential exoplanets, it's a hugely time-consuming task to pore over massive datasets. ExoMiner solves this dilemma.

"Unlike other exoplanet-detecting machine learning programs, ExoMiner isn't a black box – there is no mystery as to why it decides something is a planet or not," said Jon Jenkins, exoplanet scientist at NASA's Ames Research Center in California's Silicon Valley. "We can easily explain which features in the data lead ExoMiner to reject or confirm a planet."

What is the difference between a confirmed and validated exoplanet? A planet is "confirmed," when different observation techniques reveal features that can only be explained by a planet. A planet is "validated" using statistics – meaning how likely or unlikely it is to be a planet based on the data.

In a paper accepted for publication in The Astrophysical Journal, the team at Ames shows how ExoMiner discovered the 301 planets using data from the remaining set of possible planets – or candidates – in the Kepler Archive. All 301 machine-validated planets were originally detected by the Kepler Science Operations Center pipeline and promoted to planet candidate status by the Kepler Science Office. But until ExoMiner, no one was able to validate them as planets.

The paper also demonstrates how ExoMiner is more precise and consistent in ruling out false positives and better able to reveal the genuine signatures of planets orbiting their parent stars – all while giving scientists the ability to see in detail what led ExoMiner to its conclusion.

"When ExoMiner says something is a planet, you can be sure it's a planet," added Hamed Valizadegan, ExoMiner project lead and machine learning manager with the Universities Space Research Association at Ames. "ExoMiner is highly accurate and in some ways more reliable than both existing machine classifiers and the human experts it's meant to emulate because of the biases that come with human labeling."

None of the newly confirmed planets are believed to be Earth-like or in the habitable zone of their parent stars. But they do share similar characteristics to the overall population of confirmed exoplanets in our galactic neighborhood.

"These 301 discoveries help us better understand planets and solar systems beyond our own, and what makes ours so unique," said Jenkins.

As the search for more exoplanets continues – with missions using transit photometry such as NASA's Transiting Exoplanet Survey Satellite, or TESS, and the European Space Agency's upcoming PLAnetary Transits and Oscillations of stars, or PLATO, mission – ExoMiner will have more opportunities to prove it's up to the task.

"Now that we've trained ExoMiner using Kepler data, with a little fine-tuning, we can transfer that learning to other missions, including TESS, which we're currently working on," said Valizadegan. "There's room to grow."

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s James Webb Space Telescope Primed to Lift the Haze Surrounding Sub-Neptunes

6 min read

More than half of the Sun-like star systems surveyed in the Milky Way harbor a mysterious type of planet unlike any in our own solar system.

Larger than Earth, smaller than Neptune, and orbiting closer to their stars than Mercury orbits the Sun, these warm-to-hot sub-Neptunes are the most common type of planet observed in the galaxy. But although researchers have been able to measure basic properties – including size, mass, and orbit – of hundreds of these planets, their fundamental nature remains unclear.

Are they dense, Earth-like balls of rock and iron, blanketed in thick layers of hydrogen and helium gas? Or less dense mixtures of rock and ice, surrounded by steamy, water-rich atmospheres? With limited data and no planets of similar size and orbit in our own solar system to use for comparison, it has been difficult to answer these questions.

“What are these planets? How do they form? Why doesn’t our solar system have them? These are fundamental questions,” explains Jacob Bean, an astronomer at the University of Chicago who has led numerous observations of exoplanets.

The key to figuring out what sub-Neptunes are made of and how they formed is examining their atmospheres. But getting a clear view has not been easy.

The most effective method of analyzing exoplanet atmospheres is a technique known as transmission spectroscopy. When the planet is transiting its star, some wavelengths (colors) of starlight are filtered out by gases in the planet’s atmosphere. Because each type of gas has a unique “signature,” or set of wavelengths that it absorbs, it’s possible to figure out what an atmosphere is made of based on patterns in the transmission spectrum.

This technique has been successful for many exoplanets, but not for most sub-Neptunes. “There have been very few atmospheric observations of sub-Neptune planets,” explains Eliza Kempton of the University of Maryland–College Park, who specializes in theoretical modeling of exoplanet atmospheres. “And most of those have been dissatisfying in that the spectra have not revealed much in the way of spectral features that would allow us to identify the gases in the atmosphere.”

The issue seems to be aerosols, tiny particles and droplets that make up clouds or haze. These particles scatter starlight, eroding the prominent spectral peaks into subtle undulations and rendering the spectrum virtually useless in terms of determining gas composition.

But with Webb, researchers are confident that a much clearer view of sub-Neptunes is on the horizon. Two observation programs co-led by Bean and Kempton and scheduled for the first year of Webb operations will use Webb’s uniquely powerful capabilities to probe two sub-Neptune-sized planets: GJ 1214 b, the archetype sub-Neptune; and TOI-421 b, a more recent discovery.

GJ 1214 b, a warm sub-Neptune orbiting a nearby red dwarf star, has been the subject of dozens of investigations. Its short orbital period, large size relative to its star, and comparative proximity to Earth make it easy (as exoplanets go) to observe effectively, while its status as the benchmark sub-Neptune – and, according to Bean, “the most mysterious exoplanet that we know of” – make it a worthy target of investigation.

The team will use Webb’s Mid-Infrared Instrument (MIRI) to stare at the GJ 1214 system nearly continuously for nearly 50 hours as the planet completes a little more than one full orbit. They will then analyze the data in three different ways to narrow down the possible combinations of gases and aerosols that make up GJ 1214 b's atmosphere.

It's not clear what the aerosols surrounding warm sub-Neptunes like GJ 1214 b are made of, but they could be similar to those that make up smog-like haze found on Saturn's moon Titan. To test this hypothesis, the researchers decided to target TOI-421 b, a planet that is similar in size and density to GJ 1214 b but is thought to be too hot for sooty haze to exist.

Webb will observe TOI-421 b twice as it transits its star, once using the Near-Infrared Imager and Slitless Spectrograph (NIRISS) and again with the Near-Infrared Spectrograph (NIRSpec), to produce a complete near-infrared transmission spectrum of the planet. If the hypothesis is correct and TOI-421 b's skies are clear, the spectrum can be used to measure the abundance of molecules like water, methane, and carbon dioxide. If it turns out that TOI-421 b has an aerosol problem after all, the team will use the data to better understand what those aerosols are made of.

Kempton and Bean are confident that by probing elusive sub-Neptune atmospheres in a number of different ways with Webb, scientists will finally begin to understand not just these two specific objects, but an entire class of planets.

Both the MIRI observations of GJ 1214 b and the NIRISS and NIRSpec observations of TOI-421 b will be conducted as part of Webb's Cycle 1 General Observers program. General Observers programs were competitively selected using a dual-anonymous review system, the same system used to allocate time on Hubble.

The James Webb Space Telescope will be the world's premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency), and the Canadian Space Agency.

By Margaret CarruthersSpace Telescope Science Institute, Baltimore, Md.

Media contact: Laura BetzNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: A Giant Planet and Three Eclipses

4 min read

Alicia Cermak

The planet: TIC 172900988 b

The discovery: A newly discovered planet about as big around as Jupiter belongs to a system that's a stunner. The planet orbits two stars and, viewed from Earth, crosses the faces of both. That means this system put on quite a show for astronomers: They observed the two stars make a total of three eclipses, while the planet traced its way across one star and then, a few days later, across the other.

Key facts: Planetary transits – when a planet crosses its star's face – are a major path to the discovery of exoplanets, or planets around other stars. Space telescopes like NASA's TESS, the Transiting Exoplanet Survey Satellite, scan thousands of stars at a time, hunting for the tiny dip in starlight when an orbiting planet crosses the face of its parent star. TESS has discovered more than 150 confirmed exoplanets since its launch in 2018, including the new giant, and nearly 3,500 exoplanet candidates awaiting further confirmation.

Details: Worlds that orbit two stars are known as "circumbinary" planets because they orbit "binary" stars, or stars in orbit around each other. Finding transiting circumbinaries is quite rare; TESS's predecessor, the now retired Kepler Space Telescope, yielded discoveries of thousands of exoplanets, but only around a dozen circumbinary planets. The new planet, TIC 172900988 b, is a gas giant the size of our own Jupiter, though far more massive. It orbits two Sun-like stars that, in turn, orbit each other.

But even among circumbinaries, this discovery stands out. Its year, once around the two stars, takes about 200 days. That would normally present a big challenge to astronomers trying to figure out the dynamics of this system; they would have to wait 200 days, for example, to see another transit and confirm the planet's orbital period. But TESS makes its observations sector by sector; in this case the scientists had only 30 days of observations of the circumbinary planetary system before TESS moved on to another patch of sky.

Thanks to the configuration of these stars and their planet, and the advantages of our angle of view from Earth, astronomers had most of the information they needed. The three eclipses could be observed as part of the 20-day orbit of the stars around each other; and the scientists saw only a five-day gap between the planet's transit of the first star and the second one.

This was the first time a science team was able to calculate such intricate orbital motions from such a limited amount of data.

And high-resolution imaging in the near-infrared part of the light spectrum revealed what might be a third star in this system. The star would have a very long orbit – about 5,000 years – encircling both stars and the newly discovered planet. This ultra-cool star has a low mass (or heft), less than 10 percent of the other two stars and only 30 times more massive than the giant planet.

Fun facts: The same day the dynamic new system was entered into NASA's Exoplanet Archive, on Sept. 10, it had some extraordinary company: a strange new world called TOI-1518 b. This planet is an "ultra-hot Jupiter," strange enough in its own right, because such worlds make scorchingly tight orbits around their stars. A year on this planet takes just 1.9 days. Now add an extremely weird shape to that orbit. The orbit is sharply angled compared to the axis of the star's spin, and it gets weirder: the planet also orbits in the opposite direction from the star's rotation. TESS continues, it seems, to capture evidence not only of bizarre planets, but bizarre planetary systems as well.

The discoverers: An international science team led by Veselin B. Kostov, of NASA’s Goddard Space Flight Center, discovered the transiting circumbinary planet, TIC 172900988 b. The ultra-hot Jupiter with the wild orbit, TOI-1518 b, was confirmed using TESS data by another international team, this one led by Samuel H.C. Cabot of Yale University.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Are We Alone in the Universe? NASA Calls for New Framework

9 min read

How do we understand the significance of new scientific results related to the search for life? When would we be able to say, “yes, extraterrestrial life has been found?”

NASA scientists are encouraging the scientific community to establish a new framework that provides context for findings related to the search for life. Writing in the journal Nature, they propose creating a scale for evaluating and combining different lines of evidence that would ultimately lead to answering the ultimate question: Are we alone in the universe?

In the new article led by Jim Green, the agency’s chief scientist, a NASA group offers a sample scale to use as a starting point for discussions among anyone who would use it, such as scientists and communicators. They envision a scale informed by decades of experience in astrobiology, a field that probes the origins of life on Earth and possibilities of life elsewhere.

“Having a scale like this will help us understand where we are in terms of the search for life in particular locations, and in terms of the capabilities of missions and technologies that help us in that quest,” Green said.

The scale contains seven levels, reflective of the winding, complicated staircase of steps that would lead to scientists declaring they’ve found life beyond Earth. As an analogy, Green and colleagues point to the Technology Readiness Level scale, a system used inside NASA to rate how ready a spacecraft or technology is to fly. Along this spectrum, cutting-edge technologies such as the Mars helicopter Ingenuity begin as ideas and develop into rigorously tested components of history-making space missions.

The authors hope that in the future, scientists will note in published studies how their new astrobiology results fit into such a scale. Journalists could also refer to this kind of framework to set expectations for the public in stories about new scientific results, so that small steps don’t appear to be giant leaps.

“Until now, we have set the public up to think there are only two options: it’s life or it’s not life,” said Mary Voytek, head of NASA’s Astrobiology Program in at NASA Headquarters in Washington and study co-author. “We need a better way to share the excitement of our discoveries, and demonstrate how each discovery builds on the next, so that we can bring the public and other scientists along on the journey.”

It’s exciting each time a rover or orbiter finds proof that water once flowed on Mars. Each new finding shows us that Mars’ past climate was similar to Earth’s, and the red planet could have once supported life. But that doesn’t necessarily mean any sort of life ever lived there, or that anything lives there now. Discoveries of rocky planets orbiting stars beyond our Sun, especially those that could harbor liquid water on their surfaces, are similarly tantalizing, but not proof by themselves of life beyond Earth. So how do we understand these observations in context?

All of science is a process of asking questions, coming up with hypotheses, developing new methods to look for clues, and ruling out all alternative explanations. Any individual detection may not be completely explained by a biological process, and must be confirmed through follow-up measurements and independent investigations. Sometimes, there are problems with the instruments themselves. Other times, experiments don’t turn up anything at all, but still deliver valuable information about what doesn’t work or where not to look.

Astrobiology is no different. The field pursues some of the most profound questions that anyone could ask, regarding our origins and place in the universe. As scientists learn more and more about what kinds of signals are associated with life in diverse environments on Earth, they can create and improve upon technologies needed to find similar signs elsewhere.

While the exact details of the scale will evolve as scientists, communicators, and others weigh in, the Nature article offers a starting point for discussion.

At the first step of the scale, “level 1,” scientists would report hints of a signature of life, such as a biologically relevant molecule. An example would be a future measurement of some molecule on Mars potentially related to life. Moving up to “level 2,” scientists would ensure that the detection was not influenced by the instruments having been contaminated on Earth. At “level 3” they would show how this biological signal is found in an analog environment, such as an ancient lakebed on Earth similar to the Perseverance rover’s landing site, Jezero Crater.

To add evidence to the middle of the scale, scientists would supplement those initial detections with information about whether the environment could support life, and rule out non-biological sources. For Mars in particular, samples returned from Mars could help make this kind of progress. Perseverance will soon be collecting and storing samples with the goal of a future mission returning them one day. Since different teams on Earth would have the opportunity to independently verify hints of life in Mars samples with a variety of instruments, the combination of their evidence could achieve “level 6,” the second highest step on the scale. But in this example, to reach level 7, the standard by which scientists would be most sure they had detected life on Mars, an additional mission to a different part of Mars may be required.

“Achieving the highest levels of confidence requires the active participation of the broader scientific community,” the authors write.

This scale would apply to discoveries from beyond the solar system, too. Exoplanets, planets outside our solar system, are believed to outnumber the 300 billion stars in the Milky Way. But small, rocky planets are harder to study from afar than gas giants. Future missions and technologies would be necessary to analyze the atmospheres of Earth-size planets with Earth-like temperatures receiving adequate amounts of starlight for life as we know it. The James Webb Space Telescope, launching later this year, is the next big advance in this area. But it will likely take an even more sensitive telescope to detect the combination of molecules that would indicate life.

Detecting oxygen in the atmosphere of an exoplanet, a planet outside our solar system, would be a significant step in the process of searching for life. We associate oxygen with life because it is made by plants and we breathe it, but there are also geological processes that generate oxygen, so it is not proof by itself of life. To move upward on the scale, a mission team could demonstrate that the oxygen signal was not being contaminated by light reflected from Earth and study the chemistry of the planet’s atmosphere to rule out the geological explanation. Additional evidence of an environment that supports life, such as an ocean, would bolster the case that this hypothetical planet is inhabited.

Scientists who study exoplanets are eager to find both oxygen and methane, a combination of gases in Earth’s atmosphere indicative of life. Because these gases would lead to reactions that cancel each other out unless there are biological sources of both present, finding both would be a key “level 4” milestone.

To reach level 5, astronomers would need a second, independent detection of some hint of life, such as global images of the planet with colors suggestive of forests or algae. Scientists would need additional telescopes or longer-term observations to be sure they had found life on an exoplanet.

Study authors emphasize that the scale should not be seen as a race to the top. The scale emphasizes the importance of the groundwork that many NASA missions lay without directly detecting possible biological signals, such as in characterizing environments on other planetary bodies.

Upcoming missions such as Europa Clipper, an orbiter headed for Jupiter’s icy moon Europa later this decade, and Dragonfly, an octocopter that will explore Saturn’s moon Titan, will provide vital information about the environments in which some form of life may one day be found.

“With each measurement, we learn more about both biological and nonbiological planetary processes,” Voytek said. “The search for life beyond Earth requires broad participation from the scientific community and many kinds of observations and experiments. Together, we can be stronger in our efforts to look for hints that we are not alone.”

Learn more about the NASA Astrobiology Program at https://astrobiology.nasa.gov

Written by Elizabeth Landau

NASA Headquarters

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Are We Alone in the Universe? NASA Calls for New Framework

NASA Science Editorial Team

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

To Find Life on Other Planets, NASA Rocket Team Looks to the Stars

5 min read

UPDATE Nov. 8, 2021: The Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet host stars, or SISTINE-2 mission, was launched on a Black Brant IX sounding rocket at 2:25 a.m. MST (4:25 a.m. EST) Nov. 8 from the White Sands Missile Range in New Mexico. The payload flew to an altitude of 160 miles before descending by parachute and landing at White Sands. Preliminary indications are that good data was received.

A NASA sounding rocket will observe a nearby star to learn how starlight affects the atmospheres of exoplanets – key information in the hunt for life outside our solar system.

Using an updated instrument first launched in 2019, the mission has a new target: Procyon A, the brightest star in the constellation Canis Minor. But its question remains the same: How does a star's light affect potential signs of life on planets that orbit it?

The Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet host stars, or SISTINE-2, mission will have its first opportunity to launch from the White Sands Missile Range in New Mexico on Nov. 8.

Answering the question of whether life exists elsewhere in the universe is beset with technical challenges. We can't yet travel to planets around other stars, called exoplanets, to see for ourselves. Nor are our telescopes powerful enough to see their surfaces.

Instead, astronomers look to an exoplanet's atmosphere, scouring it for traces of chemicals associated with life. Water, methane, oxygen, ozone, and other so-called biomarkers produce unique patterns of light that telescopes can detect from afar. But to interpret them correctly, astronomers must look to the planet's star.

"The interplay between the planet's atmosphere and ultraviolet light from the host star determines which gases serve as the best biomarkers," said Kevin France, an astrophysicist at the University of Colorado Boulder and the principal investigator for the mission.

Some ultraviolet (UV) wavelengths, for instance, can break down carbon dioxide, freeing a single oxygen atom to combine with others and form molecular oxygen (made of two oxygen atoms) or ozone (made of three). Stars that shed enough of this light can create spurious biomarkers on their planets, sending astronomers searching in the wrong places.

The SISTINE team aims to avoid this quandary by creating a guide to the wavelengths each kind of star emits. There are many different types of stars, and we don't yet have a complete picture of their light output or how it varies over time. With a catalog of starlight, scientists could estimate if a detected biomarker is either a potential sign of life or a false signal cooked up by pesky starlight.

On its upcoming flight, SISTINE-2 will observe Procyon A, some 11.5 light-years away. Procyon A is an F-type star, which is slightly larger, hotter, and brighter than our Sun. Though it does not have any known exoplanets, studying Procyon A can help us understand F-type stars and their exoplanets throughout the universe.

"Knowing the ultraviolet spectra of these stars will help us find the most promising star-planet environments with future NASA observatories," France said.

SISTINE-2 comprises a telescope and an instrument known as a spectrograph, which breaks light into its separate colors. SISTINE-2 will focus on ultraviolet light from 100 to 160 nanometers, a range that includes wavelengths known to produce false positive biomarkers. By combining their data with existing observations of X-ray, extreme ultraviolet, and visible light from other F-type stars, the team hopes to assemble a reference spectrum that will help astronomers interpret biomarkers on exoplanets orbiting F-type stars.

SISTINE-2 is also testing hardware. Before its 2019 flight, the team applied an enhanced lithium fluoride optical coating to the instrument's mirrors to improve its UV reflectivity. The results some three years later help evaluate whether this specialized coating may be suitable for larger, longer-duration space missions.

As in its 2019 flight, the instrument will launch on a sounding rocket, a small suborbital rocket that makes brief observations in space before falling back to Earth. Ascending to an estimated altitude of about 174 miles (280 kilometers) to access ultraviolet light otherwise absorbed by our atmosphere, SISTINE-2 will observe Procyon A for about five minutes. The instrument will then fall back to Earth, descending by parachute for recovery and refurbishing.

The team hopes for a soft landing to aid in a quick turnaround to be ready for its third launch in July 2022, from the Arnhem Space Centre in Nhulunbuy, Australia. There, a refurbished SISTINE instrument will observe Alpha Centauri A and B, G- and K-type stars, respectively, similar to and slightly cooler than our Sun, and the closest such stars to us. This system is also home to Proxima Centauri, a cool red dwarf star orbited by the closest known exoplanet, Proxima B. These observations will add additional entries to the growing star catalog – small but critical steps in the search for life.

Related:

By Miles HatfieldNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

First Evidence of a Planet Identified Beyond Our Galaxy

6 min read

NASA Science Editorial Team

Signs of a planet transiting a star outside of the Milky Way galaxy may have been detected for the first time. This intriguing result, using NASA's Chandra X-ray Observatory, opens up a new window to search for exoplanets at greater distances than ever before.

The possible exoplanet candidate is located in the spiral galaxy Messier 51 (M51), also called the Whirlpool Galaxy because of its distinctive profile.

Exoplanets are defined as planets outside of our Solar System. Until now, astronomers have found all other known exoplanets and exoplanet candidates in the Milky Way galaxy, almost all of them less than about 3,000 light-years from Earth. An exoplanet in M51 would be about 28 million light-years away, meaning it would be thousands of times farther away than those in the Milky Way.

"We are trying to open up a whole new arena for finding other worlds by searching for planet candidates at X-ray wavelengths, a strategy that makes it possible to discover them in other galaxies," said Rosanne Di Stefano of the Center for Astrophysics | Harvard & Smithsonian (CfA) in Cambridge, Massachusetts, who led the study, which was published today in Nature Astronomy.

This new result is based on transits, events in which the passage of a planet in front of a star blocks some of the star's light and produces a characteristic dip. Astronomers using both ground-based and space-based telescopes – like those on NASA's Kepler and TESS missions – have searched for dips in optical light, electromagnetic radiation humans can see, enabling the discovery of thousands of planets.

Di Stefano and colleagues have instead searched for dips in the brightness of X-rays received from X-ray bright binaries. These luminous systems typically contain a neutron star or black hole pulling in gas from a closely orbiting companion star. The material near the neutron star or black hole becomes superheated and glows in X-rays.

Because the region producing bright X-rays is small, a planet passing in front of it could block most or all of the X-rays, making the transit easier to spot because the X-rays can completely disappear. This could allow exoplanets to be detected at much greater distances than current optical light transit studies, which must be able to detect tiny decreases in light because the planet only blocks a tiny fraction of the star.

The team used this method to detect the exoplanet candidate in a binary system called M51-ULS-1, located in M51. This binary system contains a black hole or neutron star orbiting a companion star with a mass about 20 times that of the Sun. The X-ray transit they found using Chandra data lasted about three hours, during which the X-ray emission decreased to zero. Based on this and other information, the researchers estimate the exoplanet candidate in M51-ULS-1 would be roughly the size of Saturn, and orbit the neutron star or black hole at about twice the distance of Saturn from the Sun.

While this is a tantalizing study, more data would be needed to verify the interpretation as an extragalactic exoplanet. One challenge is that the planet candidate's large orbit means it would not cross in front of its binary partner again for about 70 years, thwarting any attempts for a confirming observation for decades.

“Unfrtunately to confirm that we’re seeing a planet we would likely have to wait decades to see another transit,” said co-author Nia Imara of the University of California at Santa Cruz. “And because of the uncertainties about how long it takes to orbit, we wouldn't know exactly when to look."

Can the dimming have been caused by a cloud of gas and dust passing in front of the X-ray source? The researchers consider this to be an unlikely explanation, as the characteristics of the event observed in M51-ULS-1 are not consistent with the passage of such a cloud. The model of a planet candidate is, however, consistent with the data.

“We know we are making an exciting and bold claim so we expect that other astronomers will look at it very carefully,” said co-author Julia Berndtsson of Princeton University in New Jersey. “We think we have a strong argument, and this process is how science works.”

If a planet exists in this system, it likely had a tumultuous history and violent past. An exoplanet in the system would have had to survive a supernova explosion that created the neutron star or black hole. The future may also be dangerous. At some point the companion star could also explode as a supernova and blast the planet once again with extremely high levels of radiation.

Di Stefano and her colleagues looked for X-ray transits in three galaxies beyond the Milky Way galaxy, using both Chandra and the European Space Agency’s XMM-Newton. Their search covered 55 systems in M51, 64 systems in Messier 101 (the “Pinwheel” galaxy), and 119 systems in Messier 104 (the “Sombrero” galaxy), resulting in the single exoplanet candidate described here.

The authors will search the archives of both Chandra and XMM-Newton for more exoplanet candidates in other galaxies. Substantial Chandra datasets are available for at least 20 galaxies, including some like M31 and M33 that are much closer than M51, allowing shorter transits to be detectable. Another interesting line of research is to search for X-ray transits in Milky Way X-ray sources to discover new nearby planets in unusual environments.

The other authors of this Nature Astronomy paper are Ryan Urquhart (Michigan State University), Roberto Soria (University of the Chinese Science Academy), Vinay Kashap (CfA), and Theron Carmichael (CfA). NASA's Marshall Space Flight Center manages the Chandra program. The Smithsonian Astrophysical Observatory's Chandra X-ray Center controls science from Cambridge Massachusetts and flight operations from Burlington, Massachusetts.

Image credit: X-ray: NASA/CXC/SAO/R. DiStefano, et al.; Optical: NASA/ESA/STScI/Grendler; Illustration: NASA/CXC/M.Weiss

Read more from NASA's Chandra X-ray Observatory.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

A quarter of a century ago, NASA released the “first light” images from the agency’s Chandra X-ray Observatory. This introduction to the world of Chandra’s high-resolution X-ray imaging capabilities included an unprecedented view of Cassiopeia A, the remains of an exploded star located about 11,000 light-years from Earth. Over the years, Chandra’s views of Cassiopeia […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

How to Find Hidden Oceans on Mysterious Worlds? Chemistry

5 min read

NASA Science Editorial Team

A study shows how the chemicals in an exoplanet's atmosphere can, in some cases, reveal whether or not the temperature on its surface is too hot for liquid water In our solar system, planets are either small and rocky (like Earth) or large and gaseous (like Neptune). But around other stars, astronomers have found planets that fall in between – worlds slightly larger than Earth but smaller than Neptune. These planets may have rocky surfaces or liquid-water oceans, but most are likely to be topped with atmospheres that are many times thicker than Earth's and opaque.

In the study, accepted in the Astrophysical Journal Letters, researchers show how the chemistry of those atmospheres could reveal clues about what lies beneath – specifically, which planets are too hot to support liquid-water oceans. Since liquid water is a necessary ingredient for life as we know it, this technique could help scientists narrow their search for potentially habitable exoplanets, or planets beyond our solar system. More than 4,500 exoplanets have been confirmed in our galaxy, with over 7,700 candidates yet to be confirmed, but scientists estimate that hundreds of billions of exoplanets exist in our galaxy

Some NASA space telescopes equipped with spectrometers can reveal the chemical makeup of an exoplanet's atmosphere. A chemical profile of Earth wouldn't be able to reveal pictures of, say, cows or humans on the planet's surface, but it would show carbon dioxide and methane produced by mammals, and oxygen produced by trees. None of these chemicals alone would be a sign of life, but in combination they would point to the possibility that our planet is inhabited.

The new paper shows which chemicals might point to hidden oceans on exoplanets between 1.7 and 3.5 times the diameter of Earth. Since Neptune is about four times Earth's diameter, these planets are sometimes called "sub-Neptunes."

A thick atmosphere on a sub-Neptune planet would trap heat on the surface and raise the temperature. If the atmosphere reaches a certain threshold – typically about 1,430 degrees Fahrenheit (770 degrees Celsius) – it will undergo a process called thermochemical equilibrium that changes its chemical profile. After thermochemical equilibrium occurs – and assuming the planet's atmosphere is composed mostly of hydrogen, which is typical for gaseous exoplanets – carbon and nitrogen will predominantly be in the form of methane and ammonia.

Those chemicals would largely be missing in a cooler, thinner atmosphere where thermochemical equilibrium has not occurred. In that case, the dominant forms of carbon and nitrogen would be carbon dioxide and molecules of two nitrogen atoms.

A liquid-water ocean underneath the atmosphere would leave additional signs, according to the study, including the absence of nearly all stray ammonia, which would be dissolved in the ocean. Ammonia gas is highly soluble in water, depending on the pH of the ocean (its level of acidity). Over a wide range of plausible ocean pH levels the researchers found the atmosphere should be virtually free of ammonia when there is a massive ocean underneath.

In addition, there would be more carbon dioxide than carbon monoxide in the atmosphere; by contrast, after thermochemical equilibrium, there should be more carbon monoxide than carbon dioxide if there are detectable amounts of either.

“If we see the signatures of thermochemical equilibrium, we would conclude that the planet is too hot to be habitable,” said Renyu Hu, a researcher at NASA’s Jet Propulsion Laboratory, who led the study. “Vice versa, if we do not see the signature of thermochemical equilibrium and also see signatures of gas dissolved in a liquid-water ocean, we would take those as a strong indication of habitability.”

NASA’s James Webb Space Telescope, launched Dec. 25, 2021, carries a spectrometer capable of studying exoplanet atmospheres. Scientists like Hu are working to anticipate what kinds of chemical profiles Webb will see in those atmospheres and what they could reveal about these distant worlds. The observatory has the capabilities to identify signs of thermochemical equilibrium in sub-Neptune atmospheres – in other words, signs of a hidden ocean – as identified in the paper.

As Webb discovers new planets or does more in-depth studies of known planets, this information could help scientists decide which of them are worthy of additional observations, especially if scientists want to target planets that might harbor life.

“We don’t have direct observational evidence to tell us what the common physical characteristics for sub-Neptunes are,” said Hu. “Many of them may have massive hydrogen atmospheres, but quite a few could still be ‘ocean planets.’ I hope this paper will motivate many more observations in the near future to find out.”

JPL is managed for NASA by Caltech in Pasadena, California.

Calla Cofield

Jet Propulsion Laboratory, Pasadena, Calif.

626-808-2469

calla.e.cofield@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Dress Up Your Digital Meetings With Cool Backgrounds From NASA

2 min read

NASA Science Editorial Team

Ever been sucked into a black hole of a digital meeting or felt like a zombie on camera at 7 a.m.? We've been there! Fortunately, we've also been to space, so where else are you going to turn for the best backgrounds for your virtual meetings? This original NASA art also makes wonderful wallpaper perfect for desktops.

If your mind ever wanders during a video conference, then it should have a great destination. We've turned our popular Exoplanet Travel Bureau posters into digital backgrounds for those dreaming of an exotic vacation to worlds with double sunsets, lava seas, and nearby planets hanging like giant moons above the horizon.

Perhaps, you've got a video meeting with the team, or the big boss you want to impress. What's more impressive than storied NASA spacecraft like the Hubble, Spitzer, Kepler, and TESS space telescopes? If you want to look cutting-edge, then choose the largest and most complex space observatory ever built, the James Webb Space Telescope. Adding bonus cool? Each background is done in a different artistic style.

Not every meeting is a nightmare, but if you want to embrace the dark side, then who are we to argue? But we do have roasted planets with never-ending screams, so you don't have to!

Maybe you're just feeling festive for Halloween? (Or maybe some daysjust feel like Halloween?) Our Galaxy of Horrors backgrounds are just the thing! Based on sci-fi movie posters, these are perfect for movie and horror buffs.

These backgrounds are fun, but the most important thing about them is they're based on real science. When we depict rains of glass, it's based on observed weather patterns and atmospheric detection on the exoplanet known as HD189733b. We show lava on 55 Cancri e because we've done a weather map of the exoplanet and know temperatures would turn rock to liquid – and we've detected the chemical signature of silicates in the atmosphere so we know the ingredients for rock are present. Science drives the art!

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The Exploration Behind the Inspiration at NASA

4 min read

NASA Science Editorial Team

At NASA, our mission is to explore. We visit destinations in our solar system and study worlds beyond to better understand big questions – How did we get here? Where are we headed? Are we alone?

Our robotic explorers have toured our solar system, but so far the only place beyond Earth where humans have stood is the Moon. That's also the next place we'll send astronauts. But not the last! While humans haven't yet visited Mars, we're planning to add bootprints to the rover tire tracks there now.

We also dream. We dream of traveling to distant worlds, and what that might be like. In the video above you can see fanciful, imagined adventures to real places we've studied at NASA.

Check out how we created these otherworldly scenes in the video below. A NASA videographer used green screens to add motion and real people to bring life to our series of solar system and exoplanet travel posters.

Let's unpack one example from the video. The shot of kayaking on Titan showcases the real rivers and lakes of liquid methane and ethane that slosh and flow on Saturn's largest moon. Titan's mysterious surface was revealed by our Cassini spacecraft, which also deployed the European Space Agency's Huygens probe to the surface. The atmosphere on Titan is so thick, and the gravity so light, that with each strike of a paddle, you might be lofted above the swift current as you ride the tides through a narrow strait called the Throat of Kraken. NASA scientist Mike Malaska studies Titan and collaborated on the poster featured in the video. His research informed the artwork, and so did a hobby: kayaking. Those ultra-cold chemical seas might be even more of a challenge than shown here. Your boat might crack, or even dissolve, Malaska said.

We'll learn more about Titan when our Dragonfly mission of dual quadcoptors -- rotorcraft with eight blades each -- visits the icy moon in 2034.

Can we visit an exoplanet 42 light-years from Earth? Well, no. But we can examine it with telescopes on the ground and in space to find out more about it. We know the surface of one such world beyond our solar system, 55 Cancri e, is so hot it would melt rocks. And we've detected rocky materials, called silicates, in its atmosphere, so…LAVA PLANET!

Our understanding of other worlds is always evolving, and sometimes we learn new details after we illustrate our science. We show a traveler standing on the surface of Kepler-16b with two shadows formed by the planet's two suns. The planet does indeed orbit two stars, but with later size and mass refinements, we now think it would be hard to stand there and enjoy a binary sunset. There isn't a solid surface to stand on a gas planet, and that's what Kepler-16b now appears to be!

In addition to sharing how sublime science can be, these scenes are a reminder that there are lots of careers in the space program, not just scientist, engineer, or astronaut. A creative team at NASA's Jet Propulsion Laboratory in Southern California produced the travel posters, originally to help share the work of NASA's Exoplanet Exploration Program. They are the result of lots of brainstorming and discussion with real NASA scientists, engineers, and expert communicators. The video versions of these spacey travel scenes were produced by visualization experts at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

All of this work is meant to inspire, and to explore the edge of possibility. It’s also an invitation. With science, we’re stepping into the future. Join us?

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NEID Spectrometer Lights Up Path to Exoplanet Exploration

6 min read

As NASA expands its quest to discover exoplanets — planets beyond our solar system — it also grows its toolbox. Over the summer, a new tool called NEID (pronounced NOO-id) delivered its first batch of data on the nearest and best-studied star, our Sun.

The NEID spectrometer, which will help locate and characterize new worlds, observes the sky from Kitt Peak National Observatory in Arizona. It began its search for exoplanets in earnest in June. However, NEID will collect nearly as much data from the Sun during the day as it does from the stars at night. That's because the Sun provides astronomers with their most detailed look at the kinds of changes that occur on the host stars of exoplanets, changes that may impact the detection and habitability of these alien worlds.

A team at NASA's Goddard Space Flight Center in Greenbelt, Maryland, led by Michael McElwain, supported NEID's design, development, and commissioning. NEID was funded by NASA's Exoplanet Exploration Program, managed by the agency's Jet Propulsion Laboratory (JPL) in Southern California. The instrument measures radial velocity, the shift in a star's motion caused by the gravitational tug of its planets. This motion slightly alters the star's light. Radial velocities give astronomers a measurement of a planet's mass relative to its host star.

"What's really critical for these planets is knowing their masses," said McElwain, an instrument scientist for the NEID development team. "When you know the size and the mass, that provides two fundamental parameters for these exoplanets."

Currently, the transit technique is the main way scientists discover exoplanets and measure their relative sizes. Scientists can detect an exoplanet by hunting for periodic changes in the light of nearby stars, which occur when an orbiting planet crosses the star's face from our viewpoint.

NASA's Kepler Space Telescope and Transiting Exoplanet Survey Satellite (TESS) have already identified thousands of exoplanets using the transit technique. NEID will build upon TESS data by measuring the radial velocities of TESS-discovered planets.

Together, these size and mass measurements can be used to determine a planet's bulk density, which gives scientists insight into the planet's overall makeup. An especially dense planet, for example, could have a rocky composition. Scientists will use that information to determine which planets are best suited for additional study by NASA's upcoming James Webb Space Telescope.

The spectrometer operates on the WIYN 3.5-meter telescope at Kitt Peak, and it belongs to a new class of radial velocity instruments that can achieve precision about three times better than ever before possible. The telescope will point at a star, collecting its light and feeding it through an optical fiber that carries it into the spectrograph, which is housed in a specially built, thermally isolated clean room on the bottom floor of the observatory.

"A spectrograph, at its most basic level, splits light into its various colors, or what we call wavelengths," said Sarah Logsdon, the instrument scientist for NEID and an assistant scientist at the National Science Foundation's (NSF) NOIRLab, a national center for ground-based astronomy headquartered in Tucson, Arizona. "That's really useful to us because individual atoms and molecules have different emission or absorption at very specific wavelengths. With NEID, we can measure how much these absorption and emission lines shift relative to their rest position as a planet tugs on its star." The size of that shift allows astronomers to determine the mass of the planet relative to the mass of its star.

One potential challance to NEID's observations is that the stars themselves can change. Hot plasma bubbles up from their interiors, cools, and falls back, while the whole surface quivers with seismic oscillations. Global and local magnetic fields create darker, cooler starspots and other visible features. All this activity makes it difficult to differentiate between stellar activity and the effects of exoplanets.

However, the sun serves as a baseline to better understand stellar activity. In addition to taking light from the WIYN telescope, NEID will also receive light from a solar telescope mounted to the observatory's roof. Over time, this solar data will help scientists identify similar events in their observations of more distant stars. After being processed to aid astronomers researching the issue of stellar activity, all data from the solar telescope is made public, with the first set of solar data released in June 2021.

"The Sun points the way," said Suvrath Mahadevan, a professor of astronomy and astrophysics at Penn State University and the principal investigator of NEID. "For decades, the iconic and now decommissioned McMath Pierce telescope at Kitt Peak was the premier facility for studying the Sun. NEID is now the bridge that connects exoplanet science to solar observations, the Sun to the stars, and a bridge that connects Kitt Peak's history to its present and future."

The NEID team announced NEID's first-light observations in January 2020. NEID observed 51 Pegasi, the first Sun-like star found to host an exoplanet. NEID is now available for use by the scientific community through its guest observing program.

NEID is funded by a partnership between NASA and NSF called NN-EXPLORE (the NASA-NSF Exoplanet Observational Research partnership), which is managed by JPL. The partnership stemmed from a recommendation in the 2010 Astronomy and Astrophysics Decadal Survey calling for a program of ground-based radial velocity surveys. NEID is short for NN-EXPLORE Exoplanet Investigations with Doppler spectroscopy, but the name also draws on a word that roughly translates as "to see" in the language of the Tohono O'odham Nation, which includes Kitt Peak.

"This was a tremendous team effort, and I'm really proud of this instrument and what it's capable of observing," McElwain said.

The NEID team is led by Penn State with major partners at the University of Pennsylvania, the University of Arizona, NASA's Goddard Space Flight Center, and the NASA Exoplanet Science Institute at Caltech.

The NEID spectrograph was built at Penn State. NSF's National Optical-Infrared Astronomy Research Laboratory (NOIRLab) was responsible for modifications to the WIYN 3.5-meter telescope to accommodate NEID. The telescope port adapter design was led by NOIRLab and was constructed at the University of Wisconsin. Additional NEID participants include Carleton College, the National Institute for Standards and Technology, the University of California Irvine, the University of Colorado, and Macquarie University.

By Emma EdmundNASA's Goddard Space Flight Center

Media Contact:Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.claire.andreol@nasa.gov

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Confirms Roman Mission’s Flight Design in Milestone Review

3 min read

Editor’s Note, 14 Oct. 2021: NASA has completed an independently verified replan for the Nancy Grace Roman Space Telescope due to significant impacts of the COVID-19 pandemic. Roman is now slated to launch no later than May 2027. NASA will accommodate the estimated cost of this replan at an additional $382 million over the life of the project, bringing the total lifecycle cost to $4.3 billion.

NASA’s Nancy Grace Roman Space Telescope has successfully passed its critical design review, signaling that all design and developmental engineering work is now complete.

“After seeing our extensive hardware testing and sophisticated modeling, an independent review panel has confirmed that the observatory we have designed will work,” said Julie McEnery, the Roman Space Telescope senior project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “We know what it will look like and what it will be capable of. Now that the groundwork is laid, the team is thrilled to continue building and testing the observatory they’ve envisaged.”

The Roman Space Telescope is a next-generation observatory that will peer across vast stretches of space and time to survey the infrared universe. Thanks to the mission’s enormous field of view and fast survey speeds, astronomers will be able to observe planets by the thousands, galaxies by the millions, and stars by the billions. Astronomers expect Roman to reveal significant numbers of rocky worlds in and beyond the region where liquid water may exist. The mission’s observations will also help illuminate two of the biggest cosmic puzzles: dark energy and dark matter.

“With this review complete, we enter the exciting phase where we will assemble and test the Roman hardware that we plan to fly,” said Jackie Townsend, deputy project manager for the Roman Space Telescope at Goddard. “When all our flight hardware is ready in 2024, we’ll hold the System Integration Review and integrate the Roman observatory. Finally, we’ll test the whole observatory in environments that simulate launch and our orbit to make sure Roman will work as designed.” The mission is slated to launch no later than May 2027.

Providing the same crisp infrared resolution as Hubble over a field of view 200 times larger, Roman will conduct sweeping cosmic surveys that would take hundreds of years using Hubble. Roman will map stars, galaxies, and dark matter to explore the formation and evolution of large cosmic structures, like clusters and superclusters of galaxies, and investigate dark energy, which is thought to accelerate the expansion of the universe.

The mission will discover a diverse array of planets, including those that orbit far from their host star. Such worlds have been largely elusive for other planet-hunting missions. Roman will also conduct a range of other astrophysics surveys to investigate topics such as the stars in nearby galaxies and probe for new asteroids, comets, and minor planets in the outer solar system. Scientists will use Roman’s surveys to help us better understand the universe and our place within it.

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado; L3Harris Technologies in Melbourne, Florida; and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Ashley BalzerNASA's Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA’s TESS Tunes into an All-sky ‘Symphony’ of Red Giant Stars

6 min read

Using observations from NASA’s Transiting Exoplanet Survey Satellite (TESS), astronomers have identified an unprecedented collection of pulsating red giant stars all across the sky. These stars, whose rhythms arise from internal sound waves, provide the opening chords of a symphonic exploration of our galactic neighborhood.

TESS primarily hunts for worlds beyond our solar system, also known as exoplanets. But its sensitive measurements of stellar brightness make TESS ideal for studying stellar oscillations, an area of research called asteroseismology.

“Our initial result, using stellar measurements across TESS’s first two years, shows that we can determine the masses and sizes of these oscillating giants with precision that will only improve as TESS goes on,” said Marc Hon, a NASA Hubble Fellow at the University of Hawaii in Honolulu. “What’s really unparalleled here is that TESS’s broad coverage allows us to make these measurements uniformly across almost the entire sky.”

Hon presented the research during the second TESS Science Conference, an event supported by the Massachusetts Institute of Technology in Cambridge – held virtually from Aug. 2 to 6 – where scientists discuss all aspects of the mission. The Astrophysical Journal has accepted a paper describing the findings, led by Hon.

Sound waves traveling through any object – a guitar string, an organ pipe, or the interiors of Earth and the Sun – can reflect and interact, reinforcing some waves and canceling out others. This can result in orderly motion called standing waves, which create the tones in musical instruments.

Just below the surfaces of stars like the Sun, hot gas rises, cools, and then sinks, where it heats up again, much like a pan of boiling water on a hot stove. This motion produces waves of changing pressure – sound waves – that interact, ultimately driving stable oscillations with periods of a few minutes that produce subtle brightness changes. For the Sun, these variations amount to a few parts per million. Giant stars with masses similar to the Sun’s pulsate much more slowly, and the corresponding brightness changes can be hundreds of times greater.

Oscillations in the Sun were first observed in the 1960s. Solar-like oscillations were detected in thousands of stars by the French-led Convection, Rotation and planetary Transits (CoRoT) space telescope, which operated from 2006 to 2013. NASA’s Kepler and K2 missions, which surveyed the sky from 2009 to 2018, found tens of thousands of oscillating giants. Now TESS extends this number by another 10 times.

“With a sample this large, giants that might occur only 1% of the time become pretty common,” said co-author Jamie Tayar, a Hubble Fellow at the University of Hawaii. “Now we can start thinking about finding even rarer examples.”

The physical differences between a cello and a violin produce their distinctive voices. Similarly, the stellar oscillations astronomers observe depend on each star’s interior structure, mass, and size. This means asteroseismology can help determine fundamental properties for large numbers of stars with accuracies not achievable in any other way.

When stars similar in mass to the Sun evolve into red giants, the penultimate phase of their stellar lives, their outer layers expand by 10 or more times. These vast gaseous envelopes pulsate with longer periods and larger amplitudes, which means their oscillations can be observed in fainter and more numerous stars.

TESS monitors large swaths of the sky for about a month at a time using its four cameras. During its two-year primary mission, TESS covered about 75% of the sky, each camera capturing a full image measuring 24-by-24 degrees every 30 minutes. In mid-2020, the cameras began collecting these images at an even faster pace, every 10 minutes.

The images were used to develop light curves – graphs of changing brightness – for nearly 24 million stars over 27 days, the length of time TESS stares at each swath of the sky. To sift through this immense accumulation of measurements, Hon and his colleagues taught a computer to recognize pulsating giants. The team used machine learning, a form of artificial intelligence that trains computers to make decisions based on general patterns without explicitly programming them.

To train the system, the team used Kepler light curves for more than 150,000 stars, of which some 20,000 were oscillating red giants. When the neural network finished processing all of the TESS data, it had identified a chorus of 158,505 pulsating giants.

Next, the team found distances for each giant using data from ESA's (the European Space Agency's) Gaia mission, and plotted the masses of these stars across the sky. Stars more massive than the Sun evolve faster, becoming giants at younger ages. A fundamental prediction in galactic astronomy is that younger, higher-mass stars should lie closer to the plane of the galaxy, which is marked by the high density of stars that create the glowing band of the Milky Way in the night sky.

“Our map demonstrates for the first time empirically that this is indeed the case across nearly the whole sky,” said co-author Daniel Huber, an assistant professor for astronomy at the University of Hawaii. “With the help of Gaia, TESS has now given us tickets to a red giant concert in the sky.”

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Center in California's Silicon Valley; the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT's Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

By Francis ReddyNASA's Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb to Explore Forming Planetary Systems

6 min read

Planetary systems take millions of years to form, which introduces quite a challenge for astronomers. How do you identify which stage they are in, or categorize them? The best approach is to look at lots of examples and keep adding to the data we have – and NASA’s upcoming James Webb Space Telescope will be able to provide an infrared inventory. Researchers using Webb will observe 17 actively forming planetary systems. These particular systems were previously surveyed by the Atacama Large Millimeter/submillimeter Array (ALMA), the largest radio telescope in the world, for the Disk Substructures at High Angular Resolution Project (DSHARP).

Webb will measure spectra that can reveal molecules in the inner regions of these protoplanetary disks, complementing the details ALMA has provided about the disks’ outer regions. These inner regions are where rocky, Earth-like planets can start to form, which is one reason why we want to know more about which molecules exist there.

A research team led by Colette Salyk of Vassar College in Poughkeepsie, New York, and Klaus Pontoppidan of the Space Telescope Science Institute in Baltimore, Maryland, seek the details found in infrared light. “Once you switch to infrared light, specifically to Webb’s range in mid-infrared light, we will be sensitive to the most abundant molecules that carry common elements,” explained Pontoppidan.

Researchers will be able to assess the quantities of water, carbon monoxide, carbon dioxide, methane, and ammonia – among many other molecules – in each disk. Critically, they will be able to count the molecules that contain elements essential to life as we know it, including oxygen, carbon, and nitrogen. How? With spectroscopy: Webb will capture all the light emitted at the center of each protoplanetary disk as a spectrum, which produces a detailed pattern of colors based on the wavelengths of light emitted. Since every molecule imprints a unique pattern on the spectrum, researchers can identify which molecules are there and build inventories of the contents within each protoplanetary disk. The strength of these patterns also carries information about the temperature and quantity of each molecule.

“Webb’s data will also help us identify where the molecules are within the overall system,” Salyk said. “If they’re hot, that implies they are closer to the star. If they’re cooler, they may be farther away.” This spatial information will help inform models that scientists build as they continue examining this program’s data.

Knowing what’s in the inner regions of the disks has other benefits as well. Has water, for example, made it to this area, where habitable planets may be forming? “One of the things that’s really amazing about planets – change the chemistry just a little bit and you can get these dramatically different worlds,” Salyk continued. “That’s why we’re interested in the chemistry. We’re trying to figure out how the materials initially found in a system may end up as different types of planets.”

If this sounds like a significant undertaking, do not worry – it will be a community effort. This is a Webb Treasury Program, which means that the data is released as soon as it’s taken to all astronomers, allowing everyone to immediately pull the data, begin assessing what’s what in each disk, and share their findings.

“Webb’s infrared data will be intensively studied,” added co-investigator Ke Zhang of the University of Wisconsin–Madison. “We want the whole research community to be able to approach the data from different angles.”

Why the Up-Close Examination?

Let's step back, to see the forest for the trees. Imagine you are on a research boat off the coast of a distant terrain. This is the broadest view. If you were to land and disembark, you could begin counting how many trees there are and how many of each tree species. You could start identifying specific insects and birds and match up the sounds you heard offshore to the calls you hear under the treetops. This detailed cataloging is very similar to what Webb will empower researchers to do – but swap trees and animals for chemical elements.

The protoplanetary disks in this program are very bright and relatively close to Earth, making them excellent targets to study. It's why they were surveyed by ALMA. It's also why researchers studied them with NASA's Spitzer Space Telescope. These objects have only been studied in depth since 2003, making this a relatively newer field of research. There's a lot Webb can add to what we know.

The telescope's Mid-Infrared Instrument (MIRI) provides many advantages. Webb's location in space means that it can capture the full range of mid-infrared light (Earth's atmosphere filters it out). Plus, its data will have high resolution, which will reveal many more lines and wiggles in the spectra that the researchers can use to tease out specific molecules.

The researchers were also selective about the types of stars chosen for these observations. This sample includes stars that are about half the mass of the Sun to about twice the mass of the Sun. Why? The goal is to help researchers learn more about systems that may be like our own as it formed. "With this sample, we can start to determine if there are any common features between the disks' properties and their inner chemistry," Zhang continued. "Eventually, we want to be able to predict which types of systems are more likely to generate habitable planets."

Beginning to Answer Big Questions

This program may also help researchers begin to answer some classic questions: Are the forms taken by some of the most abundant elements found in protoplanetary disks, like carbon, nitrogen, and oxygen, "inherited" from the interstellar clouds that formed them? Or does the precise mix of chemicals change over time? "We think we can get to some of those answers by making inventories with Webb," Pontoppidan explained. "It's obviously a tremendous amount of work to do – and cannot be done only with these data – but I think we are going to make some major progress."

Thinking even more broadly about the incredibly rich spectra Webb will provide, Salyk added, "I'm hoping that we'll see things that surprise us and then begin to study those serendipitous discoveries."

This research will be conducted as part of Webb General Observer (GO) programs, which are competitively selected using a dual-anonymous review system, the same system that is used to allocate time on the Hubble Space Telescope.

The James Webb Space Telescope will be the world's premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

By Claire BlomeSpace Telescope Science Institute, Baltimore, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Accidental Discovery Hints at a Hidden Population of Cosmic Objects

7 min read

NASA Science Editorial Team

Brown dwarfs aren’t quite stars and aren’t quite planets, and a new study suggests there might be more of them lurking in our galaxy than scientists previously thought.

A new study offers a tantalizing explanation for how a peculiar cosmic object called WISEA J153429.75-104303.3 – nicknamed “The Accident” – came to be. The Accident is a brown dwarf. Though they form like stars, these objects don’t have enough mass to kickstart nuclear fusion, the process that causes stars to shine. And while brown dwarfs sometimes defy characterization, astronomers have a good grasp on their general characteristics.

Or they did, until they found this one.

The Accident got its name after being discovered by sheer luck. It slipped past normal searches because it desn’t resemble any of the just over 2,000 brown dwarfs that have been found in our galaxy so far.

As brown dwarfs age, they cool off, and their brightness in different wavelengths of light changes. It’s not unlike how some metals, when heated, go from bright white to deep red as they cool. The Accident confused scientists because it was faint in some key wavelengths, suggesting it was very cold (and old), but bright in others, indicating a higher temperature.

“This object defied all our expectations,” said Davy Kirkpatrick, an astrophysicist at IPAC at Caltech in Pasadena, California. He and his co-authors posit in their new study, appearing in the Astrophysical Journal Letters, that The Accident might be 10 billion to 13 billion years old – at least double the median age of other known brown dwarfs. That means it would have formed when our galaxy was much younger and had a different chemical makeup. If that’s the case, there are likely many more of these ancient brown dwarfs lurking in our galactic neighborhood.

The Accident was first spotted by NASA’s Near-Earth Object Wide-Field Infrared Survey Explorer (NEOWISE), launched in 2009 under the moniker WISE and managed by NASA’s Jet Propulsion Laboratory in Southern California. Because brown dwarfs are relatively cool objects, they radiate mostly infrared light, or wavelengths longer than what the human eye can see.

To figure out how The Accident could have such seemingly contradictory properties – some suggesting it is very cold, others indicating it is much warmer – the scientists needed more information. So they observed it in additional infrared wavelengths with a ground-based telescope at the W. M. Keck Observatory in Hawaii. But the brown dwarf appeared so faint in those wavelengths, they couldn’t detect it at all, apparently confirming their suggestion that it was very cold.

They next set out to determine if the dimness resulted from The Accident being farther than expected from Earth. But that wasn’t the case, according to precise distance measurements by NASA’s Hubble and Spitzer Space Telescopes. Having determined the object’s distance – about 50 light-years from Earth – the team realized that it is moving fast – about half a million miles per hour (800,000 kph). That’s much faster than all other brown dwarfs known to be at this distance from Earth, which means it has probably been careening around the galaxy for a long time, encountering massive objects that accelerate it with their gravity.

With a mound of evidence suggesting The Accident is extremely old, the researchers propose that its strange properties aren't strange at all and that they may be a clue to its age.

When the Milky Way formed about 13.6 billion years ago, it was composed almost entirely of hydrogen and helium. Other elements, like carbon, formed inside stars; when the most massive stars exploded as supernovae, they scattered the elements throughout the galaxy.

Methane, composed of hydrogen and carbon, is common in most brown dwarfs that have a temperature similar to The Accident. But The Accident's light profile suggests it contains very little methane. Like all molecules, methane absorbs specific wavelengths of light, so a methane-rich brown dwarf would be dim in those wavelengths. The Accident, by contrast, is bright in those wavelengths, which could indicate low levels of methane.

Thus, the light profile of The Accident could match that of a very old brown dwarf that formed when the galaxy was still carbon poor; very little carbon at formation means very little methane in its atmosphere today.

"It's not a surprise to find a brown dwarf this old, but it is a surprise to find one in our backyard," said Federico Marocco, an astrophysicist at IPAC at Caltech who led the new observations using the Keck and Hubble telescopes. "We expected that brown dwarfs this old exist, but we also expected them to be incredibly rare. The chance of finding one so close to the solar system could be a lucky coincidence, or it tells us that they're more common than we thought."

To find more ancient brown dwarfs like The Accident – if they're out there – researchers might have to change how they search for these objects.

The Accident was discovered by citizen scientist Dan Caselden, who was using an online program he built to find brown dwarfs in NEOWISE data. The sky is full of objects that radiate infrared light; by and large, these objects appear to remain fixed in the sky, due to their great distance from Earth. But because brown dwarfs are so faint, they are visible only when they're relatively close to Earth, and that means scientists can observe them moving across the sky over months or years. (NEOWISE maps the entire sky about once every six months.)

Caselden's program attempted to remove the stationary infrared objects (like distant stars) from the NEOWISE maps and highlight moving objects that had similar characteristics to known brown dwarfs. He was looking at one such brown dwarf candidate when he spotted another, much fainter object moving quickly across the screen. This would turn out to be WISEA J153429.75-104303.3, which hadn't been highlighted because it did not match the program's profile of a brown dwarf. Caselden caught it by accident.

"This discovery is telling us that there's more variety in brown dwarf compositions than we've seen so far," said Kirkpatrick. "There are likely more weird ones out there, and we need to think about how to look for them."

Launched in 2009, the WISE spacecraft was placed into hibernation in 2011 after completing its primary mission. In September 2013, NASA reactivated the spacecraft with the primary goal of scanning for near-Earth objects, or NEOs, and the mission and spacecraft were renamed NEOWISE. JPL, a division of Caltech, managed and operated WISE for NASA's Science Mission Directorate (SMD). The mission was selected competitively under NASA's Explorers Program managed by the agency's Goddard Space Flight Center in Greenbelt, Maryland. NEOWISE is a project of JPL, a division of Caltech, and the University of Arizona, supported by NASA's Planetary Defense Coordination Office.

For more information about WISE, go to:

https://www.nasa.gov/mission_pages/WISE/main/index.html

JPL managed Spitzer mission operations for NASA's SMD until the spacecraft was retired in 2020. Science operations were conducted at the Spitzer Science Center at IPAC at Caltech. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado. The Spitzer data archive is housed at the Infrared Science Archive at IPAC at Caltech.

or more information about NASA's Spitzer mission, go to:

https://www.nasa.gov/mission_pages/spitzer/main/index.html

https://www.ipac.caltech.edu/project/spitzer

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington.

For more information about NASA's Hubble, go to:

https://www.nasa.gov/mission_pages/hubble/main/index.html

For more opportunities to participate in NASA Citizen Science Projects, go to:

https://science.nasa.gov/citizenscience

Calla Cofield

Jet Propulsion Laboratory, Pasadena, Calif.

626-808-2469

calla.e.cofield@jpl.nasa.gov

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cosmic Legacy: Retired Space Telescope Reveals ‘Hot Jupiter’ Secrets

6 min read

Pat Brennan

Among the first, and strangest, planets to be detected around other stars is a variety known as “hot Jupiters” – star-hugging, superheated giants once thought so unlikely that many scientists doubted their existence.

But 25 years later, hot Jupiters have been confirmed across the galaxy and even in our stellar neighborhood. Now a survey using data from NASA’s Spitzer Space Telescope, switched off in 2020, is teasing out important features of hot Jupiter atmospheres and providing a few surprises for scientists.

Spitzer’s parting gift also offers a glimmer of the future – a coming revolution in our understanding of exoplanets, the worlds orbiting other stars.

Measurements of the temperature and chemical properties of hot Jupiters, and how these affect their cauldron-like atmospheres, were made by gathering light from the infrared part of the spectrum – the “heat maps” that were Spitzer’s specialty.

Far more detailed observations in the same tradition are expected from the James Webb Space Telescope, which will launch in 2021, and other instruments to come in the decades ahead.

“To me, the transition is going from more than 15 years of exoplanetary science with Spitzer to a new era,” said Jean-Michel Desert, an astronomer at the University of Amsterdam and a co-author of the new study. “The legacy of Spitzer for the future – that to me is the key moment.”

Hot Jupiters are gas giants, in some ways similar to our own Jupiter in terms of mass and size, but with far higher temperatures. They orbit their stars so tightly that a “year” – once around the star – can take just a few days. This short orbital leash keeps them infernally hot.

Astronomers have found more than 700 so far in our galaxy – so many that they now have been able to conduct the largest statistical survey of these extreme planets using Spitzer data.

The new study, involving 49 hot Jupiters – chosen in part because molecular signatures in their atmospheres could be measured more precisely – begins to reveal trends and commonalities in an entire population.

“Hot Jupiters – all of them are quite peculiar,” Desert said. “But we do see families of [these] exoplanets.”

They seem to group into three families, the science team found: the “cooler” hot Jupiters, with atmospheric temperatures up to about 1,300 degrees Fahrenheit (700 degrees Celsius), “hot” hot Jupiters, from about 1,300 to 3,100 degrees Fahrenheit (700 to 1,700 degrees Celsius), and ultra-hot Jupiters, those above 3,100 Fahrenheit (1,700 degrees Celsius).

The most unexpected finding for scientists who study these behemoths: Among the cooler hot Jupiters, no trace of methane was seen in their atmospheres.

Computer models – simulations of hot Jupiter atmospheres – that are calculated using common scientific assumptions predicted methane in abundance for these worlds. The gas is present in small amounts in the atmosphere of our own (non-hot) Jupiter and plentiful in the gas giants Uranus and Neptune.

“We saw that some atmospheres behave differently compared to the [simpler models],” lead author Claire Baxter, also of the University of Amsterdam, wrote in an email. “To not find methane in any of the planets [at temperatures lower than about 1,300 degrees Fahrenheit] was surprising with the basic assumptions we had made.”

A few papers in previous years suggested a lack of methane on these planets, Desert said, but the question was whether these were anomalies or not. The new studies show, instead, that lack of methane at the cool end of the hot Jupiter spectrum is a widespread character trait.

“We know that simple models can’t match the data, and that we have to include more accurate physics into those basic models,” Desert said.

Another important result among the ultra-hot Jupiters is the evidence of vertical mixing in their atmospheres. Carbon monoxide and methane are stirred together on these planets, as interpreted from Spitzer data, with the strongest mixing on the hottest planets. Such a stew is best explained by mixing of the atmosphere’s upper and lower regions.

“Seeing the evidence for vertical mixing in a statistical sense is an important step because it is predicted by models and was also previously seen in brown dwarfs [a kind of failed star],” Baxter wrote. “Now we have collected evidence that this effect is also seen in exoplanet atmospheres.”

A third finding helps improve understanding of a long-running mystery. Some previous analyses suggested that hot Jupiters might have a higher metal content than their stars, which would be difficult to explain.

But the Spitzer data from the new survey appears to put that concern in a different light. The Spitzer observations fit the picture of planets with about the same chemical composition as their stars, which would be expected from planets and stars that formed from the same protoplanetary disk.

As in most families, the various members of the hot Jupiter groups have plenty of individual quirks, while still maintaining close relations.

“We’re not necessarily claiming we’re the first to see diversity [among hot Jupiters],” Desert said. “What is nice is that we see it statistically, looking at 50 objects that we’ve analyzed and interpreted in a systematic way.”

And while the Webb telescope and its successors will be able to analyze the atmospheres of individual planets more deeply, another broad survey of hot Jupiters – analyzing a large population to find common characteristics – might not be possible in the immediate future. The European Space Agency’s ARIEL mission, which will carry the CASE instrument developed by NASA’s Jet Propulsion Laboratory and is expected to launch in 2029, is designed to conduct a broad-scale survey of exoplanet atmospheres.

The new study, in a way, also brings the retired Spitzer Space Telescope full circle. One of the earliest news releases issued about Spitzer’s discoveries, in 2005, involved its capturing of infrared light from two hot Jupiters – a “first” at the time.

That also was hailed as the start of a new era in planetary science.

The extensive data collected by Spitzer continues to yield discoveries, but the baton is being passed to a new generation of more powerful infrared instruments. They will seek to unravel more mysteries, perhaps including the formation of small, rocky, potentially habitable worlds like our own.

“Our work is the result of the huge efforts of Spitzer in the field of exoplanet science over the last 15 years,” Baxter wrote. “Our work will serve as a benchmark for infrared studies in the future of exoplanet science. It allows us to understand planetary atmospheres in a broad context, which helps us understand planet formation and evolution.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb to Explore a Neighboring, Dusty Planetary System

8 min read

Researchers will use NASA’s upcoming James Webb Space Telescope to study Beta Pictoris, an intriguing young planetary system that sports at least two planets, a jumble of smaller, rocky bodies, and a dusty disk. Their goals include gaining a better understanding of the structures and properties of the dust to better interpret what is happening in the system. Since it’s only about 63 light-years away and chock full of dust, it appears bright in infrared light – and that means there is a lot of information for Webb to gather.

Beta Pictoris is the target of several planned Webb observing programs, including one led by Chris Stark of NASA’s Goddard Space Flight Center and two led by Christine Chen of the Space Telescope Science Institute in Baltimore, Maryland. Stark’s program will directly image the system after blocking the light of the star to gather a slew of new details about its dust. Chen’s programs will gather spectra, which spread light out like a rainbow to reveal which elements are present. All three observing programs will add critical details to what’s known about this nearby system.

First, a Review of What We Know

Beta Pictoris has been regularly studied in radio, infrared, and visible light since the 1980s. The star itself is twice as massive as our Sun and quite a bit hotter, but also significantly younger. (The Sun is 4.6 billion years old, but Beta Pictoris is approximately 20 million years old.) At this stage, the star is stable and hosts at least two planets, which are both far more massive than Jupiter. But this planetary system is remarkable because it is where the first exocomets (comets in other systems) were discovered. There are quite a lot of bodies zipping around this system!

Like our own solar system, Beta Pictoris has a debris disk, which includes comets, asteroids, rocks of various sizes, and plenty of dust in all shapes that orbit the star. (A debris disk is far younger and can be more massive than our solar system’s Kuiper Belt, which begins near Neptune’s orbit and is where many short-period comets originate.)

This outside ring of dust and debris is also where a lot of activity is happening. Pebbles and boulders could be colliding and breaking into far smaller pieces — sending out plenty of dust.

Scrutinizing This Planetary System

Stark’s team will use Webb’s coronagraphs, which block the light of the star, to observe the faint portions of the debris disk that surround the entire system. “We know there are two massive planets around Beta Pictoris, and farther out there is a belt of small bodies that are colliding and fragmenting,” Stark explained. “But what’s in between? How similar is this system to our solar system? Can dust and water ice from the outer belt eventually make its way into the inner region of the system? Those are details we can help tease out with Webb.”

Webb’s imagery will allow the researchers to study how the small dust grains interact with planets that are present in that system. Plus, Webb will detail all the fine dust that streams off these objects, permitting the researchers to infer the presence of larger rocky bodies and what their distribution is in the system. They’ll also carefully assess how the dust scatters light and reabsorbs and reemits light when it’s warm, allowing them to constrain what the dust is made of. By cataloging the specifics of Beta Pictoris, the researchers will also assess how similar this system is to our solar system, helping us understand if the contents of our solar system are unique.

Isabel Rebollido, a team member and postdoctoral researcher at STScI, is already building complex models of Beta Pictoris. The first model combines existing data about the system, including radio, near-infrared, far-infrared, and visible light from both space- and ground-based observatories. In time, she will add Webb's imagery to run a fuller analysis.

The second model will feature only Webb's data – and will be the first they explore. "Is the light Webb will observe symmetrical?" Rebollido asked. "Or are there 'bumps' of light here and there because there is an accumulation of dust? Webb is far more sensitive than any other space telescope and gives us a chance to look for this evidence, as well as water vapor where we know there's gas."

Dust as a Decoder Ring

Think of the debris disk of Beta Pictoris as a very busy, elliptical highway – except one where there aren't many traffic rules. Collisions between comets and larger rocks can produce fine dust particles that subsequently scatter throughout the system.

"After planets, most of the mass in the Beta Pictoris system is thought to be in smaller planetesimals that we can't directly observe," Chen explained. "Fortunately, we can observe the dust left behind when planetesimals collide."

This dust is where Chen's team will focus its research. What do the smallest dust grains look like? Are they compact or fluffy? What are they made of?

"We'll analyze Webb's spectra to map the locations of dust and gas – and figure out what their detailed compositions are," Chen explained. "Dust grains are 'fingerprints' of planetesimals we can't see directly and can tell us about what these planetesimals are made of and how they formed." For example, are the planetesimals ice-rich like comets in our solar system? Are there signs of high-speed collisions between rocky planetesimals? Clearly analyzing if grains in one region are more solid or fluffy than another will help the researchers understand what is happening to the dust, and map out the subtle differences in the dust in each region.

"I'm looking forward to analyzing Webb's data since it will provide exquisite detail," added Cicero X. Lu, a team member and a fourth-year Ph.D. student at Johns Hopkins University in Baltimore. "Webb will allow us to identify more elements and pinpoint their precise structures."

In particular, there's a cloud of carbon monoxide at the edge of the disk that greatly interests these researchers. It's asymmetric and has an irregular, blobby side. One theory is that collisions released dust and gas from larger, icy bodies to form this cloud. Webb's spectra will help them build scenarios that explain its origin.

The Reach of Infrared

These research programs are only possible because Webb has been designed to provide crisp, high-resolution detail in infrared light. The observatory specializes in collecting infrared light – which travels through gas and dust – both with images and spectra. Webb also has another advantage – its position in space. Webb will not be hindered by Earth's atmosphere, which filters out some types of light, including several infrared wavelength bands. This observatory will allow researchers to gather a more complete range of infrared light and data about Beta Pictoris for the first time.

These studies will be conducted as part of Webb Guaranteed Time Observations (GTO) and General Observers (GO) programs. The GTO programs are led by scientists who helped develop the key hardware and software components or technical and inter-disciplinary knowledge for the observatory. GO programs are competitively selected using a dual-anonymous review system, the same system that is used to allocate time on the Hubble Space Telescope.

The James Webb Space Telescope will be the world's premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

By Claire BlomeSpace Telescope Science Institute, Baltimore, Md.

Media contacts:

Christine Pulliam Space Telescope Science Institute, Baltimore, Md.cpulliam@stsci.edu

Laura BetzNASA's Goddard Space Flight Center, Greenbelt, Md.Laura.e.betz@nasa.gov

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Discovers Stellar Siblings Host ‘Teenage’ Exoplanets

6 min read

Thanks to data from NASA’s Transiting Exoplanet Survey Satellite (TESS), an international collaboration of astronomers has identified four exoplanets, worlds beyond our solar system, orbiting a pair of related young stars called TOI 2076 and TOI 1807.

These worlds may provide scientists with a glimpse of a little-understood stage of planetary evolution.

“The planets in both systems are in a transitional, or teenage, phase of their life cycle,” said Christina Hedges, an astronomer at the Bay Area Environmental Research Institute in Moffett Field and NASA’s Ames Research Center in Silicon Valley, both in California. “They’re not newborns, but they’re also not settled down. Learning more about planets in this teen stage will ultimately help us understand older planets in other systems.”

A paper describing the findings, led by Hedges, was published in The Astronomical Journal.

TOI 2076 and TOI 1807 reside over 130 light-years away with some 30 light-years between them, which places the stars in the northern constellations of Boötes and Canes Venatici, respectively. Both are K-type stars, dwarf stars more orange than our Sun, and around 200 million years old, or less than 5% of the Sun’s age. In 2017, using data from ESA’s (the European Space Agency’s) Gaia satellite, scientists showed that the stars are traveling through space in the same direction.

Astronomers think the stars are too far apart to be orbiting each other, but their shared motion suggests they are related, born from the same cloud of gas.

Both TOI 2076 and TOI 1807 experience stellar flares that are much more energetic and occur much more frequently than those produced by our own Sun.

“The stars produce perhaps 10 times more UV light than they will when they reach the Sun’s age,” said co-author George Zhou, an astrophysicist at the University of Southern Queensland in Australia. “Since the Sun may have been equally as active at one time, these two systems could provide us with a window into the early conditions of the solar system.”

TESS monitors large swaths of the sky for nearly a month at a time. This long gaze allows the satellite to find exoplanets by measuring small dips in stellar brightness caused when a planet crosses in front of, or transits, its star.

Alex Hughes initially brought TOI 2076 to astronomers’ attention after spotting a transit in the TESS data while working on an undergraduate project at Loughborough University in England, and he has since graduated with a bachelor’s degree in physics. Hedges’ team eventually discovered three mini-Neptunes, worlds between the diameters of Earth and Neptune, orbiting the star. Innermost planet TOI 2076 b is about three times Earth’s size and circles its star every 10 days. Outer worlds TOI 2076 c and d are both a little over four times larger than Earth, with orbits exceeding 17 days.

TOI 1807 hosts only one known planet, TOI 1807 b, which is about twice Earth’s size and orbits the star in just 13 hours. Exoplanets with such short orbits are rare. TOI 1807 b is the youngest example yet discovered of one of these so-called ultra-short period planets.

Scientists are currently working to measure the planets’ masses, but interference from the hyperactive young stars could make this challenging.

According to theoretical models, planets initially have thick atmospheres left over from their formation in disks of gas and dust around infant stars. In some cases, planets lose their initial atmospheres due to stellar radiation, leaving behind rocky cores. Some of those worlds go on to develop secondary atmospheres through planetary processes like volcanic activity.

The ages of the TOI 2076 and TOI 1807 systems suggest that their planets may be somewhere in the middle of this atmospheric evolution. TOI 2076 b receives 400 times more UV light from its star than Earth does from the Sun – and TOI 1807 b gets around 22,000 times more.

If scientists can discover the planets’ masses, the information could help them determine if missions like NASA’s Hubble and upcoming James Webb space telescopes can study the planets’ atmospheres – if they have them.

The team is particularly interested in TOI 1807 b because it’s an ultra-short period planet. Theoretical models suggest it should be difficult for worlds to form so close to their stars, but they can form farther out and then migrate inward. Because it would have had to both form and migrate in just 200 million years, TOI 1807 b will help scientists further understand the life cycles of these types of planets. If it doesn’t have a very thick atmosphere and its mass is mostly rock, the planet’s proximity to its star could potentially mean its surface is covered in oceans or lakes of molten lava.

“Many objects we study in astronomy evolve on such long timescales that a human being can’t see changes month to month or year to year,” said co-author Trevor David, a research fellow at the Flatiron Institute’s Center for Computational Astrophysics in New York. “If you want to see how planets evolve, your best bet is to find many planets of different ages and then ask how they’re different. The TESS discovery of the TOI 2076 and TOI 1807 systems advances our understanding of the teenage exoplanet stage.”

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Marble in the Sky: the Hunt for Another Earth

7 min read

Alicia Cermak

Capturing even a faint, blurry image of a distant world that looks something like our own would mark a profound shift in history – and our place in the universe.

The hunt for such a world has been described as a search for “Earth 2.0,” an “Earth-like” planet, even an “Earth twin.” But each of these terms implies its own raft of assumptions. We might, or might not, catch a glimpse of an exoplanet – a planet orbiting another star – that looks like present-day Earth. A blue, water-covered world marbled with clouds of white.

Yet even our own planet probably looked very different in the deep past.

The term “Earth-like” also carries some burdensome baggage. That begins with how we define it. Which characteristics, exactly, make Earth Earth-like? How would we recognize these qualities on a planet hundreds or thousands of light-years away?

“The kinds of planets that could be [considered] Earth-like may be very different from modern Earth,” said Giada Arney, an astronomer and astrobiologist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

And suppose life elsewhere is not “life as we know it.” Would we recognize life as we don’t know it?

This all comes down to the one big question we’ve been asking ourselves through the ages: Are we alone?

We’ve taken a journey through NASA’s efforts to answer this question:

How life on Earth might have looked from a vast distance over billions of years, and how it might look somewhere else

As we search the heavens for a possible twin, we’ll have to take into account the stages of growth – infancy to maturity. A rocky planet with the beginnings of life could be shrouded in an orange haze, as Earth once might have been.

Timing is everything. Our own Earth was uninhabitable for millions of years, and we might find a planet at a similar stage – perhaps an unimaginably hot or cold surface that had a liquid water ocean in the past, or might develop one in the future.

“We tend to talk about Earth-like planets as planets like ours is today,” said Douglas Hudgins, program scientist for NASA’s Exoplanet Exploration Program at NASA Headquarters in Washington. “But our planet has been radically different throughout its history, while still supporting an abundance of life.”

Where we might find signs of life in our own solar system

Mars, once warm and wet and now cold, dry and forbidding, might reveal evidence of past life. Even present life can’t be ruled out.

A life-bearing world also might be covered in a crust of ice. Jupiter’s moon, Europa, and Saturn’s Enceladus, both hide subsurface oceans sealed inside icy shells.

Titan, another moon of Saturn, also is the only other solar system body with rain, rivers and lakes. The liquid in this case, however, is composed of methane and ethane instead of water, but could be home to “weird life.” Titan also might have a subterranean ocean. If other planets and moons in our solar system harbor life forms, it isn’t obvious – but the possibility is being actively investigated by NASA and other space agencies.

“The more we study our own cosmic backyard, the more surprises we find,” said Morgan Cable, a researcher with the Astrobiology and Ocean Worlds Group at NASA’s Jet Propulsion Laboratory in Southern California. “And I’m excited. We’ll be surprised more and more as we continue to extend our senses to the outer solar system and beyond.”

The sky full of exoplanets found so far, and how they compare to our own world

Scientists have confirmed more than 4,000 exoplanets in our galaxy, many of them likely rocky worlds in Earth’s size-range. Thousands more are expected to be confirmed in the years ahead. But one very special type of planet still eludes us: a world in Earth’s size range orbiting a Sun-like star, at a distance that would give it a year comparable to our own.

While it’s possible that such planets will turn out to be rare, another factor better explains the mystery. Present-day technology used in the hunt for exoplanets, primarily space telescopes and the instruments they carry, has a tough time resolving such systems.

Future, more powerful space telescopes could help bridge this gap, or peer into the atmospheres of Earth-sized worlds that have been found in abundance – those in close orbits around red-dwarf stars – to look for signs of habitability.

“The day we detect life on an exoplanet will be nothing short of a Copernican revolution,” Hudgins said. “It will changes the way human beings view our place in the universe forever.”

The chances of finding life elsewhere

We could say that the chances of finding life somewhere else in the galaxy are improving. While scientists have confirmed thousands of exoplanets so far, the Milky Way likely holds trillions. A good percentage of these exoplanets are in Earth’s size range, and believed to be of similar composition.

Yet the cosmos is stubbornly silent on the question. Exoplanet-hunting technology, though developing rapidly, probably is not yet sufficient to detect signs of possible life in exoplanet atmospheres.

We’ve seen or heard no credible indications of a technological species among the sea of stars; a question more than half a century old, “Where is everybody?” still has no answer.

Concepts like the “habitable zone” – the orbital distance from a star allowing a planet, with a suitable atmosphere, to retain liquid water on its surface – are helping astronomers sort through the many possibilities to find likelier candidates for life-bearing worlds. Still, planets with life could be far outside this zone if there were, for example, an ice-covered planet with a deep ocean supporting aquatic organisms.

“To search for life anywhere, we have this ‘follow the water’ approach,” said Shawn Domagal-Goldman, a research astronomer at Goddard. “Anywhere you find water on Earth, you find life. Whether it’s life on Mars, ocean worlds, or exoplanets, water is the first signpost we’re looking for.”

Technology now under development that will allow us to peer into exoplanet atmospheres to look for signs of life

We’re on the brink of a new era in exoplanet science: sifting through the atmospheres of distant worlds to look for combinations of gases that could reveal a living planet.

First in line is the James Webb Space Telescope, targeted for launch in October 2021. The Webb telescope will be a cosmic multi-tasker, looking deep into the universe – and deep into its past – to discover clues to its origin and early formation.

The Webb telescope also will capture starlight shining through the atmospheres of exoplanets, which provides a kind of profile of the gases present. That will pave the way for future, more powerful space telescopes to look in on small, rocky planets perhaps resembling our own.

With more advanced technology, astronomers could detect atmospheric chemicals that are considered “biosignatures,” potentially indicating the influence of lifeforms.

This new era of characterizing exoplanets will continue with the launch of the Nancy Grace Roman telescope in the mid-2020s. An intricate instrument onboard called a coronagraph will help blot out the glare of parent stars to reveal orbiting planets.

That will mean direct images of large, gaseous planets. Those targets are unlikely to be habitable, but demonstrating this technology will open the door to future such instruments with greater resolving power. A future telescope might even find a small, rocky world with an atmosphere of oxygen, methane, and carbon dioxide – in other words, an atmosphere that reminds us of home.

“We could actually find out: Is Earth common or rare? Is life common or rare?” said Aki Roberge, an astronomer at Goddard. “We honestly have zero clue what habitable or inhabited planets look like in general. We really need to just take a look.”

Climate change is rapidly reshaping a region of the world that’s home to millions of people. In the next 30 years, Pacific Island nations such as Tuvalu, Kiribati, and Fiji will experience at least 6 inches (15 centimeters) of sea level rise, according to an analysis by NASA’s sea level change science team. This amount […]

Arctic sea ice retreated to near-historic lows in the Northern Hemisphere this summer, likely melting to its minimum extent for the year on Sept.11, 2024, according to researchers at NASA and the National Snow and Ice Data Center (NSIDC). The decline continues the decades-long trend of shrinking and thinning ice cover in the Arctic Ocean. […]

Designed to be user-friendly, the resource contains the latest sea level data, explainers, and other information from several U.S. agencies. The U.S. Interagency Task Force on Sea Level Change launched the U.S. Sea Level Change website on Monday, Sept. 23. Designed to help communities prepare for rising seas, the site features the latest science on […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: a ‘Cool’ Planet – with Plenty of Atmosphere?

3 min read

Alicia Cermak

The planet: TOI-1231 b

The discovery: A planet some 90 light-years away from Earth is oddly reminiscent of our own Neptune – that is, a gaseous world with a potentially rich atmosphere, ripe for study. The planet is more than 3 ½ times as big around as Earth and warm by Earthly standards at 134 degrees Fahrenheit (57 Celsius). But astronomers say it is one of the “coolest,” comparatively small planets known to date, and in a prime position for the components of its atmosphere to be teased apart by space telescopes.

Key facts: TOI-1231 b orbits a red-dwarf star – smaller but longer lived than our own Sun – with a year, once around the star, that is 24 days long. But the planet stays relatively cool despite its close orbit because its star also is on the cooler side. Though not habitable due to its size, the planet could offer scientists one of their first chances to capture a “bar-code” type reading of the atmosphere of a temperate, Neptune-sized exoplanet – a planet orbiting another star. This will allow comparisons with similar worlds elsewhere in the galaxy, bringing potentially deep insights into the composition and formation of exoplanets and planetary systems, including our own.

Details: A new era in the study of exoplanets is just beginning, as we move from simply detecting these planets, and counting them up, to zeroing in on individual worlds to analyze their atmospheres. With a technique called transmission spectroscopy, scientists should be able to use the Hubble Space Telescope – and soon the far more sensitive James Webb Space Telescope – to capture starlight shining through the atmosphere of TOI-1231 b. Molecules in this planet’s atmosphere will absorb slices of light from this spectrum, leaving dark lines that can be read like a bar-code, revealing which gases are present.

The planet’s red-dwarf star, though small, is quite bright in the infrared part of the light spectrum, or light beyond the red end of the spectrum that can’t be seen with the naked eye. It is, however, ideal for investigation by Hubble and Webb. Also helpful: From our perspective on Earth, TOI-1231 b crosses the face of its star, which allowed its detection in the first place by NASA’s Transiting Exoplanet Survey Satellite (TESS). And that crossing, called a “transit,” takes nearly 3 ½ hours – plenty of time to capture and analyze starlight shining through the planet’s atmosphere.

Fun facts: We might see evidence of clouds (perhaps even made of water) in this planet’s atmosphere. And because this star-and-planet system is moving at a high velocity away from Earth, hydrogen atoms escaping from the planet’s atmosphere might be readily detected. In other words, the planet could turn out to have a tail.

In general, such atoms are almost impossible to detect even when using space-based facilities; their presence is masked both by the outer wisps of Earth’s atmosphere and by interstellar gas. But the TOI-1231 system is moving so quickly that escaping hydrogen atoms are shifted out of phase with the blocking material, where they could be detected by telescopes like Hubble.

The discoverers: Using data from TESS, a large, international team of astronomers led by Dr. Jennifer Burt, an exoplanet researcher at NASA’s Jet Propulsion Laboratory in Southern California, and Professor Diana Dragomir, an exoplanet researcher at the University of New Mexico, announced the discovery of TOI-1231 b in a new paper. The discovery was entered into NASA’s Exoplanet Archive on June 3.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Citizen Scientists Discover Two Gaseous Planets around a Bright Sun-like Star

7 min read

At night, seven-year-old Miguel likes talking to his father Cesar Rubio about planets and stars. “I try to nurture that,” says Rubio, a machinist in Pomona, California, who makes parts for mining and power generation equipment.

Now, the boy can claim his father helped discover planets, too. Cesar Rubio is one of thousands of volunteers participating in Planet Hunters TESS, a NASA-funded citizen science project that looks for evidence of planets beyond our solar system, or exoplanets. Citizen science is a way for members of the public to collaborate with scientists. More than 29,000 people worldwide have joined the Planet Hunters TESS effort to help scientists find exoplanets.

Planet Hunters TESS has now announced the discovery of two exoplanets in a study published online in Monthly Notices of the Royal Astronomical Society, listing Rubio and more than a dozen other citizen scientists as co-authors.

These exotic worlds orbit a star called HD 152843, located about 352 light-years away. This star is about the same mass as the Sun, but almost 1.5 times bigger and slightly brighter.

Planet b, about the size of Neptune, is about 3.4 times bigger than Earth, and completes an orbit around its star in about 12 days. Planet c, the outer planet, is about 5.8 times bigger than Earth, making it a “sub-Saturn,” and its orbital period is somewhere between 19 and 35 days. In our own solar system, both of these planets would be well within the orbit of Mercury, which is about 88 days.

“Studying them together, both of them at the same time, is really interesting to constrain theories of how planets both form and evolve over time,” said Nora Eisner, a doctoral student in astrophysics at the University of Oxford in the United Kingdom and lead author of the study.

TESS stands for Transiting Exoplanet Survey Satellite, a NASA spacecraft that launched in April 2018. The TESS team has used data from the observatory to identify more than 100 exoplanets and over 2,600 candidates that await confirmation.

Planet Hunters TESS, operated through the Zooniverse website, began in December 2018, shortly after the first TESS data became publicly available. Volunteers look at graphs showing the brightness of different stars over time. They note which of those plots show a brief dip in the star’s brightness and then an upward swing to the original level. This can happen when a planet crosses the face of its star, blocking out a tiny bit of light — an event called a “transit.”

The Planet Hunters project shares each brightness plot, called a “light curve,” with 15 volunteers. In the background of the website, an algorithm collects all of the volunteers’ submissions and picks out light curves that multiple volunteers have flagged. Eisner and colleagues then look at the highest-ranked light curves and determine which ones would be good for scientific follow-up.

Even in an era of sophisticated computing techniques like machine learning, having a large group of volunteers looking through telescope data is a big help to researchers. Since researchers can’t perfectly train computers to identify the signatures of potential planets, the human eye is still valuable. “That’s why a lot of exoplanet candidates are missed, and why citizen science is great,” Eisner said.

In the case of HD 152843, citizen scientists looked at a plot showing its brightness during one month of TESS observations. The light curve showed three distinct dips, meaning at least one planet could be orbiting the star. All 15 citizen scientists who looked at this light curve flagged at least two transits, and some flagged the light curve on the Planet Hunters TESS online discussion forum.

Then, scientists took a closer look. By comparing the data to their models, they estimated that two transits came from the inner planet and the other came from a second, outer planet.

To make sure the transit signals came from planets and not some other source, such as stars that eclipse each other, passing asteroids, or the movements of TESS itself, scientists needed to look at the star with a different method. They used an instrument called HARPS-N (the High Accuracy Radial velocity Planet Searcher for the Northern hemisphere) at the Telescopio Nazionale Galileo in La Palma, Spain, as well as EXPRES (the Extreme Precision Spectrometer), an instrument at Lowell Observatory in Flagstaff, Arizona. Both HARPS and EXPRES look for the presence of planets by examining whether starlight is “wobbling” due to planets orbiting their star. This technique, called the radial velocity method, allows scientists to estimate the mass of a distant planet, too.

While scientists could not get a signal clear enough to pinpoint the planets’ masses, they got enough radial velocity data to make mass estimates — about 12 times the mass of Earth for planet b and about 28 times the mass of Earth for planet c. Their measurements validate that signals that indicate the presence of planets; more data are needed for confirmation of their masses. Scientists continue to observe the planetary system with HARPS-N and hope to have more information about the planets soon.

Researchers may soon have high-tech tools to see if these planets have atmospheres and what gases are present in them. NASA’s James Webb Space Telescope, launching later this year, will be able to look at what kinds of molecules make up the atmospheres of planets like those in this system, especially the larger outer planet. The HD 152843 planets are far too hot and gaseous to support life as we know it, but they are valuable to study as scientists learn about the range of possible planets in our galaxy.

“We’re taking baby steps towards the direction of finding an Earth-like planet and studying its atmosphere, and continue to push the boundaries of what we can see,” Eisner said.

The citizen scientists who classified the HD 152843 light curve as a possible source of transiting planets, in addition to three Planet Hunters discussion forum moderators, were invited to have their names listed as co-authors on the study announcing the discovery of these planets.

One of these citizen scientists is Alexander Hubert, a college student concentrating in mathematics and Latin in Würzburg, Germany, with plans to become a secondary school teacher. So far, he has classified more than 10,000 light curves through Planet Hunters TESS.

“I regret sometimes that in our times, we have to constrain ourselves to one, maybe two subjects, like for me, Latin and mathematics,” Hubert said. “I’m really grateful that I have the opportunity on Zooniverse to participate in something different.”

Elisabeth Baeten of Leuven, Belgium, another co-author, works in the administration of reinsurance, and says classifying light curves on Planet Hunters TESS is “relaxing.” Interested in astronomy since childhood, she was one of the original volunteers of Galaxy Zoo, an astronomy citizen science project that started in 2007. Galaxy Zoo invited participants to classify the shapes of distant galaxies.

While Baeten has been part of more than a dozen published studies through Zooniverse projects, the new study is Rubio’s first scientific publication. Astronomy has been a life-long interest, and something he can now share with his son. The two sometimes look at the Planet Hunters TESS website together.

“I feel that I’m contributing, even if it’s only like a small part,” Rubio said. “Especially scientific research, it’s satisfying for me.”

NASA has a wide variety of citizen science collaborations across topics ranging from Earth science to the Sun to the wider universe. Anyone in the world can participate. Check out the latest opportunities at science.nasa.gov/citizenscience.

By Elizabeth Landau

NASA Headquarters

Media Contact

Claire Andreoli

NASA’s Goddard Space Flight Center, Greenbelt, Md.

(301) 286-1940

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

In a surprise finding, astronomers using NASA’s Hubble Space Telescope have discovered that the blowtorch-like…

Overview Our planetary system is located in an outer spiral arm of the Milky Way galaxy. We call it the…

Other Citizen Science Projects NASA Has Supported

Overview Asteroids, comets, and meteors are chunks of rock, ice, and metal left over from the formation of our solar…

NASA Images

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The Searchers: How Will NASA Look for Signs of Life Beyond Earth?

7 min read

Pat Brennan

If telescopes are humanity's eyes on the universe, our vision is growing sharper by the decade.

Starting in the late 1990s, we saw what was thought to be impossible: the shadows of planets, hundreds to thousands of light-years away, as they crossed the faces of their stars. We also watched the gyrations of stars from the gravitational tugs of orbiting planets, revealing the planets' "mass" or heft.

NASA's Hubble and Spitzer space telescopes then opened a window on the atmospheres of these far distant worlds, capturing early evidence of the gases present. Now we're on the verge seeing more detail than ever before, scanning the gases of these worlds for possible signs of life.

And as our "eyes," in space and on the ground, reach ever farther, the universe seems ever stranger.

"Every new telescope that gets launched gives us a totally new way of looking at the universe," said Erika Hamden, a University of Arizona assistant professor and a NASA Roman Technology Fellow. "We always discover all these weird, interesting things because the universe is very weird and strange."

NASA's array of technological marvels includes the Kepler Space Telescope, now retired, and its successor, TESS, the Transiting Exoplanet Survey Satellite, still operating on an extended mission. Both were built to hunt for those shadows – a tiny dip in starlight as an "exoplanet," a planet beyond our solar system, crosses the face of its parent star. Finding exoplanet shadows is called the "transit" method.

On the ground, more telescopes are being equipped with instruments that measure changes in the light from stars as they are pulled away from us, or pushed a bit closer. The push and pull comes from orbiting planets, and the detection method is known as the radial velocity technique.

And the next generation of space telescopes will bring a sea change in the planet search: measuring the atmospheres of the planets themselves.

"So far, we've confirmed more than 4,000 exoplanets," said Mario Perez, the chief technologist in the Astrophysics Division at NASA Headquarters in Washington. "Discovering additional planets could become great additions to our current sample. But now, a pressing goal is characterizing them – getting to know their intrinsic attributes to assess the possibility of habitability."

First on deck for this new generation: NASA's James Webb Space Telescope, a giant among robotic spacecraft that looks like nothing previously seen. Imagine a huge, segmented, gold-coated light-collecting dish attached to a giant silver sunshade – a little like a piece of honeycomb riding atop a shingle that would cover the better part of a tennis court.

The Webb telescope will be a very busy observatory after its launch, targeted for October 2021. It will plumb the depths of the universe and try to uncover secrets of the earliest galaxies, black holes, and other cosmological phenomena. One of its jobs, however, will be to capture starlight shining through the atmospheres of exoplanets. Gases in these atmospheres will block out certain slices of the spectrum in this starlight, in a way that scientists can read like a bar code – a light-sifting method known as spectroscopy.

In a sense, Webb will take “samples” of exoplanet atmospheres. In some cases, this might include searching for potential signs of life in these gases – biosignatures – although that investigation is far more likely to be taken up by even more powerful space telescopes in the future.

“I think we will be successful, eventually, in detecting life on distant worlds through atmospheric characterization routes,” said Nick Siegler, chief technologist for NASA’s Exoplanet Exploration Program at the Jet Propulsion Laboratory in Southern California.

Another space telescope that will advance the goal of exoplanet characterization is named after Nancy Grace Roman, NASA’s first chief astronomer. Likely to launch in the mid 2020s, the Roman telescope will include an intricate piece of technology called a coronagraph. This system of masks, shape-changing mirrors, and detectors inside the telescope will blot out the light from a star, revealing the planets around it. The pixels of light from the planets themselves can be split into a spectrum, allowing spectroscopic analysis.

The Roman telescope will have the power to capture direct images of large, gaseous planets unlikely to be habitable worlds, though probably not smaller targets. But this technology demonstration will point the way to the future: spaceborne instruments that could look in on a rocky planet the size of Earth and search for familiar gases – oxygen, methane, carbon dioxide – that, seen together, might indicate the presence of life.

Critical to any observation of such exoplanets is squelching the glare from the parent star. The intense starshine otherwise drowns out the dim light from its planets – in the case of Earth-sized planets orbiting Sun-like stars, overwhelming it by a factor of 10 billion.

“The hard part is suppressing all of that starlight from the host star, to give you a fighting chance to collect the minuscule amount of reflected light from the exoplanet,” Siegler said. “The key technology is starlight suppression.”

So those starlight-muting coronagraphs will mark a major advance. But concepts for starlight blocking technology are not confined to the inside of a telescope. NASA scientists also are working on early designs for an unusual proposal: a spacecraft shaped like a sunflower that, once fully unfurled, would be the size of a baseball diamond.

Called the “starshade,” it would propel itself to a position some 25,000 miles (40,000 kilometers) ahead of a space telescope. The petals of this huge screen would cast a deep, dark shadow on the telescope, blocking the light from a star and allowing the space telescope to capture photons – particles of light – directly from planets in the star’s orbit.

Coupled with a powerful telescope, these starlight-blocking technologies could yield the first direct images of a potential life-bearing world – another blue and white marble, or perhaps even an orange one.

“It would be the birth of something that never really existed before,” said Aki Roberge, an astronomer at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Comparative exobiology, comparing two independent evolutionary histories, two presumably different origins of life.”

Potential signs of life, of course, might be detected among the planets in our own solar system – or, more speculatively, via signals from intelligent, technological lifeforms somewhere in the galaxy. But capturing signs of biological activity from exoplanets is a higher technological hurdle. We’ll need not just starlight suppression and spectroscopy but new analytical tools, such as computer models that simulate possible exoplanet atmospheres.

“At the end of the day, we’re not going to see little green aliens riding around in spacecraft,” Siegler said. “We’re going to have to piece the story together. Information about temperature, pressure, and gases – plugged into a sophisticated exoplanet atmospheres model – is going to be the way that scientists conclude whether or not an exoplanet is possibly habitable.”

All these rapidly advancing technologies are NASA’s – and humanity’s – way of answering an age-old question: Are we alone?

“It’s one of those fundamental questions people have been arguing about, philosophers have argued about, for who knows how long – possibly millennia,” Roberge said. “We could actually find out: Is Earth common or rare? Is life common or rare? We honestly have zero clue what habitable or inhabited planets look like in general. We really need to just take a look.”

Search for Life

Stars

Universe

Black Holes

Neighboring Star’s Bad Behavior: Large and Frequent Flares

5 min read

NASA Science Editorial Team

The star known as Proxima Centauri, the Sun’s nearest interstellar neighbor, turns out to have a hair-trigger temper – frequently erupting with potentially damaging stellar flares, including its largest ever recorded.

And these sizzling outbursts might be bad news for any potential lifeforms on the surface of a closely orbiting, probably rocky planet called Proxima b.

“It’s hard to imagine that life could emerge, being subjected to radiation that frequently,” said Meredith MacGregor, an astronomer at the University of Colorado and lead author of a newly published paper on Proxima’s surprisingly powerful flares.

“You’re not only eroding the atmosphere; it’s not great for any [possible] lifeforms hanging around on the planet,” MacGregor said.

Over a 40-hour period in 2019, MacGregor led a group of scientists to observe one extremely high-energy flare – and a great many large, medium and small ones – on Proxima, a type of star known as a red dwarf. The biggest flare briefly made the star 14,000 times brighter than normal, as measured in ultraviolet light.

Previous research has found such flares before. But in this study, for the first time, these flare measurements were captured in a variety of wavelengths, or different slices of the light spectrum. The study team included Thomas Barclay of the University of Maryland, Baltimore County, now working at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and the work was funded in part by NASA.

The results were contrary to many scientists’ expectations. And they raise questions about the potential habitability of rocky, Earth-sized planets that orbit other red dwarf stars, known to scientists as “M-dwarfs.”

M-dwarfs are smaller and fainter than our Sun. They also happen to far outnumber other types of stars in our galaxy – including larger, yellow stars like ours. One famous example of Earth-size planets around an M-dwarf is the TRAPPIST-1 system, which consists of seven rocky worlds. Telescope observations have uncovered many other rocky planets around M-dwarfs, too. But the new findings suggest stars like this may present problems for the emergence of life.

“M-dwarfs are in fact much more flarey, more active, than Sun-like stars,” MacGregor said. “We keep finding planets around M-dwarfs, and talking about habitability. At the same time, these stars are doing something crazy.”

To make her measurements, MacGregor orchestrated a global performance worthy of a master conductor. She coordinated simultaneous observations with nine telescopes, on the ground and in space, gaining flare observations from five. These included NASA’s Hubble Space Telescope, the Transiting Exoplanet Survey Satellite (TESS) and ALMA, a massive grid of radio telescopes in the Chilean desert.

Critically, this telescopic assortment captured measurements from across the electromagnetic spectrum, from long, slow, ponderous radio waves to the short, rapidly pulsing ultra-violet.

That provided a far richer picture of the subtle inner workings of Proxima’s gigantic flare – and its many smaller cousins.

Stellar flares are believed to be a kind of high-energy whiplash caused by twisting and writhing magnetic fields. These loops and arcs can cross each other up as their “feet” – the points where they connect with the star’s surface – dance around in complex patterns.

When the tension becomes too great, they can snap, releasing huge amounts of energy before reconnecting to the surface.

Our Sun also flares, but its eruptions are puny compared to Proxima’s – even though Proxima is a far smaller star.

“We were observing giant flares every day [on Proxima], and medium and small flares many times per day,” MacGregor said.

The cross-section of wavelengths obtained in the new study also could offer a roadmap to understanding other red dwarf stars. It’s among the few such efforts to capture slices of the spectrum of the “millimeter” variety – those long, ponderous waves – during flaring events.

The millimeter spikes were tightly linked to those of the shorter ultraviolet (or UV) waves. That discovery, also unexpected, could mean that millimeter discharges might be used as a proxy to hunt for corresponding UV radiation. And that, in turn, could allow astronomers to pore over old data, as well as new, to look for signs of flaring that were previously unseen.

The new millimeter and UV measurements also appear to originate at the top of those reconnecting, energy-releasing magnetic loops. This was previously unknown, and shows that the multi-wavelength readings allow scientists to puzzle out the physical structure of the flares themselves.

MacGregor is planning an encore, arranging another command performance of telescopes to examine more red dwarfs. Her goal: an intimate understanding of the true temperament of these volatile stars, and whether that might strongly influence the chances for life on the planets locked in their orbit.

“This really motivates going out and looking at more stars,” she said. “If we’re talking about the habitability of M-dwarfs, clearly we need to understand this. You have to understand stars and planets together: Neither acts in isolation from the other.”

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Watches How a Giant Planet Grows

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA's Hubble Space Telescope is giving astronomers a rare look at a Jupiter-sized, still-forming planet that is feeding off material surrounding a young star.

"We just don't know very much about how giant planets grow," said Brendan Bowler of the University of Texas at Austin. "This planetary system gives us the first opportunity to witness material falling onto a planet. Our results open up a new area for this research."

Though over 4,000 exoplanets have been cataloged so far, only about 15 have been directly imaged to date by telescopes. And the planets are so far away and small, they are simply dots in the best photos. The team's fresh technique for using Hubble to directly image this planet paves a new route for further exoplanet research, especially during a planet's formative years.

This huge exoplanet, designated PDS 70b, orbits the orange dwarf star PDS 70, which is already known to have two actively forming planets inside a huge disk of dust and gas encircling the star. The system is located 370 light-years from Earth in the constellation Centaurus.

"This system is so exciting because we can witness the formation of a planet," said Yifan Zhou, also of the University of Texas at Austin. "This is the youngest bona fide planet Hubble has ever directly imaged." At a youthful five million years, the planet is still gathering material and building up mass.

Hubble's ultraviolet light (UV) sensitivity offers a unique look at radiation from extremely hot gas falling onto the planet. "Hubble's observations allowed us to estimate how fast the planet is gaining mass," added Zhou.

The UV observations, which add to the body of research about this planet, allowed the team to directly measure the planet's mass growth rate for the first time. The remote world has already bulked up to five times the mass of Jupiter over a period of about five million years. The present measured accretion rate has dwindled to the point where, if the rate remained steady for another million years, the planet would only increase by approximately an additional 1/100th of a Jupiter-mass.

Zhou and Bowler emphasize that these observations are a single snapshot in time – more data are required to determine if the rate at which the planet is adding mass is increasing or decreasing. "Our measurements suggest that the planet is in the tail end of its formation process."

The youthful PDS 70 system is filled with a primordial gas-and-dust disk that provides fuel to feed the growth of planets throughout the entire system. The planet PDS 70b is encircled by its own gas-and-dust disk that's siphoning material from the vastly larger circumstellar disk. The researchers hypothesize that magnetic field lines extend from its circumplanetary disk down to the exoplanet's atmosphere and are funneling material onto the planet's surface.

"If this material follows columns from the disk onto the planet, it would cause local hot spots," Zhou explained. "These hot spots could be at least 10 times hotter than the temperature of the planet." These hot patches were found to glow fiercely in UV light.

These observations offer insights into how gas giant planets formed around our Sun 4.6 billion years ago. Jupiter may have bulked up on a surrounding disk of infalling material. Its major moons would have also formed from leftovers in that disk.

A challenge to the team was overcoming the glare of the parent star. PDS 70b orbits at approximately the same distance as Uranus does from the Sun, but its star is more than 3,000 times brighter than the planet at UV wavelengths. As Zhou processed the images, he very carefully removed the star’s glare to leave behind only light emitted by the planet. In doing so, he improved the limit of how close a planet can be to its star in Hubble observations by a factor of five.

“Thirty-one years after launch, we’re still finding new ways to use Hubble,” Bowler added. “Yifan’s observing strategy and post-processing technique will open new windows into studying similar systems, or even the same system, repeatedly with Hubble. With future observations, we could potentially discover when the majority of the gas and dust falls onto their planets and if it does so at a constant rate.”The researchers' results were published in April 2021 in The Astronomical Journal.The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Media Contacts:Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.claire.andreoli@nasa.gov

Claire BlomeSpace Telescope Science Institute, Baltimore, Md.

Ray VillardSpace Telescope Science Institute, Baltimore, Md.

As a radio frequency wireless engineer in NASA’s Johnson Space Center Avionic Systems Division in Houston, Melissa Moreno makes an impact in space exploration while proudly sharing her cultural heritage in the NASA community. Moreno works in the Electronic Systems Test Laboratory, developing communication systems critical to Gateway, NASA’s first lunar-orbiting space station. But her […]

Researchers found that long-duration spaceflight affected the mechanical properties of eye tissues, including reducing the stiffness of tissue around the eyeball. A better understanding of these changes could help researchers prevent, diagnose, and treat the vision impairment often seen in crew members. SANSORI, a Canadian Space Agency investigation, examined whether reduced stiffness of eye tissue contributes to […]

On Sept. 30, 1994, space shuttle Endeavour took to the skies on its 7th trip into space. During the 11-day mission, the STS-68 crew of Commander Michael A. Baker, Pilot Terrence “Terry” W. Wilcutt, and Mission Specialists Steven L. Smith, Daniel W. Bursch, Peter J.K. “Jeff” Wisoff, and Payload Commander Thomas “Tom” D. Jones operated […]

Hubble Space Telescope

Exoplanet Stories

Parker Solar Probe

Stars Stories

How NASA’s Roman Space Telescope Will Uncover Lonesome Black Holes

7 min read

NASA’s Nancy Grace Roman Space Telescope will provide an unprecedented window into the infrared universe when it launches in the mid-2020s. One of the mission’s planned surveys will use a quirk of gravity to reveal thousands of new planets beyond our solar system. The same survey will also provide the best opportunity yet to definitively detect solitary small black holes for the first time. Formed when a star with more than 20 solar masses exhausts the nuclear fuel in its core and collapses under its own weight, these objects are known as stellar-mass black holes.

Black holes have such powerful gravity that not even light can escape their clutches. Since they’re invisible, we can only find black holes indirectly, by seeing how they affect their surroundings. The supermassive black holes found at the centers of galaxies, which contain millions of times the mass of the Sun, disrupt the orbits of nearby stars and occasionally tear them apart with visible consequences.

But astronomers think the vast majority of stellar-mass black holes, which are much lighter, have nothing around them that can tip us off to their presence. Roman will find planets throughout our galaxy by observing how their gravity distorts distant starlight, and because stellar-mass black holes produce the same effects, the mission should be able to find them too.

“Astronomers have identified about 20 stellar-mass black holes so far in the Milky Way, but all of them have a companion that we can see,” said Kailash Sahu, an astronomer at the Space Telescope Science Institute in Baltimore. “Many scientists, myself included, have spent years trying to find black holes on their own using other telescopes. It’s exciting that with Roman, it will finally be possible.”

Stars seem like eternal beacons, but each is born with a limited supply of fuel. Stars spend the majority of their lives turning hydrogen in their centers into helium, which creates an enormous amount of energy. This process, called nuclear fusion, is like a controlled explosion – a finely balanced game of tug-of-war between outward pressure and gravity.

But as a star’s fuel runs low and fusion slows, gravity takes over and the star’s core contracts. This inward pressure heats up the core and sparks a new round of fusion, which produces so much energy that the star’s outer layers expand. The star swells in size, its surface cools, and it becomes a red giant or supergiant.

The type of stellar corpse that’s ultimately left behind depends on the star’s mass. When a Sun-like star runs out of fuel, it eventually ejects its outer layers, and only a small, hot core called a white dwarf remains. The white dwarf will fade out over time, like the dying embers of a once-roaring fire. Our Sun has about five billion years of fuel remaining.

More massive stars run hotter, so they use up their fuel faster. Above about eight times the mass of the Sun, most stars are doomed to die in cataclysmic explosions called supernovae before becoming black holes. At the highest masses, stars may skip the explosion and collapse directly into black holes.

The cores of these massive stars collapse until their protons and electrons crush together to form neutrons. If the leftover core weighs less than about three solar masses, the collapse stops there, leaving behind a neutron star. For larger leftover cores, even the neutrons cannot support the pressure and the collapse continues to form a black hole.

Millions of massive stars have undergone this process and now lurk throughout the galaxy as black holes. Astronomers think there should be about 100 million stellar-mass black holes in our galaxy, but we've only been able to find them when they noticeably affect their surroundings. Astronomers can infer the presence of a black hole when hot, glowing accretion disks form around them, or when they spot stars orbiting a massive but invisible object.

"Roman will revolutionize our search for black holes because it will help us find them even when there's nothing nearby," Sahu said. "The galaxy should be littered with these objects."

Roman will primarily use a technique called gravitational microlensing to discover planets beyond our solar system. When a massive object, such as a star, crosses in front of a more distant star from our vantage point, light from the farther star will bend as it travels through the curved space-time around the nearer one.

The result is that the closer star acts as a natural lens, magnifying light from the background star. Planets orbiting the lens star can produce a similar effect on a smaller scale.

In addition to causing a background star to brighten, a more massive lensing object can warp space-time so much that it noticeably alters the distant star's apparent location in the sky. This change in position, called astrometric microlensing, is extremely small – only about one milliarcsecond. That's like distinguishing movement as small as about the width of a quarter on top of the Empire State Building in New York all the way from Los Angeles. Using Roman's exquisite spatial resolution to detect such a tiny apparent movement – the telltale sign of a massive black hole – astronomers will be able to constrain the black hole's mass, distance, and motion through the galaxy.

Microlensing signals are so rare that astronomers need to monitor hundreds of millions of stars for long periods to catch them. Observatories must be able to track the position and brightness of the background star extremely precisely – something that can only be done from above Earth's atmosphere. Roman's location in space and enormous field of view will provide us with the best opportunity yet to probe our galaxy's black hole population.

"The stellar-mass black holes we've discovered in binary systems have strange properties compared to what we expect," Sahu said. "They're all about 10 times more massive than the Sun, but we think they should span a much wider range of between three and 80 solar masses. By conducting a census of these objects, Roman will help us understand more about stars' death throes."

The Nancy Grace Roman Space Telescope is managed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado, L3Harris Technologies in Melbourne, Florida, and Teledyne Scientific & Imaging in Thousand Oaks, California.

Download media from NASA Goddard's Scientific Visualization Studio

By Ashley BalzerNASA's Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Fast-Spinning Brown Dwarfs May Reveal a Rotational Speed Limit

6 min read

NASA Science Editorial Team

Using data from NASA's Spitzer Space Telescope, scientists have identified the three fastest-spinning brown dwarfs ever found. More massive than most planets but not quite heavy enough to ignite like stars, brown dwarfs are cosmic in-betweeners. And though they aren't as well known as stars and planets to most people, they are thought to number in the billions in our galaxy.

In a study appearing in the Astronomical Journal, the team that made the new speed measurements argue that these three rapid rotators could be approaching a spin speed limit for all brown dwarfs, beyond which they would break apart. The rapidly rotating brown dwarfs are all about the same diameter as Jupiter but between 40 and 70 times more massive. They each rotate about once per hour, while the next-fastest known brown dwarfs rotate about once every 1.4 hours and Jupiter spins once every 10 hours. Based on their size, that means the largest of the three brown dwarfs whips around at more than 60 miles per second (100 kilometers per second), or about 220,000 miles per hour (360,000 kilometers per hour).

The speed measurements were made using data from Spitzer, which NASA retired in January 2020. (The brown dwarfs were discovered by the ground-based Two Micron All Sky Survey, or 2MASS, which ran until 2001). The team then corroborated their unusual findings through observations with the ground-based Gemini North and Magellan telescopes.

Brown dwarfs, like stars or planets, are already spinning when they form. As they cool down and contract, they spin faster, just like when a spinning ice skater draws her arms into her body. Scientists have measured the spin rates of about 80 brown dwarfs, and they vary from less than two hours (including the three new entries) to tens of hours.

With so much variety among the brown dwarf speeds already measured, it surprised the authors of the new study that the three fastest brown dwarfs ever found have almost the exact same spin rate (about one full rotation per hour) as each other. This cannot be attributed to the brown dwarfs having formed together or being at the same stage in their development, as they are physically different: One is a warm brown dwarf, one is cold, and the other falls between them. Since brown dwarfs cool as they age, the temperature differences suggest these brown dwarfs are different ages.

The authors aren't chalking this up to coincidence. They think the members of the speedy trio have all reached a spin speed limit; beyond this, a brown dwarf could break apart.

All rotating objects generate centripetal force, which increases the faster the object spins. On a carnival ride, this force can threaten to throw riders from their seats; in stars and planets, it can tear the object apart. Before a spinning object breaks apart it will often start bulging around its midsection as it deforms under the pressure. Scientists call this oblation. Saturn, which rotates once every 10 hours like Jupiter, has a perceptible oblation. Based on the known characteristics of the brown dwarfs, they likely have similar degrees of oblation, according to the paper authors.

Considering that brown dwarfs tend to speed up as they age, are these objects regularly exceeding their spin speed limit and being torn apart? In other rotating cosmic objects, like stars, there are there natural braking mechanisms that stop them from destroying themselves. It's not clear yet if similar mechanisms exist in brown dwarfs.

“It would be pretty spectacular to find a brown dwarf rotating so fast it is tossing its atmosphere out into space,” said Megan Tannock, a PhD candidate at the Western University in London, Ontario. “But so far, we haven’t found such a thing. I think that must mean that either something is slowing the brown dwarfs down before they hit that extreme or that they can’t get that fast in the first place. The result of our paper supports some sort of limit on the rotation rate, but we’re not sure of the reason yet.”

The maximum spin rate of any object is determined not only by its total mass but by how that mass is distributed. That’s why, when very rapid spin rates are involved, understanding a brown dwarf’s interior structure becomes increasingly important: The material inside likely shifts and deforms in ways that could change how fast the object can spin. Similar to gas planets such as Jupiter and Saturn, brown dwarfs are composed mostly of hydrogen and helium.

But they are also significantly denser than most giant planets. Scientists think the hydrogen in the core of a brown dwarf is under such tremendous pressures that it starts behaving like a metal rather than an inert gas: It has free-floating conducting electrons, much like a copper conductor. That changes how heat is conducted through the interior, and with very fast spin rates, may also affect how the mass inside an astronomical object is distributed.

“This state of hydrogen, or any gas under such extreme pressure, is still very enigmatic,” said Stanimir Metchev, co-author on the paper and the Canada Research Chair in Extrasolar Planets at the Institute for Earth and Space Exploration at the Western University. “It is extremely challenging to reproduce this state of matter even in the most advanced high-pressure physics laboratories.”

Physicists use observations, laboratory data, and mathematics to create models of what brown dwarf interiors should look like and how they should behave, even under extreme conditions. But current models show that the maximum brown dwarf spin speed should be about 50% to 80% faster than the one-hour rotation period described in the new study.

“It is possible that these theories don’t have the full picture yet,” said Metchev. “Some unappreciated factor may be coming into play that doesn’t let the brown dwarf spin faster.” Additional observations and theoretical work may yet reveal whether there’s some braking mechanism that stops brown dwarfs from self-destruction and whether there are brown dwarfs spinning even faster in the darkness.

NASA's Jet Propulsion Laboratory, a division of Caltech, managed Spitzer mission operations for NASA's Science Mission Directorate in Washington. Science operations were conducted at the Spitzer Science Center at IPAC at Caltech. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado. The Spitzer data archive is housed at the Infrared Science Archive at IPAC at Caltech in Pasadena, California. The international Gemini Observatory is a Program of the National Science Foundation’s NOIRLab.

For more information about NASA’s Spitzer mission, visit:

https://science.nasa.gov/mission/spitzer/ or

https://www.ipac.caltech.edu/project/spitzer

News Media Contact

Calla Cofield

Jet Propulsion Laboratory, Pasadena, Calif. 818-393-1821

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s

other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Webb to Study Young Exoplanets on the Edge

9 min read

Before planets around other stars were first discovered in the 1990s, these far-flung exotic worlds lived only in the imagination of science fiction writers.

But even their creative minds could not have conceived of the variety of worlds astronomers have uncovered. Many of these worlds, called exoplanets, are vastly different from our solar system’s family of planets. They range from star-hugging “hot Jupiters” to oversized rocky planets dubbed “super Earths.” Our universe apparently is stranger than fiction.

Seeing these distant worlds isn’t easy because they get lost in the glare of their host stars. Trying to detect them is like straining to see a firefly hovering next to a lighthouse’s brilliant beacon.

That’s why astronomers have identified most of the more than 4,000 exoplanets found so far using indirect techniques, such as through a star’s slight wobble or its unexpected dimming as a planet passes in front of it, blocking some of the starlight.

These techniques work best, however, for planets orbiting close to their stars, where astronomers can detect changes over weeks or even days as the planet completes its racetrack orbit. But finding only star-skimming planets doesn’t provide astronomers with a comprehensive picture of all the possible worlds in star systems.

Another technique researchers use in the hunt for exoplanets, which are planets orbiting other stars, is one that focuses on planets that are farther away from a star’s blinding glare. Scientists have uncovered young exoplanets that are so hot they glow in infrared light using specialized imaging techniques that block out the glare from the star. In this way, some exoplanets can be directly seen and studied.

NASA’s upcoming James Webb Space Telescope will help astronomers probe farther into this bold new frontier. Webb, like some ground-based telescopes, is equipped with special optical systems called coronagraphs, which use masks designed to block out as much starlight as possible to study faint exoplanets and to uncover new worlds.

Two targets early in Webb’s mission are the planetary systems 51 Eridani and HR 8799. Out of the few dozen directly imaged planets, astronomers plan to use Webb to analyze in detail the systems that are closest to Earth and have planets at the widest separations from their stars. This means that they appear far enough away from a star’s glare to be directly observed. The HR 8799 system resides 133 light-years and 51 Eridani 96 light-years from Earth.

Webb’s Planetary Targets

Two observing programs early in Webb’s mission combine the spectroscopic capabilities of the Near Infrared Spectrograph (NIRSpec) and the imaging of the Near Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI) to study the four giant planets in the HR 8799 system. In a third program, researchers will use NIRCam to analyze the giant planet in 51 Eridani.

The four giant planets in the HR 8799 system are each roughly 10 Jupiter masses. They orbit more than 14 billion miles from a star that is slightly more massive than the Sun. The giant planet in 51 Eridani is twice the mass of Jupiter and orbits about 11 billion miles from a Sun-like star. Both planetary systems have orbits oriented face-on toward Earth. This orientation gives astronomers a unique opportunity to get a bird’s-eye view down on top of the systems, like looking at the concentric rings on an archery target.

Many exoplanets found in the outer orbits of their stars are vastly different from our solar system planets. Most of the exoplanets discovered in this outer region, including those in HR 8799, are between 5 and 10 Jupiter masses, making them the most massive planets ever found to date.

These outer exoplanets are relatively young, from tens of millions to hundreds of millions of years old—much younger than our solar system's 4.5 billion years. So they're still glowing with heat from their formation. The images of these exoplanets are essentially baby pictures, revealing planets in their youth.

Webb will probe into the mid-infrared, a wavelength range astronomers have rarely used before to image distant worlds. This infrared "window" is difficult to observe from the ground because of thermal emission from and absorption in Earth's atmosphere.

"Webb's strong point is the uninhibited light coming through space in the mid-infrared range," said Klaus Hodapp of the University of Hawaii in Hilo, lead investigator of the NIRSpec observations of the HR 8799 system. "Earth's atmosphere is pretty difficult to work through. The major absorption molecules in our own atmosphere prevent us from seeing interesting features in planets."

The mid-infrared "is the region where Webb really will make seminal contributions to understanding what are the particular molecules, what are the properties of the atmosphere that we hope to find which we don't really get just from the shorter, near-infrared wavelengths," said Charles Beichman of NASA's Jet Propulsion Laboratory in Pasadena, California, lead investigator of the NIRCam and MIRI observations of the HR 8799 system. "We'll build on what the ground-based observatories have done, but the goal is to expand on that in a way that would be impossible without Webb."

How Do Planets Form?

One of the researchers' main goals in both systems is to use Webb to help determine how the exoplanets formed. Were they created through a buildup of material in the disk surrounding the star, enriched in heavy elements such as carbon, just as Jupiter probably did? Or, did they form from the collapse of a hydrogen cloud, like a star, and become smaller under the relentless pull of gravity?

Atmospheric makeup can provide clues to a planet's birth. "One of the things we'd like to understand is the ratio of the elements that have gone into the formation of these planets," Beichman said. "In particular, carbon versus oxygen tells you quite a lot about where the gas that formed the planet comes from. Did it come from a disk that accreted a lot of the heavier elements or did it come from the interstellar medium? So it's what we call the carbon-to-oxygen ratio that is quite indicative of formation mechanisms."

To answer these questions, the researchers will use Webb to probe deeper into the exoplanets' atmospheres. NIRCam, for example, will measure the atmospheric fingerprints of elements like methane. It also will look at cloud features and the temperatures of these planets. "We already have a lot of information at these near-infrared wavelengths from ground-based facilities," said Marshall Perrin of the Space Telescope Science Institute in Baltimore, Maryland, lead investigator of NIRCam observations of 51 Eridani b. "But the data from Webb will be much more precise, much more sensitive. We'll have a more complete set of wavelengths, including filling in gaps where you can't get those wavelengths from the ground."

The astronomers will also use Webb and its superb sensitivity to hunt for less-massive planets far from their star. "From ground-based observations, we know that these massive planets are relatively rare," Perrin said. "But we also know that for the inner parts of systems, lower-mass planets are dramatically more common than larger-mass planets. So the question is, does it also hold true for these further separations out?" Beichman added, "Webb's operation in the cold environment of space allows a search for fainter, smaller planets, impossible to detect from the ground."

Another goal is understanding how the myriad planetary systems discovered so far were created.

“I think what we are finding is that there is a huge diversity in solar systems,” Perrin said. “You have systems where you have these hot Jupiter planets in very close orbits. You have systems where you don’t. You have systems where you have a 10-Jupiter-mass planet and ones in which you have nothing more massive than several Earths. We ultimately want to understand how the diversity of planetary system formation depends on the environment of the star, the mass of the star, all sorts of other things and eventually through these population-level studies, we hope to place our own solar system in context.”

The NIRSpec spectroscopic observations of HR 8799 and the NIRCam observations of 51 Eridani are part of the Guaranteed Time Observations programs that will be conducted shortly after Webb’s launch later this year. The NIRCam and MIRI observations of HR 8799 is a collaboration of two instrument teams and is also part of the Guaranteed Time Observations program.

The James Webb Space Telescope will be the world’s premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

By Donna WeaverSpace Telescope Science Institute, Baltimore, Md.

Media Contact:

Laura BetzNASA’s Goddard Space Flight Center, Greenbelt, Md.laura.e.betz@nasa.gov

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Roman Telescope Predicted to Find 100,000 Transiting Planets

6 min read

NASA Science Editorial Team

NASA’s Nancy Grace Roman Space Telescope will create enormous cosmic panoramas, helping us answer questions about the evolution of our universe. Astronomers also expect the mission to find thousands of planets using two different techniques as it surveys a wide range of stars in the Milky Way.

Roman will locate these potential new worlds, or exoplanets, by tracking the amount of light coming from distant stars over time. In a technique called gravitational microlensing, a spike in light signals that a planet may be present. On the other hand, if the light from a star dims periodically, it could be because there is a planet crossing the face of a star as it completes an orbit. This technique is called the transit method. By employing these two methods to find new worlds, astronomers will capture an unprecedented view of the composition and arrangement of planetary systems across our galaxy.

Scheduled for launch in the mid-2020s, Roman will be one of NASA’s most prolific planet hunters.

The mission’s large field of view, exquisite resolution, and incredible stability will provide a unique observational platform for discovering the tiny changes in light required to find other worlds via microlensing. This detection method takes advantage of the gravitational light-bending effects of massive objects predicted by Einstein's general theory of relativity.

It occurs when a foreground star, the lens, randomly aligns with a distant background star, the source, as seen from Earth. As the stars drift along in their orbits around the galaxy, the alignment shifts over days to weeks, changing the apparent brightness of the source star. The precise pattern of these changes provides astronomers with clues about the nature of the lensing star in the foreground, including the presence of planets around it.

Many of the stars Roman will already be looking at for the microlensing survey may harbor transiting planets.

“Microlensing events are rare and occur quickly, so you need to look at a lot of stars repeatedly and precisely measure brightness changes to detect them,” said astrophysicist Benjamin Montet, a Scientia Lecturer at the University of New South Wales in Sydney. “Those are exactly the same things you need to do to find transiting planets, so by creating a robust microlensing survey, Roman will produce a nice transit survey as well.”

In a 2017 paper, Montet and his colleagues showed that Roman – formerly known as WFIRST – could catch more than 100,000 planets passing in front of, or transiting, their host stars. Periodic dimming as a planet repeatedly crosses in front of its star provides strong evidence of its presence, something astronomers typically have to confirm through follow-up observations.

The transit approach to finding exoplanets has been wildly successful for NASA's Kepler and K2 missions, which have discovered about 2,800 confirmed planets to date, and is currently used by NASA’s Transiting Exoplanet Survey Satellite (TESS). Since Roman will find planets orbiting more distant, fainter stars, scientists will often have to rely on the mission’s expansive data set to verify the planets. For example, Roman might see secondary eclipses – small brightness dips when a planetary candidate passes behind its host star, which could help confirm its presence.

The twin detection methods of microlensing and transits complement each other, allowing Roman to find a diverse array of planets. The transit method works best for planets orbiting very close to their star. Microlensing, on the other hand, can detect planets orbiting far from their host stars. This technique can also find so-called rogue planets, which are not gravitationally bound to a star at all. These worlds can range from rocky planets smaller than Mars to gas giants.

Roughly three quarters of the transiting planets Roman will find are expected to be gas giants like Jupiter and Saturn, or ice giants like Uranus and Neptune. Most of the remainder will likely be planets that are between four and eight times as massive as Earth, known as mini-Neptunes. These worlds are particularly interesting since there are no planets like them in our solar system.

Some of the transiting worlds Roman captures are expected to lie within their star's habitable zone, or the range of orbital distances where a planet may host liquid water on its surface. The location of this region varies depending on how large and hot the host star is – the smaller and cooler the star, the closer in its habitable zone will be. Roman's sensitivity to infrared light makes it a powerful tool for finding planets around these dimmer orange stars.

Roman will also look farther out from Earth than previous planet-hunting missions. Kepler's original survey monitored stars at an average distance of around 2,000 light-years. It viewed a modest region of the sky, totaling about 115 square degrees. TESS scans nearly the entire sky, however it aims to find worlds that are closer to Earth, with typical distances of around 150 light-years. Roman will use both the microlensing and transit detection methods to find planets up to 26,000 light-years away.

Combining the results from Roman's microlensing and transiting planet searches will help provide a more complete planet census by revealing worlds with a wide range of sizes and orbits. The mission will offer the first opportunity to find large numbers of transiting planets located thousands of light-years away, helping astronomers learn more about the demographics of planets in different regions of the galaxy.

"The fact that we'll be able to detect thousands of transiting planets just by looking at microlensing data that's already been taken is exciting," said study co-author Jennifer Yee, an astrophysicist at the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts. "It's free science."

The Nancy Grace Roman Space Telescope is managed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado, L3Harris Technologies in Melbourne, Florida, and Teledyne Scientific & Imaging in Thousand Oaks, California.

For more information about NASA's Nancy Grace Roman Space Telescope, visit:

https://science.nasa.gov/mission/roman-space-telescope/

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

The stars in the big Wyoming skies inspired Aaron Vigil as a child to dream big. Today, he's a mechanical engineer working on the Solar Array Sun Shield (SASS) for the Nancy Grace Roman Space Telescope at Goddard. Name: Aaron VigilTitle: Mechanical EngineerFormal Job Classification: Aerospace Technology, Flight StructuresOrganization: Mechanical Engineering, Engineering and Technology Directorate (Code […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Pandora Mission Would Expand NASA's Capabilities in Probing Alien Worlds

6 min read

In the quest for habitable planets beyond our own, NASA is studying a mission concept called Pandora, which could eventually help decode the atmospheric mysteries of distant worlds in our galaxy. One of four low-cost astrophysics missions selected for further concept development under NASA's new Pioneers program, Pandora would study approximately 20 stars and exoplanets – planets outside of our solar system – to provide precise measurements of exoplanetary atmospheres.

This mission would seek to determine atmospheric compositions by observing planets and their host stars simultaneously in visible and infrared light over long periods. Most notably, Pandora would examine how variations in a host star's light impacts exoplanet measurements. This remains a substantial problem in identifying the atmospheric makeup of planets orbiting stars covered in starspots, which can cause brightness variations as a star rotates.

Pandora is a small satellite mission known as a SmallSat, one of three such orbital missions receiving the green light from NASA to move into the next phase of development in the Pioneers program. SmallSats are low-cost spaceflight missions that enable the agency to advance scientific exploration and increase access to space. Pandora would operate in Sun-synchronous low-Earth orbit, which always keeps the Sun directly behind the satellite. This orbit minimizes light changes on the satellite and allows Pandora to obtain data over extended periods. Of the SmallSat concepts selected for further study, Pandora is the only one focused on exoplanets.

"Exoplanetary science is moving from an era of planet discovery to an era of atmospheric characterization," said Elisa Quintana, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and the principal investigator for Pandora. "Pandora is focused on trying to understand how stellar activity affects our measurements of exoplanet atmospheres, which will lay the groundwork for future exoplanet missions aiming to find planets with Earth-like atmospheres."

Pandora concentrates on studying exoplanetary and stellar atmospheres by surveying planets as they cross in front of – or transit – their host stars. To accomplish this, Pandora would take advantage of a proven technique called transit spectroscopy, which involves measuring the amount of starlight filtering through a planet's atmosphere, and splitting it into bands of color known as a spectrum. These colors encode information that helps scientists identify gases present in the planet's atmosphere, and can help determine if a planet is rocky with a thin atmosphere like Earth or if it has a thick gas envelope like Neptune.

This mission, however, would take transit spectroscopy a step further. Pandora is designed to mitigate one of the technique's most crucial setbacks: stellar contamination. "Stars have atmospheres and changing surface features like spots that affect our measurements," said Jessie Christiansen, the deputy science lead at the NASA Exoplanet Archive at Caltech in Pasadena, California, and a co-investigator for Pandora. "To be sure we're really observing an exoplanet's atmosphere, we need to untangle the planet's variations from those of the star."

Pandora would separate stellar and exoplanetary signals by observing them simultaneously in infrared and visible light. Stellar contamination is easier to detect at the shorter wavelengths of visible light, and so obtaining atmospheric data through both infrared and visible light would allow scientists to better differentiate observations coming from exoplanet atmospheres and stars.

"Stellar contamination is a sticking point that complicates precise observations of exoplanets," said Benjamin Rackham, a 51 Pegasi b Postdoctoral Fellow at the Massachusetts Institute of

Technology in Cambridge and a co-investigator for Pandora. “Pandora would help build the necessary tools for disentangling stellar and planetary signals, allowing us to better study the properties of both starspots and exoplanetary atmospheres.”

Joining forces with NASA’s larger missions, Pandora would operate concurrently with the James Webb Space Telescope, slated for launch later this year. Webb will provide the ability to study the atmospheres of exoplanets as small as Earth with unprecedented precision, and Pandora would seek to expand the telescope’s research and findings by observing the host stars of previously identified planets over longer periods.

Missions such as NASA’s Transiting Exoplanet Survey Satellite (TESS), Hubble Space Telescope, and the retired Kepler and Spitzer spacecraft have given scientists astonishing glimpses at these distant worlds, and laid a strong foundation in exoplanetary knowledge. These missions, however, have yet to fully address the stellar contamination problem, the magnitude of which is uncertain in previous studies of exoplanetary atmospheres. Pandora seeks to fill these critical gaps in NASA’s understanding of planetary atmospheres and increase the capabilities in exoplanet research.

“Pandora is the right mission at the right time because thousands of exoplanets have already been discovered, and we are aware of many that are amenable to atmospheric characterization that orbit small active stars,” said Jessie Dotson, an astrophysicist at NASA’s Ames Research Center in California’s Silicon Valley and the deputy principal investigator for Pandora. “The next frontier is to understand the atmospheres of these planets, and Pandora would play a key role in uncovering how stellar activity impacts our ability to characterize atmospheres. It would be a great complement to Webb’s mission.”

Lawrence Livermore National Laboratory (LLNL), in Livermore, California, is co-leading the Pandora mission with NASA’s Goddard Space Flight Center. LLNL will manage the mission and leverage capabilities developed for other government agencies, including a low-cost approach to the telescope design and fabrication that enables this groundbreaking exoplanet science from a SmallSat platform.

NASA’s Pioneers program, which consists of SmallSats, payloads attached to the International Space Station, and scientific balloon experiments, fosters innovative space and suborbital experiments for early-to-mid-career researchers through low-cost, small hardware missions. Under this new program, Pandora would operate on a five-year timeline with a budget cap of $20 million.

Despite tight constraints, the Pioneers program enables Pandora to concentrate on a focused research question while engaging a diverse team of students and early career scientists from more than a dozen of universities and research institutes. This SmallSat platform creates an excellent blueprint for small-scale missions to make an impact in the astrophysics community.

“Pandora’s long-duration observations in visible and infrared light are unique and well-suited for SmallSats,” said Quintana. “We are excited that Pandora will play a crucial role in NASA’s quest for finding other worlds that could potentially be habitable.”

For more information about the Pioneers program, visit:

https://science.nasa.gov/astrophysics/programs/astrophysics-pioneers

By Anisha EngineerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

In a surprise finding, astronomers using NASA’s Hubble Space Telescope have discovered that the blowtorch-like…

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Roman Mission Predicted to Find 100,000 Transiting Planets

6 min read

NASA’s Nancy Grace Roman Space Telescope will create enormous cosmic panoramas, helping us answer questions about the evolution of our universe. Astronomers also expect the mission to find thousands of planets using two different techniques as it surveys a wide range of stars in the Milky Way.

Roman will locate these potential new worlds, or exoplanets, by tracking the amount of light coming from distant stars over time. In a technique called gravitational microlensing, a spike in light signals that a planet may be present. On the other hand, if the light from a star dims periodically, it could be because there is a planet crossing the face of a star as it completes an orbit. This technique is called the transit method. By employing these two methods to find new worlds, astronomers will capture an unprecedented view of the composition and arrangement of planetary systems across our galaxy.

Scheduled for launch in the mid-2020s, Roman will be one of NASA’s most prolific planet hunters.

The mission’s large field of view, exquisite resolution, and incredible stability will provide a unique observational platform for discovering the tiny changes in light required to find other worlds via microlensing. This detection method takes advantage of the gravitational light-bending effects of massive objects predicted by Einstein’s general theory of relativity.

It occurs when a foreground star, the lens, randomly aligns with a distant background star, the source, as seen from Earth. As the stars drift along in their orbits around the galaxy, the alignment shifts over days to weeks, changing the apparent brightness of the source star. The precise pattern of these changes provides astronomers with clues about the nature of the lensing star in the foreground, including the presence of planets around it.

Many of the stars Roman will already be looking at for the microlensing survey may harbor transiting planets.

“Microlensing events are rare and occur quickly, so you need to look at a lot of stars repeatedly and precisely measure brightness changes to detect them,” said astrophysicist Benjamin Montet, a Scientia Lecturer at the University of New South Wales in Sydney. “Those are exactly the same things you need to do to find transiting planets, so by creating a robust microlensing survey, Roman will produce a nice transit survey as well.”

In a 2017 paper, Montet and his colleagues showed that Roman – formerly known as WFIRST – could catch more than 100,000 planets passing in front of, or transiting, their host stars. Periodic dimming as a planet repeatedly crosses in front of its star provides strong evidence of its presence, something astronomers typically have to confirm through follow-up observations.

The transit approach to finding exoplanets has been wildly successful for NASA’s Kepler and K2 missions, which have discovered about 2,800 confirmed planets to date, and is currently used by NASA’s Transiting Exoplanet Survey Satellite (TESS). Since Roman will find planets orbiting more distant, fainter stars, scientists will often have to rely on the mission’s expansive data set to verify the planets. For example, Roman might see secondary eclipses – small brightness dips when a planetary candidate passes behind its host star, which could help confirm its presence.

The twin detection methods of microlensing and transits complement each other, allowing Roman to find a diverse array of planets. The transit method works best for planets orbiting very close to their star. Microlensing, on the other hand, can detect planets orbiting far from their host stars. This technique can also find so-called rogue planets, which are not gravitationally bound to a star at all. These worlds can range from rocky planets smaller than Mars to gas giants.

Roughly three quarters of the transiting planets Roman will find are expected to be gas giants like Jupiter and Saturn, or ice giants like Uranus and Neptune. Most of the remainder will likely be planets that are between four and eight times as massive as Earth, known as mini-Neptunes. These worlds are particularly interesting since there are no planets like them in our solar system.

Some of the transiting worlds Roman captures are expected to lie within their star's habitable zone, or the range of orbital distances where a planet may host liquid water on its surface. The location of this region varies depending on how large and hot the host star is – the smaller and cooler the star, the closer in its habitable zone will be. Roman's sensitivity to infrared light makes it a powerful tool for finding planets around these dimmer orange stars.

Roman will also look farther out from Earth than previous planet-hunting missions. Kepler's original survey monitored stars at an average distance of around 2,000 light-years. It viewed a modest region of the sky, totaling about 115 square degrees. TESS scans nearly the entire sky, however it aims to find worlds that are closer to Earth, with typical distances of around 150 light-years. Roman will use both the microlensing and transit detection methods to find planets up to 26,000 light-years away.

Combining the results from Roman's microlensing and transiting planet searches will help provide a more complete planet census by revealing worlds with a wide range of sizes and orbits. The mission will offer the first opportunity to find large numbers of transiting planets located thousands of light-years away, helping astronomers learn more about the demographics of planets in different regions of the galaxy.

"The fact that we'll be able to detect thousands of transiting planets just by looking at microlensing data that's already been taken is exciting," said study co-author Jennifer Yee, an astrophysicist at the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts. "It's free science."

The Nancy Grace Roman Space Telescope is managed at NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado, L3Harris Technologies in Melbourne, Florida, and Teledyne Scientific & Imaging in Thousand Oaks, California.

For more information about NASA's Nancy Grace Roman Space Telescope, visit: https://www.nasa.gov/roman

Download high-resolution video and images from NASA's Scientific Visualization Studio

By Claire Andreoli and Ashley BalzerNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Distant Planet May Be On Its Second Atmosphere, NASA's Hubble Finds

6 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Scientists using NASA's Hubble Space Telescope have found evidence that a planet orbiting a distant star may have lost its atmosphere but gained a second one through volcanic activity.

The planet, GJ 1132 b, is hypothesized to have begun as a gaseous world with a thick hydrogen blanket of atmosphere. Starting out at several times the diameter of Earth, this so-called "sub-Neptune" is believed to have quickly lost its primordial hydrogen and helium atmosphere due to the intense radiation of the hot, young star it orbits. In a short period of time, such a planet would be stripped down to a bare core about the size of Earth. That's when things got interesting.

To the surprise of astronomers, Hubble observed an atmosphere which, according to their theory, is a "secondary atmosphere" that is present now. Based on a combination of direct observational evidence and inference through computer modeling, the team reports that the atmosphere consists of molecular hydrogen, hydrogen cyanide, methane and also contains an aerosol haze. Modeling suggests the aerosol haze is based on photochemically produced hydrocarbons, similar to smog on Earth.

Scientists interpret the current atmospheric hydrogen in GJ 1132 b as hydrogen from the original atmosphere which was absorbed into the planet's molten magma mantle and is now being slowly released through volcanic processes to form a new atmosphere. The atmosphere we see today is believed to be continually replenished to balance the hydrogen escaping into space.

"It's super exciting because we believe the atmosphere that we see now was regenerated, so it could be a secondary atmosphere," said study co-author Raissa Estrela of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California. "We first thought that these highly irradiated planets could be pretty boring because we believed that they lost their atmospheres. But we looked at existing observations of this planet with Hubble and said, 'Oh no, there is an atmosphere there.'"

The findings could have implications for other exoplanets, planets beyond our solar system.

"How many terrestrial planets don't begin as terrestrials? Some may start as sub-Neptunes, and they become terrestrials through a mechanism that photo-evaporates the primordial atmosphere. This process works early in a planet's life, when the star is hotter," said lead author Mark Swain of JPL. "Then the star cools down and the planet's just sitting there. So you've got this mechanism where you can cook off the atmosphere in the first 100 million years, and then things settle down. And if you can regenerate the atmosphere, maybe you can keep it."

In some ways GJ 1132 b, located about 41 light-years from Earth, has tantalizing parallels to Earth, but in some ways it is very different. Both have similar densities, similar sizes, and similar ages, being about 4.5 billion years old. Both started with a hydrogen-dominated atmosphere, and both were hot before they cooled down. The team's work even suggests that GJ 1132 b and Earth have similar atmospheric pressure at the surface.

But the planets have profoundly different formation histories. Earth is not believed to be the surviving core of a sub-Neptune. And Earth orbits at a comfortable distance from our Sun. GJ 1132 b is so close to its red dwarf star that it completes an orbit around its host star once every day and a half. This extremely close proximity keeps GJ 1132 b tidally locked, showing the same face to its star at all times—just as our Moon keeps one hemisphere permanently facing Earth.

"The question is, what is keeping the mantle hot enough to remain liquid and power volcanism?" asked Swain. "This system is special because it has the opportunity for quite a lot of tidal heating."

Tidal heating is a phenomenon that occurs through friction, when energy from a planet's orbit and rotation is dispersed as heat inside the planet. GJ 1132 b is in an elliptical orbit, and the tidal forces acting on it are strongest when it is closest to or farthest from its host star. At least one other planet in the host star's system also gravitationally pulls on the planet.

The consequences are that the planet is squeezed or stretched through this gravitational "pumping." That tidal heating keeps the mantle liquid for a long time. A nearby example in our own solar system is Jupiter's moon Io, which has continuous volcanic activity due to a tidal tug-of-war from Jupiter and the neighboring Jovian moons.

Given GJ 1132 b's hot interior, the team believes the planet's cooler, overlying crust is extremely thin, perhaps only hundreds of feet thick. That's much too feeble to support anything resembling volcanic mountains. Its flat terrain may also be cracked like an eggshell due to tidal flexing. Hydrogen and other gases could be released through such cracks.

NASA's upcoming James Webb Space Telescope has the ability to observe this exoplanet. Webb's infrared vision may allow scientists to see down to the planet's surface. "If there are magma pools or volcanism going on, those areas will be hotter," explained Swain. "That will generate more emission, and so they'll be looking potentially at the actual geologic activity—which is exciting!"

The team's findings will be published an upcoming issue of The Astronomical Journal.

Science: NASA, ESA, and M. Swain (Jet Propulsion Laboratory)

Media Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.govAnn Jenkins / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4488 / 410-338-4514jenkins@stsci/edu / villard@stsci.edu

Science Contacts:

Mark Swain / Raissa EstrelaJet Propulsion Laboratory, Pasadena, Californiamark.r.swain@jpl.nasa.gov / restrela@jpl.nasa.gov

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

Life in the Universe: What are the Odds?

9 min read

Pat Brennan

As humanity casts an ever-wider net across the cosmos, capturing evidence of thousands of worlds, an ancient question haunts us: Is anybody out there?

The good news: We know vastly more than any previous generation. Our galaxy is crowded with exoplanets – planets around other stars. A healthy percentage of them are small, rocky worlds, of a similar size and likely similar composition to our home planet.

The ingredients in the recipe for earthly life – water, elements associated with life, available sources of energy – appear to be almost everywhere we've looked.

Now the bad news. We have yet to find another "Earth" with life, intelligent or not. Observing signs of possible microbial life in exoplanet atmospheres is currently just out of reach. No convincing evidence of advanced technology – artificial signals by radio or other means, or the telltale sign of, say, massive extraterrestrial engineering projects – has yet crossed our formidable arrays of telescopes in space or on the ground.

And finding non-intelligent life is far more likely; Earth existed for most of its history, 4.25 billion years, without a whisper of technological life, and human civilization is a very late-breaking development.

Is there life beyond Earth? So far, the silence is deafening.

"I hope it's there," said Shawn Domagal-Goldman, a research astronomer at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "I want it to be there. I'll be planning a party if we find it."

Domagal-Goldman co-leads a team of exoplanet hunters who, in the years and decades ahead, are planning to do just that. Working with scientists across NASA, as well as academic and international partners, his team and others are helping to design and build the next generation of instruments to sift through light from other worlds, and other suns. The goal: unambiguous evidence of another living, breathing world.

While the chances of finding life elsewhere remain unknown, the odds can be said to be improving. A well-known list of the data needed to determine the likely abundance of life-bearing worlds, though highly conjectural, is known as the "Drake equation."

Put forward in 1961 by astronomer Frank Drake, the list remains mostly blank. It begins with the rate of star formation in the galaxy and the fraction of stars that have planets, leading step-by-step through the portion of planets that support life and – most speculatively – to the existence and durability of detectable, technological civilizations.

When Drake introduced this roadmap to life beyond Earth, all the terms – the signposts along the way – were blank.

Some of the first few items are now known, including the potential presence of habitable worlds, said researcher Ravi Kopparapu from Goddard, also a co-leader of Domagal-Goldman's team. He studies the habitability and potential for life on exoplanets.

If we develop and launch a powerful enough space telescope, “we could figure out if we have advanced life or biological life,” he said.

Drake’s list can be a good conversation starter, and a useful way to frame the complex questions around the possibility of other life. But these days, scientists don’t spend a great deal of time discussing it, Domagal-Goldman said.

Instead, they use a narrower yardstick: the habitable zone.

Every star, like every campfire, has a definable zone of radiated warmth. Too close, and your marshmallow – or your planet – might end up as nothing more than a charred cinder. Too far away, and its surface remains cold and unappetizing.

In both cases, “just right” is more likely to be somewhere in between.

For a planet, the habitable zone is the distance from a star that allows liquid water to persist on its surface – as long as that planet has a suitable atmosphere.

In our solar system, Earth sits comfortably inside the Sun’s habitable zone. Broiling planet Venus is within the inner edge, while refrigerated Mars is near the outer boundary.

Determine the distance of an exoplanet from the star itself, as well as the star’s size and energy output, and you can estimate whether the planet falls within the habitable zone.

For larger, hotter stars, the zone is farther away; for smaller, cooler stars, it can be very close indeed. Finding these “just right” planets in the habitable zone is one of the keys to finding signs of life.

“If they fit within these parameters, they could potentially support a temperate environment,” said Natasha Batalha, a research scientist at the NASA Ames Research Center. “Therefore it would be incredibly interesting to study their atmospheres.”

Batalha’s specialty, in fact, is finding ways to read exoplanet atmospheres – and building computer models to better understand them.

“That is the next step, the next frontier,” she said.

The habitable zone concept is not yet definitive. Small, rocky worlds like ours that orbit other stars are too far away to determine whether they have atmospheres, at least using present-day technology.

That’s where teams like the one co-led by Kopparapu and Domagal-Goldman come in. The space telescopes and instruments now on their drawing boards are meant to be powerful enough to peer into these atmospheres and identify the molecules present. That will tell us which gases dominate.

We could find a small, rocky, watery world around a Sun-like star with an atmosphere of nitrogen, oxygen, and carbon dioxide: a little like looking in a mirror.

“To search for life anywhere, we have this ‘follow the water’ approach,” Domagal-Goldman said. “Anywhere you find water on Earth, you find life. Whether it’s life on Mars, ocean worlds, or exoplanets, water is the first signpost we’re looking for.”

For now, the habitable zone remains a kind of first cut in the search for life-bearing worlds.

“The habitable zone is a very useful tool for mission design,” said Rhonda Morgan of NASA’s Jet Propulsion Laboratory in Southern California.

She studies how to use the data gathered so far on exoplanets to refine designs for future space telescopes.

Over the past quarter century, thousands of exoplanets have been confirmed in a Milky Way galaxy that likely holds trillions. Thousands more will come to light in the years ahead. Tools like the habitable zone will help planet hunters sort through these growing ranks to pick the most likely candidates for supporting life.

“We are in a position now where we can propose a potential, future mission that would be capable of directly imaging an Earth-like planet around a nearby, Sun-like star,” she said. “This is the first time in history that the technology has been this close, probably less than 10 years from launch.”

Still, we might need something beyond the habitable-zone concept for more extreme cases. It won’t help much, for instance, with “weird” life – life as we don’t know it. Living things on other worlds might use vastly different chemistry and molecular compounds, or even a solvent other than water.

“This is one of the questions we get from the public often: If there are aliens, how are we going to recognize them if they’re really weird?” Domagal-Goldman said. “How do we find what we would consider to be weird life? And how do we make sure not to be tricked by strange, dead planets that look alive – mirages in the desert?”

Life on planets around other stars also might be hidden in a subsurface ocean encased in ice, invisible even to our most powerful space telescopes. Moons of Jupiter and Saturn are known to harbor such oceans, some revealing through remote sensing at least a few of the characteristics we expect for habitable worlds.

Some “exo-moons” also might be habitable worlds, as in the film, “Avatar.” But even proposed, future instruments are unlikely to have sufficient power to detect atmospheres of moons around giant exoplanets.

Still, the habitable zone is a good start, a way to zero in on signs of life made familiar by our fellow organisms here on planet Earth.

A shortcut to finding lifeforms like ourselves, of course, would be to intercept tech-savvy communications. Searches for signs of intelligent life have been underway for decades.

In recent years, among NASA scientists, such potential signs have acquired an intriguing new name: technosignatures.

Evidence of a communicative, technological species somewhere among the endless fields of stars could come in the traditional form: signals by radio or optical light waves, or from some other slice of the electromagnetic spectrum.

But scientists imagine many other forms. An exoplanet atmosphere might show signs of synthetic gases, such as CFCs, revealing an industrial species like us.

Or maybe we’ll see the glimmer of something like a “Dyson sphere,” popularized by physicist Freeman Dyson: an epic-scale structure built around a star to capture the lion’s share of its energy.

Such possibilities remain speculative. For now, we have no real answer to a disturbing question from another 20th century physicist, Enrico Fermi.

Where is everybody?

The question has fueled more than 70 years of debate, but boils down to a simple observation. Our Milky Way galaxy has plenty of stars, plenty of planets, and plenty of time to develop intelligent lifeforms – some of whom might well have had billions of years to develop interstellar travel.

Yet so far, we've seen no sign of such technology, nor heard a peep of conversation. Why is the cosmos so profoundly silent?

"If life had so much time to evolve, why haven't we found it?" Batalha asks, to summarize the question. "Why isn't life just crawling everywhere in the galaxy, or the universe? It could be a combination of a lot of things. Space travel is very difficult for us."

Vast amounts of energy would be needed just to get us to our nearest neighboring star, Proxima Centauri, she said. "It would just be incredibly expensive, and require a lot of resources."

And once we – or some other civilization – reached such a distant destination, she said, another problem would be perpetuating the travelers' existence into future generations.

Experts offer many reasons why somebody, or something, might be out there, yet beyond our detection. On the other hand, the ultra-cautious might remind us that, while a lifeless cosmos seems unlikely, we have exactly zero information one way or the other.

Still, scientists like Kopparapu say they like our chances of finding some form of life, and are hard at work on the telescopes and instruments that could make that future, party-starting epiphany a reality.

"It's not a question of 'if,' it's a question of 'when' we find life on other planets," he said. "I'm sure in my lifetime, in our lifetime, we will know if there is life on other worlds."

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Space Telescope Delivers the Goods: 2,200 Possible Planets

6 min read

NASA Science Editorial Team

The news is out of this world: NASA's TESS space telescope has captured evidence of more than 2,200 candidate planets orbiting bright, nearby stars, including hundreds of "smaller" planets – many possibly rocky worlds in some ways similar to Earth.

As scientists seek to confirm the discoveries, TESS's large haul promises a possible explosion in the number of known exoplanets – planets orbiting other stars. Perhaps even better: The relative brightness of the stars they orbit should allow TESS's successor telescopes to probe some of these planets' atmospheres to search for water, oxygen, and other molecules that might make them hospitable to life.

The bonanza of exoplanet candidates is detailed in a newly published paper that catalogs the two-year prime mission for TESS (the Transiting Exoplanet Survey Satellite), that has produced a steady stream of exoplanet discoveries since its launch in 2018. TESS, in a wide orbit between Earth and the Moon, is now on an extended mission: to fill in gaps in its nearly all-sky survey – that is, both domes of the night sky over Earth's northern and southern hemispheres.

"The exciting thing is to look at the map of TESS exoplanets as a kind of to-do list – with 2,000 things on it," said Natalia Guerrero, a researcher at the Massachusetts Institute of Technology and the paper's lead author.

An international team of astronomers examined TESS's rich trove of "light curves," or changes in the brightness of stars as orbiting planets pass in front of them. This search for shadows relies on extremely sensitive detectors behind TESS's four cameras that can pick up dips in stellar brightness as tiny as 0.1% or even less.

"It's an incredible body of work – a rich stockpile of exoplanet candidates for the community to mine and explore for years to come," Jessie Christiansen, a research scientist at NASA's Exoplanet Science Institute and a co-author of the study, said in an email.

She said the next generation of space telescopes, such as NASA's James Webb and the European Space Agency's ARIEL, "will explore many of these planets in exquisite detail, allowing us to better understand exoplanet composition, formation, and migration."

The first step, of course, will be confirming the existence of many in the catalog that remain candidate planets; about 120 have been confirmed to date with dozens more on the way. Confirmation often requires ground-based observations using gravitational measurements, high-resolution imaging, and stellar characterization.

Bottom line: The huge new planet catalog is a kind of candy store for the astronomical community, allowing deeper investigation of some of the galaxy's most fascinating questions.

"Now the community's role is to connect the dots," Guerrero said. "It's really cool because the field is so young, there's still a lot of room for discovery: those 'Aha' moments."

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's

other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

What’s Out There? The Exoplanet Sky So Far

12 min read

NASA Science Editorial Team

Since a giant planet in a scorching orbit captured public attention in 1995, a sky full of strange and exotic exoplanets – planets orbiting other stars – has only grown richer in variety and detail.

Hot Jupiters, mini-Neptunes, “super-Earths,” planets with two or three suns in their skies, rocky planets drowned in global oceans of lava, planets where it might rain glass – these make up just a short list of oddities among more than 5,500 confirmed so far in our Milky Way galaxy.

And we’ve only scratched the surface. The galaxy likely holds trillions.

The search for life beyond Earth has grown up alongside the search for distant worlds. Computer simulations of possible life-bearing planets look more and more like the real thing. Deeper understanding of possible habitable worlds in our own solar system – Mars, Jupiter’s moon Europa, Saturn’s Enceladus – informs the hunt for life among the stars.

Planetary scientists, exoplanet hunters, and astrobiologists, who seek to understand the origins and requirements of life, have begun to join forces. On many fronts, NASA, with help from its academic and international partners, is leading the charge.

“I never fail to be thrilled by just the energy and innovation and creativity of the exoplanet community,” said Doug Hudgins, program scientist for NASA’s Exoplanet Exploration Program at NASA headquarters in Washington. “One of the things that makes the field as compelling as it is, is that it’s hugely important to people’s worldview, where we are as human beings. Are we alone? It’s directly addressing a fundamental question of humankind.”

Though not the first exoplanet ever found, 51 Pegasi b was the first detected in orbit around a Sun-like star. The planet ignited international excitement when it was confirmed in 1995, ushering in a new era of discovery.

A gas giant with about half the heft, or “mass,” of our own Jupiter, 51 Peg orbits its star so tightly that a year – once around the star – takes only four days.

That keeps 51 Peg infernally hot; life on this planet is out of the question. But 51 Peg showed that exoplanets could be detected by the “wobble” method, or radial velocity – tracking by telescope the gravitational jiggles a planet causes its star to make, tugging it first one way, then another.

This method resulted in dozens, then hundreds of exoplanet discoveries, and is still an important detection method. But since 2009, it’s been eclipsed by the search for shadows.

Also called the “transit” method, this approach involves waiting for a planet to cast a shadow as it crosses (or transits) the face of its star. It’s an extremely faint shadow – a dip in the star’s light that typically amounts to less than 1%.

Radial velocity, watching for wobble

Take a look at the above animation. At first glance, things look normal. There's a big star and a small planet, and the small planet orbits the big star. You've probably seen this many times.

But check out the star. See how it's moving a little bit, too? The effect is exaggerated for this animation, but that's what actually happens in space. The planet's gravity causes the star to 'wobble'around a little bit.

As you might imagine, the bigger the planet, the bigger the effect it has on its star. Small planets, like Earth, make their stars only wobble a tiny bit. Bigger planets, like Jupiter, have a much stronger effect.

Wobbling stars are great for finding exoplanets, but how do we see the wobbling stars?

The method used is one called 'Doppler shift'. It's named after the physicist who figured it out about 150 years ago.

Energy - sound, radio waves, heat, and light - moves in waves. Like the waves you see in the animation above.

Those waves can be stretched and squeezed, based on the movement of the object that's producing them.

You may not know it, but you've probably experienced the Doppler effect before. Have you ever noticed how the sound of an ambulance passing you on the street gets higher in pitch as it gets close to you, and then lower in pitch as it speeds away?

The reason is because when an object that emits energy (like an ambulance speaker or a massive, burning star) moves closer to you, the waves bunch up and squish together. And when the object is moving away, the waves stretch out.

Those changes in the wavelength change how we perceive the energy that we're seeing or listening to. As sound waves scrunch together, they sound higher in pitch. And when visible light waves scrunch together, they look more blue in color.

When sound waves stretch out, they sound lower in pitch. And when visible light waves stretch out, they make an object look more reddish.

This change in color is called 'redshift', and scientists can use it to see if an object in the sky is moving towards us or farther away.

You can see this method working in the animation above. The planet causes the star to wobble around in its orbit, and as the planet moves to and fro, the light waves compress together and then stretch out, changing the color of the light we see.

The radial velocity method was one of the first successful ways to find exoplanets, and continues to be one of the most productive methods. Often, this method will be used to confirm planets found with other methods - an extra step that can prove a planet exists.

Lots of astronomers and telescopes around the world use this method to discover exoplanets, but two notable observatories where this work happens are the Keck Telescopes in Hawaii and the La Silla Observatory in Chile.

NASA’s Kepler Space Telescope began a flood of transit discoveries when it launched in 2009; transit detection is now the dominant method in the field, responsible for thousands of exoplanet finds by numerous telescopes in space and on the ground. And despite Kepler’s retirement in 2020, scientists continue mining data sent home by the space telescope for new discoveries.

Other methods also have yielded discoveries, though far fewer. Still, when it comes to revealing the intimate details of exoplanets, one of them is poised to join the bigger players in the decades ahead: direct imaging.

So far, few exoplanets have been directly imaged – when pixels of light are captured from the planet itself. Very large, very young planets still glowing from the heat of formation are, so far, the only ones to be imaged this way.

Doug Hudgins

Program scientist for NASA's Exoplanet Exploration Program

But planets past their youth, lit up only by their stars, would be targeted for direct imaging by space telescopes now in the conceptual phase. Some of these would use a type of starlight-blocking technology called a coronagraph. This system of masks, prisms, mirrors, and filters inside a telescope blots out the light of a star, revealing the planets in orbit around it.

Another possible technology would deploy a "starshade," a sunflower-shaped spacecraft as big as a baseball diamond, some 25,000 miles (40,000 kilometers) ahead of a space telescope. The starshade also would block starlight, allowing the telescope to capture direct images of a star's suite of planets.

A prime target for all these methods is one of the most sought-after and elusive exoplanets of all: an Earth-sized world orbiting a Sun-like star, with a "year" – an orbit – comparable to our own.

It might seem puzzling that, with the head-spinning variety among the thousands of exoplanets confirmed so far, a world checking all these boxes still hasn't turned up.

But our inability to find such a world is not so mysterious when you consider the technology we have at our disposal. The telescopes and the instruments we attach to them, both in space and on the ground, have made astonishing progress since the early days of the 1990s. They've also run up against stubborn limits.

Exoplanets tens or hundreds of light years away are usually much too dim to see, lost in the glare of their stars. Light-blocking technology might one day overcome this barrier, but – aside from those young, self-luminous planets – hasn't done so yet.

"Exoplanets are just insanely faint," Hudgins said.

The question of orbital distance is even more of a challenge.

Space telescopes already are powerful enough to pick up transits by Earth-sized planets around Sun-like stars. But they would have to wait far too long to confirm planets with long-period orbits. If the planet has a year comparable to Earth's, for instance, they'd have to wait on the order of 365 days to see a second transit.

That turned out to be out of reach for the history-making Kepler space telescope, and none of the telescopes launched since then can do so, either.

Many small, rocky planets in Earth's size range have been discovered, like the seven roughly Earth-sized planets orbiting a star called TRAPPIST-1. But all found so far orbit red-dwarf stars – smaller, cooler versions of our own Sun.

While some of these planets might be habitable – though very close to their stars, the lower temperature could allow water to pool on their surfaces – their "years" are typically only a few days long.

Red dwarfs also have a bad habit of erupting with potentially sterilizing flares, especially in their younger years. That could be a disqualifying feature for the habitability of closely orbiting planets, like moths flying too near the flame.

Finding an analog of the Earth-Sun system, or even a likely home for life, also requires far more than just scouring the skies for a world that looks something like our own. Context matters. Learning how life arose on Earth means understanding its origins: its formation from a disk of gas and dust spinning around a newborn star, the formation of its sibling planets, and how this process unfolds in planetary systems around other stars.

Are systems like ours – a large “Jupiter” and other giants farther out, small, rocky worlds closer in – common or rare? Does our system’s family of planets resemble others, or do we look, at the moment, just a bit odd?

“We can’t even begin to understand whether our planetary system is typical or not,” Hudgins said. “We don’t have a complete picture.”

The strangest planets, perhaps, are those we see elsewhere that are not found in our system. “Super-Earths,” or planets as much as 1.8 times as big around as Earth, appear to be fairly common in the galaxy. Are they scaled-up, rocky worlds, like giant Earths, or more gaseous like Neptune, especially at the larger end of the scale? Chalk up another “unknown.”

Another type, often called “mini-Neptunes,” are probably about what they sound like: gaseous worlds smaller than our own Neptune. Why don’t we have one? And why are so many sprinkled around the cosmos?

We’re also mystified by what’s not out there. Between these two size ranges – super-Earths and mini Neptunes – seems to be a kind of demographic desert: very few planets.

It’s been called the “Fulton gap,” after B.J. Fulton, a scientist who outlined their absence in a 2017 paper.

Fulton, a research astronomer at Caltech, says he’s now working to understand why the gap exists, and how it might change for planets around different types of stars.

“It looks like the gap, and the planets around the gap, move to larger sizes when the planets orbit more massive stars,” Fulton said. “It’s a hint, I’d say – not very strong evidence yet.”

Answering many of these questions requires not just observing exoplanets and their stars, but creating computer simulations – models – of other planets and other systems.

Such models are growing in sophistication, representing complex planetary atmospheres, or formation scenarios involving migrations of planets toward or away from their stars.

Models, by definition, never can be truly complete (that would require recreating an entire planet, or system). But they can reveal physics and attributes that surprise the modelers, shedding light on conditions that might be found on real exoplanets including their potential habitability.

This will be critical with space telescopes that can “read” the atmospheres of exoplanets. The James Webb Space Telescope employs “spectroscopy”: breaking down the light from exoplanet atmospheres into a spectrum, creating something like a bar code that reveals which gases are present.

Some of these could be “biosignatures” – signs of possible life – such as oxygen, though this alone would not be definitive.

“It’s not enough to say, ‘Oh, goodie, I have oxygen,’” said Vikki Meadows, an astrobiologist who heads the Virtual Planetary Laboratory in NASA’s Nexus for Exoplanet System Science. “Can you interpret it in the context of the environment? Can you prove that the oxygen didn’t come from planetary processes, rather than life?”

That’s where the modeling comes in. Meadows’ lab creates models of such possible worlds. Although future telescopes in space and on the ground could find oxygen in exoplanet atmospheres, it will be essential to know how it got there. Some models show oxygen can arise without life being present.

“We need to understand as much as possible about the planet we’re looking at, to guard against being fooled,” Meadows said. “Does it have an atmosphere, and what is it like? Does it have oceans? Is that really life?”

As the exoplanets we find grow ever stranger, modeling will be the key to understanding them.

And the astrobiologists, modelers, planet experts, and exoplanet hunters will be the key to finding life.

Only by understanding entire planetary systems, not just a single element, can we take the pulse of a potentially living planet, Hudgins said.

“Job number one is to try to establish a framework,” he said. “Can we bring astrobiologists, planetary science, and astrophysics-technologists all together to make this field of comparative planetology – and ultimately, the search for life – a reality?”

The scientific stakes, it seems, couldn’t be higher.

"The day we detect life on an exoplanet is nothing short of a Copernican revolution," he said. "It changes human beings forever."

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

New ‘Eyewear’ to Deepen the View of NASA’s Roman Space Telescope

8 min read

NASA’s Nancy Grace Roman Space Telescope will be able to explore even more cosmic questions, thanks to a new near-infrared filter. The upgrade will allow the observatory to see longer wavelengths of light, opening up exciting new opportunities for discoveries from the edge of our solar system to the farthest reaches of space.

“It’s incredible that we can make such an impactful change to the mission after all of the primary components have already passed their critical design reviews,” said Julie McEnery, the Roman Space Telescope senior project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Using the new filter, we will be able to see the full infrared range the telescope is capable of viewing, so we’re maximizing the science Roman can do.”

With the new filter, Roman’s wavelength coverage of visible and infrared light will span 0.5 to 2.3 microns – a 20% increase over the mission’s original design. This range will also enable more collaboration with NASA’s other big observatories, each of which has its own way of viewing the cosmos. The Hubble Space Telescope can see from 0.2 to 1.7 microns, which allows it to observe the universe in ultraviolet to near-infrared light. The James Webb Space Telescope, launching in October, will see from 0.6 to 28 microns, enabling it to see near-infrared, mid-infrared, and a small amount of visible light. Roman’s improved range of wavelengths, along with its much larger field of view, will reveal more interesting targets for Hubble and Webb to follow up on for detailed observations.

Expanding Roman’s capabilities to include much of the near-infrared K band, which extends from 2.0 to 2.4 microns, will help us peer farther across space, probe deeper into dusty regions, and view more types of objects. Roman’s sweeping cosmic surveys will unveil countless celestial bodies and phenomena that would otherwise be difficult or impossible to find.

“A seemingly small change in wavelength range has an enormous effect,” said George Helou, director of IPAC at Caltech in Pasadena, California, and one of the advocates for the modification. “Roman will see things that are 100 times fainter than the best ground-based K-band surveys can see because of the advantages of space for infrared astronomy. It’s impossible to foretell all of the mysteries Roman will help solve using this filter.”

While the mission is optimized to explore dark energy and exoplanets – planets beyond our solar system – its enormous field of view will capture troves of other cosmic wonders too.

Roman will excel at detecting the myriad small, dark bodies located in the outskirts of our solar system, beyond Neptune’s orbit. Using its improved vision, the mission will now be able to search these bodies for water ice.

This region, known as the Kuiper belt, contains the remnants of a primordial disk of icy bodies that were left over from the formation of the solar system. Many of these cosmic fossils are largely unchanged since they formed billions of years ago. Studying them provides a window into the solar system’s early days.

Most of the Kuiper belt’s original inhabitants are no longer there. Many were thrown out into interstellar space as the solar system took shape. Others were eventually sent toward the inner solar system, becoming comets. Occasionally their new paths crossed Earth’s orbit.

Scientists think ancient comet impacts delivered at least some of Earth's water, but they're not sure how much. A census of the water ice on bodies in the outer solar system could offer valuable clues.

Though it's a bit counterintuitive, our Milky Way galaxy can be one of the most difficult galaxies to study. When we peer through the plane of the Milky Way, many objects are shrouded from view by clouds of dust and gas that drift in between stars.

Dust scatters and absorbs visible light because the particles are the same size or even larger than the light's wavelength. Since infrared light travels in longer waves, it can pass more easily through clouds of dust.

Viewing space in infrared light allows astronomers to pierce hazy regions, revealing things they wouldn't be able to see otherwise. With Roman's new filter, the observatory will now be able to peer through dust clouds up to three times thicker than it could as originally designed, which will help us study the structure of the Milky Way.

The mission will spot stars that lie in and beyond our galaxy's central hub, which is densely packed with stars and debris. By estimating how far away the stars are, scientists will be able to piece together a better picture of our home galaxy.

Roman's expanded view will also help us learn even more about brown dwarfs – objects that are not massive enough to undergo nuclear fusion in their cores like stars. The mission will find these "failed stars" near the heart of the galaxy, where catastrophic events like supernovae occur more often.

Astronomers think this location may affect how stars and planets form since exploding stars seed their surroundings with new elements when they die. Using the new filter, the mission will be able to characterize brown dwarfs by probing their composition. This could help us identify differences between objects near the heart of the galaxy and out in the spiral arms.

If we want to view the most far-flung objects in space, we need an infrared telescope. As light travels through the expanding universe, it stretches into longer wavelengths. The longer it travels before reaching us, the more extended its wavelengths become. UV light stretches to visible light wavelengths, and then visible light extends to infrared.

By extending Roman's view even further into the infrared, the mission will be able to see back to when the universe was less than 300 million years old, or about 2% of its current age of 13.8 billion years. Exploring such distant regions of space could help us understand when stars and galaxies first began forming.

The origin of galaxies is still a mystery because the first objects that formed are extremely faint and spread sparsely across the sky. Roman's new filter, coupled with the telescope's wide field of view and its sensitive camera, could help us find enough first-generation galaxies to understand the population as a whole. Then astronomers can select prime targets for missions like the James Webb Space Telescope to zoom in for more detailed follow-up observations.

The new filter could also provide another way to pin down the Hubble constant, a number that describes how fast the universe is expanding. It has recently sparked debate among astronomers because different results have emerged from different measurements.

Astronomers often use a certain type of star called Cepheid variables to help determine the expansion rate. These stars brighten and dim periodically, and in the early 1900s American astronomer Henrietta Leavitt noticed a relationship between a Cepheid's luminosity – that is, its average intrinsic brightness – and the cycle's length.

When astronomers detect Cepheids in remote galaxies, they can determine accurate distances by comparing the actual, intrinsic brightness of the stars to their apparent brightness from Earth. Then astronomers can measure how fast the universe is expanding by seeing how fast galaxies at different distances are moving away.

Another type of star, called RR Lyrae variables, have a similar relationship between their actual brightness and the amount of time it takes to brighten, dim, and brighten again. They’re fainter than Cepheids, and their period-luminosity relationship can’t easily be determined in most wavelengths of light, but Roman will be able to study them using its new filter. Observing RR Lyrae and Cepheid stars in infrared light to determine distances to other galaxies may help clear up recently revealed discrepancies in our measurements of the universe’s expansion rate.

“Enhancing Roman’s vision further into the infrared provides astronomers with a powerful new tool to explore our universe,” said McEnery. “Using the new filter we will make discoveries over a vast area, from distant galaxies all the way to our local neighborhood.”

The Nancy Grace Roman Space Telescope is managed at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Southern California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and Technologies Corporation in Boulder, Colorado, L3Harris Technologies in Melbourne, Florida, and Teledyne Scientific & Imaging in Thousand Oaks, California.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media Contact:Claire AndreoliNASA’s Goddard Space Flight Center301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Discovers New Worlds in a River of Young Stars

7 min read

Using observations from NASA’s Transiting Exoplanet Survey Satellite (TESS), an international team of astronomers has discovered a trio of hot worlds larger than Earth orbiting a much younger version of our Sun called TOI 451. The system resides in the recently discovered Pisces-Eridanus stream, a collection of stars less than 3% the age of our solar system that stretches across one-third of the sky.

The planets were discovered in TESS images taken between October and December 2018. Follow-up studies of TOI 451 and its planets included observations made in 2019 and 2020 using NASA’s Spitzer Space Telescope, which has since been retired, as well as many ground-based facilities. Archival infrared data from NASA’s Near-Earth Object Wide-Field Infrared Survey Explorer (NEOWISE) satellite – collected between 2009 and 2011 under its previous moniker, WISE – suggests the system retains a cool disk of dust and rocky debris. Other observations show that TOI 451 likely has two distant stellar companions circling each other far beyond the planets.

“This system checks a lot of boxes for astronomers,” said Elisabeth Newton, an assistant professor of physics and astronomy at Dartmouth College in Hanover, New Hampshire, who led the research. “It’s only 120 million years old and just 400 light-years away, allowing detailed observations of this young planetary system. And because there are three planets between two and four times Earth’s size, they make especially promising targets for testing theories about how planetary atmospheres evolve.”

A paper reporting the findings was published on Jan. 14 in The Astronomical Journal and is available online.

Stellar streams form when the gravity of our Milky Way galaxy tears apart star clusters or dwarf galaxies. The individual stars move out along the cluster’s original orbit, forming an elongated group that gradually disperses.

In 2019, a team led by Stefan Meingast at the University of Vienna used data from the European Space Agency’s Gaia mission to discover the Pisces-Eridanus stream, named for the constellations containing the greatest concentrations of stars. Stretching across 14 constellations, the stream is about 1,300 light-years long. However, the age initially determined for the stream was much older than we now think.

Later in 2019, researchers led by Jason Curtis at Columbia University in New York City analyzed TESS data for dozens of stream members. Younger stars spin faster than their older counterparts do, and they also tend to have prominent starspots – darker, cooler regions like sunspots. As these spots rotate in and out of our view, they can produce slight variations in a star’s brightness that TESS can measure.

The TESS measurements revealed overwhelming evidence of starspots and rapid rotation among the stream’s stars. Based on this result, Curtis and his colleagues found that the stream was only 120 million years old – similar to the famous Pleiades cluster and eight times younger than previous estimates. The mass, youth, and proximity of the Pisces-Eridanus stream make it an exciting fundamental laboratory for studying star and planet formation and evolution.

“Thanks to TESS’s nearly all-sky coverage, measurements that could support a search for planets orbiting members of this stream were already available to us when the stream was identified,” said Jessie Christiansen, a co-author of the paper and the deputy science lead at the NASA Exoplanet

Archive, a facility for researching worlds beyond our solar system managed by Caltech in Pasadena, California. “TESS data will continue to allow us to push the limits of what we know about exoplanets and their systems for years to come.”

The young star TOI 451, better known to astronomers as CD-38 1467, lies about 400 light-years away in the constellation Eridanus. It has 95% of our Sun’s mass, but it is 12% smaller, slightly cooler, and emits 35% less energy. TOI 451 rotates every 5.1 days, which is more than five times faster than the Sun.

TESS spots new worlds by looking for transits, the slight, regular dimmings that occur when a planet passes in front of its star from our perspective. Transits from all three planets are evident in the TESS data. Newton’s team obtained measurements from Spitzer that supported the TESS findings and helped to rule out possible alternative explanations. Additional follow-up observations came from Las Cumbres Observatory – a global telescope network headquartered in Goleta, California – and the Perth Exoplanet Survey Telescope in Australia.

Even TOI 451’s most distant planet orbits three times closer than Mercury ever approaches to the Sun, so all of these worlds are quite hot and inhospitable to life as we know it. Temperature estimates range from about 2,200 degrees Fahrenheit (1,200 degrees Celsius) for the innermost planet to about 840 F (450 C) for the outermost one.

TOI 451 b orbits every 1.9 days, is about 1.9 times Earth’s size, and its estimated mass ranges from two to 12 times Earth’s. The next planet out, TOI 451 c, completes an orbit every 9.2 days, is about three times larger than Earth, and holds between three and 16 times Earth’s mass. The farthest and largest world, TOI 451 d, circles the star every 16 days, is four times the size of our planet, and weighs between four and 19 Earth masses.

Astronomers expect planets as big as these to retain much of their atmospheres despite the intense heat from their nearby star. Different theories of how atmospheres evolve by the time a planetary system reaches TOI 451’s age predict a wide range of properties. Observing starlight passing through the atmospheres of these planets provides an opportunity to study this phase of development and could aid in constraining current models.

“By measuring starlight penetrating a planet’s atmosphere at different wavelengths, we can infer its chemical composition and the presence of clouds or high-altitude hazes,” said Elisa Quintana, an astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “TOI 451’s planets offer excellent targets for such studies with Hubble and the upcoming James Webb Space Telescope.”

Observations from WISE show that the system is unusually bright in infrared light, which is invisible to human eyes, at wavelengths of 12 and 24 micrometers. This suggests the presence of a debris disk, where rocky asteroid-like bodies collide and grind themselves to dust. While Newton and her team cannot determine the extent of the disk, they envision it as a diffuse ring of rock and dust centered about as far from the star as Jupiter is from our Sun.

The researchers also investigated a faint neighboring star that appears about two pixels away from TOI 451 in TESS images. Based on Gaia data, Newton’s team determined this star to be a gravitationally bound companion located so far from TOI 451 that its light takes 27 days to get there. In fact, the researchers think the companion is likely a binary system of two M-type dwarf stars, each with about 45% of the Sun’s mass and emitting only 2% of its energy.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

NASA’s Jet Propulsion Laboratory in Southern California manages NEOWISE for NASA’s Science Mission Directorate in Washington. Ball Aerospace & Technologies Corp. of Boulder, Colorado, built the spacecraft. Science data processing takes place at IPAC at Caltech in Pasadena. Caltech manages JPL for NASA.

Download high-resolution images from NASA’s Scientific Visualization Studio

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: First Six-star System Where All Six Stars Undergo Eclipses

3 min read

Alicia Cermak

Six-star system: TYC 7037-89-1

The discovery: TYC 7037-89-1 is the first six-star system ever found where all of the stars participate in eclipses, a discovery made by NASA’s Transiting Exoplanet Survey Satellite (TESS). The system is located about 1,900 light-years away in the constellation Eridanus.

Key facts: The system, also called TIC 168789840, is the first known sextuple composed of three sets of eclipsing binaries, stellar pairs whose orbits tip into our line of sight so we observe the stars alternatively passing in front of each other. Each eclipse causes a dip in the system’s overall brightness. Astronomers designate the binaries by the letters A, B, and C. The stars in the A and C systems orbit each other roughly every day and a half, and the two binaries orbit each other about every four years. The B binary’s members circle each other about every eight days, but the pair is much farther away, orbiting around the inner systems roughly every 2,000 years. The primary stars in all three binaries are all slightly bigger and more massive than the Sun and about as hot. The secondaries are all around half the Sun’s size and a third as hot.

Details: Scientists used the NASA Center for Climate Simulation’s Discover supercomputer at NASA’s Goddard Space Flight Center to chart how the brightness of around 80 million stars observed by TESS changed over time. They then analyzed the data using autonomous software trained to recognize the tell-tale brightness dips of eclipsing binaries. Among the 450,000 candidates, researchers identified at least 100 with potentially three or more stars, including the new sextuple system.

Fun facts: Astrophysicists are very interested in eclipsing binaries because their structure aids detailed measurements of the stars’ sizes, masses, temperatures, and separation as well as the distance to the system. They can use this information to build better models of star formation and evolution. For example, in the case of TYC 7037-89-1, scientists want to learn more about how the primary and secondary stars across the three binaries developed such similar properties and how the three systems became gravitationally bound.

The discoverers: An international team, led by data scientist Brian P. Powell and astrophysicist Veselin Kostov at Goddard, made the discovery using TESS data. The researchers incorporated archival measurements and also obtained follow-up observations with ground-based facilities. The core team includes Saul Rappaport at MIT, Tamás Borkovits at the University of Szeged in Hungary, Petr Zasche at Charles University in the Czech Republic, and Andrei Tokovinin at NSF’s NOIRLab.

The paper, "TIC 168789840: A Sextuply-Eclipsing Sextuple Star System," has been accepted by The Astronomical Journal. A pre-print version is available online.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Burning Questions for a Hot Super-Earth

3 min read

Pat Brennan

The planet: HD 108236 b

The discovery: This scorchingly hot "super-Earth," more than 1 1/2 times as big around as our home planet, orbits a star very much like our Sun some 210 light-years away. It has a family of four sibling planets, all in tight, star-hugging orbits. But the embrace of HD 108236 b is the tightest, keeping this planet infernally hot.

Key facts: With a likely surface temperature of more than 1,500 Fahrenheit (825 Celsius), this planet has no chance of being habitable. The same is probably the case for the other four planets detected in this system, all possible "mini-Neptunes," or gaseous worlds that are smaller versions of our Neptune. But scientists who study exoplanets – planets around other stars – are excited about this system nevertheless. It offers the chance to help solve a major mystery of how planetary systems form, and how some rocky worlds – those that otherwise might have been something like Earth – are instead condemned to broil.

Details: This planetary system seems almost perfectly poised for scientific investigation. The star, similar to our Sun, is bright and reasonably close (at least by astronomical standards).Space telescopes, including NASA's James Webb Space Telescope, which launched late in 2021, can capture starlight shining through the atmospheres of these mini-Neptunes as they cross the face of their star. With such a star, of just the right brightness, that potentially would yield a clear "readout" of the gases that dominate planetary atmospheres – in other words, a snapshot of the molecules and chemistry in the skies of distant worlds.

The brightly shining system also could shed light on a scientific puzzle that has emerged over a quarter century of exoplanet hunting. Between two planetary size-ranges, "super-Earths" and mini-Neptunes, is a gap – very few planets. The hot super-Earth in this system, HD 108236 b, is among the few found so far that seems to fall just within the gap; its larger sister planets fall outside it. Among the theories about why this occurs is the idea of photo-evaporation, when intense radiation from a star strips away the atmosphere of, say, a mini-Neptune that wanders too close. That could potentially leave behind a broiling, rocky hulk – no longer mini-Neptune-sized, and instead kicked to the smaller side of the "radius gap." Scientists, helped by this bright star, will investigate whether HD 108236 b is just such a planet.

Fun facts: While none of the five planets found so far in this system is likely to be habitable, other planets in more distant orbits might be discovered in the future. A rocky planet at an orbital distance comparable to Earth's – and so potentially habitable – is not out of the question. That would qualify as an Earth-Sun analog, which has so far eluded exoplanet hunters.

The discoverers: An international team led by astrophysicist Tansu Daylan of MIT used data from TESS (the Transiting Exoplanet Survey Satellite) taken in 2019 to reveal this system's super-Earth and three of its mini-Neptunes. A second team using the European CHEOPS (CHaracterising ExOPlanet Satellite) space telescope confirmed these planets and discovered a fifth, also a possible mini-Neptune.

Read the latest paper

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Roman Mission Will Probe Galaxy’s Core for Hot Jupiters, Brown Dwarfs

8 min read

When it launches in the mid-2020s, NASA’s Nancy Grace Roman Space Telescope will explore an expansive range of infrared astrophysics topics. One eagerly anticipated survey will use a gravitational effect called microlensing to reveal thousands of worlds that are similar to the planets in our solar system. Now, a new study shows that the same survey will also unveil more extreme planets and planet-like bodies in the heart of the Milky Way galaxy, thanks to their gravitational tug on the stars they orbit.

“We were thrilled to discover that Roman will be able to offer even more information about the planets throughout our galaxy than originally planned,” said Shota Miyazaki, a graduate student at Osaka University in Japan who led the study. “It will be very exciting to learn more about a new, unstudied batch of worlds.”

Roman will primarily use the gravitational microlensing detection method to discover exoplanets – planets beyond our solar system. When a massive object, such as a star, crosses in front of a more distant star from our vantage point, light from the farther star will bend as it travels through the curved space-time around the nearer one.

The result is that the closer star acts as a natural lens, magnifying light from the background star. Planets orbiting the lens star can produce a similar effect on a smaller scale, so astronomers aim to detect them by analyzing light from the farther star.

Since this method is sensitive to planets as small as Mars with a wide range of orbits, scientists expect Roman’s microlensing survey to unveil analogs of nearly every planet in our solar system. Miyazaki and his colleagues have shown that the survey also has the power to reveal more exotic worlds – giant planets in tiny orbits, known as hot Jupiters, and so-called “failed stars,” known as brown dwarfs, which are not massive enough to power themselves by fusion the way stars do.

This new study shows that Roman will be able to detect these objects orbiting the more distant stars in microlensing events, in addition to finding planets orbiting the nearer (lensing) stars.

The team’s findings are published in The Astronomical Journal.

Astronomers see a microlensing event as a temporary brightening of the distant star, which peaks when the stars are nearly perfectly aligned. Miyazaki and his team found that in some cases, scientists will also be able to detect a periodic, slight variation in the lensed starlight caused by the motion of planets orbiting the farther star during a microlensing event.

As a planet moves around its host star, it exerts a tiny gravitational tug that shifts the star’s position a bit. This can pull the distant star closer and farther from a perfect alignment. Since the nearer star acts as a natural lens, it’s like the distant star’s light will be pulled slightly in and out of focus by the orbiting planet. By picking out little shudders in the starlight, astronomers will be able to infer the presence of planets.

“It’s called the xallarap effect, which is parallax spelled backward. Parallax relies on motion of the observer – Earth moving around the Sun – to produce a change in the alignment between the distant source star, the closer lens star and the observer. Xallarap works the opposite way, modifying the alignment due to the motion of the source,” said David Bennett, who leads the gravitational microlensing group at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

While microlensing is generally best suited to finding worlds farther from their star than Venus is from the Sun, the xallarap effect works best with very massive planets in small orbits, since they make their host star move the most. Revealing more distant planets will also allow us to probe a different population of worlds.

Most of the first few hundred exoplanets discovered in our galaxy had masses hundreds of times greater than Earth's. Unlike the giant planets in our solar system, which take 12 to 165 years to orbit the Sun, these newfound worlds whirl around their host stars in as little as a few days.

These planets, now known as hot Jupiters due to their giant size and the intense heat from their host stars, weren't expected from existing planetary formation models and forced astronomers to rethink them. Now there are several theories that attempt to explain why hot Jupiters exist, but we still aren't sure which – if any – is correct. Roman's observations should reveal new clues.

Even more massive than hot Jupiters, brown dwarfs range from about 4,000 to 25,000 times Earth's mass. They're too heavy to be characterized as planets, but not quite massive enough to undergo nuclear fusion in their cores like stars.

Other planet-hunting missions have primarily searched for new worlds relatively nearby, up to a few thousand light-years away. Close proximity makes more detailed studies possible. However, astronomers think that studying bodies close to our galaxy's core may yield new insight into how planetary systems evolve. Miyazaki and his team estimate that Roman will find around 10 hot Jupiters and 30 brown dwarfs nearer to the center of the galaxy using the xallarap effect.

The center of the galaxy is populated mainly with stars that formed around 10 billion years ago. Studying planets around such old stars could help us understand whether hot Jupiters form so close to their stars, or are born farther away and migrate inward over time. Astronomers will be able to see if hot Jupiters can maintain such small orbits for long periods of time by seeing how frequently they're found around ancient stars.

Unlike stars in the galaxy's disk, which typically roam the Milky Way at comfortable distances from one another, stars near the core are packed much closer together. Roman could reveal whether having so many stars so close to each other affects orbiting planets. If a star passes close to a planetary system, its gravity could pull planets out of their usual orbits.

Supernovae are also more common near the center of the galaxy. These catastrophic events are so intense that they can forge new elements, which are spewed into the surrounding area as the exploding stars die. Astronomers think this might affect planet formation. Finding worlds in this region could help us understand more about the factors that influence the planet-building process.

Roman will open up a window into the distant past by looking at older stars and planets. The mission will also help us explore whether brown dwarfs form as easily near the center of the galaxy as they do closer to Earth by comparing how frequently they're found in each region.

By tallying up very old hot Jupiters and brown dwarfs using the xallarap effect and finding more familiar worlds using microlensing, Roman will bring us another step closer to understanding our place in the cosmos.

"We've found a lot of planetary systems that seem strange compared with ours, but it's still not clear whether they're the oddballs or we are," said Samson Johnson, a graduate student at Ohio State University in Columbus and a co-author of the paper. "Roman will help us figure it out, while helping answer other big questions in astrophysics."

The Nancy Grace Roman Space Telescope is managed at NASA's Goddard Space Flight Center in Greenbelt, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Pasadena, California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from various research institutions. The primary industrial partners are Ball Aerospace and

Technologies Corporation in Boulder, Colorado, L3Harris Technologies in Melbourne, Florida, and Teledyne Scientific & Imaging in Thousand Oaks, California.

Download high-resolution video and images from NASA’s Scientific Visualization Studio

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Seven Rocky TRAPPIST-1 Planets May Be Made of Similar Stuff

5 min read

NASA Science Editorial Team

The red dwarf star TRAPPIST-1 is home to the largest group of roughly Earth-size planets ever found in a single stellar system. Located about 40 light-years away, these seven rocky siblings provide an example of the tremendous variety of planetary systems that likely fill the universe.

A study published in the Planetary Science Journal shows that the TRAPPIST-1 planets have remarkably similar densities. That could mean they all contain about the same ratio of materials thought to compose most rocky planets, like iron, oxygen, magnesium, and silicon. But if this is the case, that ratio must be notably different than Earth's: The TRAPPIST-1 planets are about 8% less dense than they would be if they had the same makeup as our home planet. Based on that conclusion, the paper authors hypothesized a few different mixtures of ingredients could give the TRAPPIST-1 planets the measured density.

Some of these planets have been known since 2016, when scientists announced that they'd found three planets around the TRAPPIST-1 star using the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile. Subsequent observations by NASA's now-retired Spitzer Space Telescope, in collaboration with ground-based telescopes, confirmed two of the original planets and discovered five more. Managed by NASA's Jet Propulsion Laboratory in Southern California, Spitzer observed the system for over 1,000 hours before being decommissioned in January 2020. NASA's Hubble and now-retired Kepler space telescopes have also studied the system.

All seven TRAPPIST-1 planets, which are so close to their star that they would fit within the orbit of Mercury, were found via the transit method: Scientists can't see the planets directly (they're too small and faint relative to the star), so they look for dips in the star's brightness created when the planets cross in front of it.

Repeated observations of the starlight dips combined with measurements of the timing of the planets' orbits enabled astronomers to estimate the planets' masses and diameters, which were in turn used to calculate their densities. Previous calculations determined that the planets are roughly the size and mass of Earth and thus must also be rocky, or terrestrial – as opposed to gas-dominated, like Jupiter and Saturn. The new paper offers the most precise density measurements yet for any group of exoplanets – planets beyond our solar system.

The seven TRAPPIST-1 planets possess similar densities – the values differ by no more than 3%. This makes the system quite different from our own. The difference in density between the TRAPPIST-1 planets and Earth and Venus may seem small – about 8% – but it is significant on a planetary scale. For example, one way to explain why the TRAPPIST-1 planets are less dense is that they have a similar composition to Earth, but with a lower percentage of iron – about 21% compared to Earth's 32%, according to the study.

Alternatively, the iron in the TRAPPIST-1 planets might be infused with high levels of oxygen, forming iron oxide, or rust. The additional oxygen would decrease the planets' densities. The surface of Mars gets its red tint from iron oxide, but like its three terrestrial siblings, it has a core composed of non-oxidized iron. By contrast, if the lower density of the TRAPPIST-1 planets were caused entirely by oxidized iron, the planets would have to be rusty throughout and could not have solid iron cores.

.

Eric Agol, an astrophysicist at the University of Washington and lead author of the new study, said the answer might be a combination of the two scenarios – less iron overall and some oxidized iron.

The team also looked into whether the surface of each planet could be covered with water, which is even lighter than rust and which would change the planet's overall density. If that were the case, water would have to account for about 5% of the total mass of the outer four planets. By comparison, water makes up less than one-tenth of 1% of Earth's total mass.

Because they're positioned too close to their star for water to remain a liquid under most circumstances, the three inner TRAPPIST-1 planets would require hot, dense atmospheres like Venus', such that water could remain bound to the planet as steam. But Agol says this explanation seems less likely because it would be a coincidence for all seven planets to have just enough water present to have such similar densities.

"The night sky is full of planets, and it's only been within the last 30 years that we've been able to start unraveling their mysteries," said Caroline Dorn, an astrophysicist at the University of Zurich and a co-author of the paper. "The TRAPPIST-1 system is fascinating because around this one star we can learn about the diversity of rocky planets within a single system. And we can actually learn more about a planet by studying its neighbors as well, so this system is perfect for that."

JPL, a division of Caltech in Pasadena, California, managed the Spitzer mission for NASA's Science Mission Directorate in Washington. Science operations were conducted at the Spitzer Science Center at IPAC at Caltech. Spitzer's entire science catalogue is available via the Spitzer data archive, housed at the Infrared Science Archive at IPAC. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado.

News Media Contacts

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The 7 Rocky TRAPPIST-1 Planets May Be Made of Similar Stuff

6 min read

Precise measurements reveal that the exoplanets have remarkably similar densities, which provides clues about their composition.

The red dwarf star TRAPPIST-1 is home to the largest group of roughly Earth-size planets ever found in a single stellar system. Located about 40 light-years away, these seven rocky siblings provide an example of the tremendous variety of planetary systems that likely fill the universe.

A new study published today in the Planetary Science Journal shows that the TRAPPIST-1 planets have remarkably similar densities. That could mean they all contain about the same ratio of materials thought to compose most rocky planets, like iron, oxygen, magnesium, and silicon. But if this is the case, that ratio must be notably different than Earth's: The TRAPPIST-1 planets are about 8% less dense than they would be if they had the same makeup as our home planet. Based on that conclusion, the paper authors hypothesized a few different mixtures of ingredients could give the TRAPPIST-1 planets the measured density.

Some of these planets have been known since 2016, when scientists announced that they'd found three planets around the TRAPPIST-1 star using the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile. Subsequent observations by NASA's now-retired Spitzer Space Telescope, in collaboration with ground-based telescopes, confirmed two of the original planets and discovered five more. Managed by NASA's Jet Propulsion Laboratory in Southern California, Spitzer observed the system for over 1,000 hours before being decommissioned in January 2020. NASA's Hubble and now-retired Kepler space telescopes have also studied the system.

Click on this interactive visualization to explore the TRAPPIST-1 planets in their orbit around a small, faint red dwarf star. The full interactive experience is at Eyes on Exoplanets. Image credit: NASA/JPL-Caltech

All seven TRAPPIST-1 planets, which are so close to their star that they would fit within the orbit of Mercury, were found via the transit method: Scientists can't see the planets directly (they're too small and faint relative to the star), so they look for dips in the star's brightness created when the planets cross in front of it.

Repeated observations of the starlight dips combined with measurements of the timing of the planets' orbits enabled astronomers to estimate the planets' masses and diameters, which were in turn used to calculate their densities. Previous calculations determined that the planets are roughly the size and mass of Earth and thus must also be rocky, or terrestrial – as opposed to gas-dominated, like Jupiter and Saturn. The new paper offers the most precise density measurements yet for any group of exoplanets – planets beyond our solar system.

The more precisely scientists know a planet's density, the more limits they can place on its composition. Consider that a paperweight might be about the same size as a baseball yet is usually much heavier. Together, width and weight reveal each object's density, and from there it is possible to infer that the baseball is made of something lighter (string and leather) and the paperweight is made of something heavier (usually glass or metal).

The densities of the eight planets in our own solar system vary widely. The puffy, gas-dominated giants – Jupiter, Saturn, Uranus, and Neptune – are larger but much less dense than the four terrestrial worlds because they're composed mostly of lighter elements like hydrogen and helium. Even the four terrestrial worlds show some variety in their densities, which are determined by both a planet’s composition and compression due to the gravity of the planet itself. By subtracting the effect of gravity, scientists can calculate what’s known as a planet’s uncompressed density and potentially learn more about a planet’s composition.

The seven TRAPPIST-1 planets possess similar densities – the values differ by no more than 3%. This makes the system quite different from our own. The difference in density between the TRAPPIST-1 planets and Earth and Venus may seem small – about 8% – but it is significant on a planetary scale. For example, one way to explain why the TRAPPIST-1 planets are less dense is that they have a similar composition to Earth, but with a lower percentage of iron – about 21% compared to Earth’s 32%, according to the study.

Alternatively, the iron in the TRAPPIST-1 planets might be infused with high levels of oxygen, forming iron oxide, or rust. The additional oxygen would decrease the planets’ densities. The surface of Mars gets its red tint from iron oxide, but like its three terrestrial siblings, it has a core composed of non-oxidized iron. By contrast, if the lower density of the TRAPPIST-1 planets were caused entirely by oxidized iron, the planets would have to be rusty throughout and could not have solid iron cores.

Eric Agol, an astrophysicist at the University of Washington and lead author of the new study, said the answer might be a combination of the two scenarios – less iron overall and some oxidized iron.

The team also looked into whether the surface of each planet could be covered with water, which is even lighter than rust and which would change the planet’s overall density. If that were the case, water would have to account for about 5% of the total mass of the outer four planets. By comparison, water makes up less than one-tenth of 1% of Earth’s total mass.

Because they’re positioned too close to their star for water to remain a liquid under most circumstances, the three inner TRAPPIST-1 planets would require hot, dense atmospheres like Venus’, such that water could remain bound to the planet as steam. But Agol says this explanation seems less likely because it would be a coincidence for all seven planets to have just enough water present to have such similar densities.

“The night sky is full of planets, and it’s only been within the last 30 years that we’ve been able to start unraveling their mysteries,” said Caroline Dorn, an astrophysicist at the University of Zurich and a co-author of the paper. “The TRAPPIST-1 system is fascinating because around this one star we can learn about the diversity of rocky planets within a single system. And we can actually learn more about a planet by studying its neighbors as well, so this system is perfect for that.”

JPL, a division of Caltech in Pasadena, California, managed the Spitzer mission for NASA’s Science Mission Directorate in Washington. Science operations were conducted at the Spitzer Science Center at IPAC at Caltech. Spitzer’s entire science catalogue is available via the Spitzer data archive, housed at the Infrared Science Archive at IPAC. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado.

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

2021-015

Citizen Scientists Help Create 3D Map of Cosmic Neighborhood

6 min read

Elizabeth Landau

Is our solar system located in a typical Milky Way neighborhood? Scientists have gotten closer to answering this question, thanks to the NASA-funded Backyard Worlds: Planet 9 project, a “citizen science” collaboration between professional scientists and members of the public.

Scientists tapped into the worldwide network of 150,000 volunteers using Backyard Worlds: Planet 9 to find new examples of brown dwarfs. These objects are balls of gas that are not heavy enough to be stars, since they can’t power themselves through nuclear fusion the way stars do. And while “brown” is in the name, they would appear magenta or orange-red if a person could see them close up. By making a complete map of these objects, scientists could find out whether different kinds of brown dwarfs are evenly distributed in our solar system’s neighborhood.

Telescopes can detect brown dwarfs because they emit heat, in the form of infrared light, left over from their formation. Infrared light is invisible to human eyes, but it can reveal tantalizing details about brown dwarfs and other objects throughout the universe.

The result of the new citizen science effort is the most complete map to date of L, T and Y dwarfs in the vicinity of the solar system. These brown dwarf varieties can have temperatures of up to thousands of degrees Fahrenheit, but the Y dwarfs, which are the coolest, may have below-freezing temperatures and clouds made of water.

Of course, an astronomer’s idea of a neighborhood is different in space than on Earth. The map encompasses a radius of 65 light-years, or about 400 trillion miles, with “close neighbors” inhabiting space within about 35 light-years, or 200 trillion miles.

Since 2017, citizen scientists have been searching for brown dwarf candidates as part of Backyard Worlds, using data from NASA’s Near-Earth Object Wide-Field Infrared Survey Explorer (NEOWISE) satellite along with all-sky observations collected between 2010 and 2011 under its previous moniker, WISE. The Backyard Worlds team also collaborated with Caltech’s Summer Research Connection program to involve high school students in finding brown dwarfs. Both worldwide volunteers and high school students in the Pasadena, California, area are listed as co-authors of the study, which was presented at the 237th meeting of the American Astronomical Society.

While brown dwarfs are millions to billions of years old, this team of professional and citizen scientists had a much shorter deadline to find them. They knew that NASA’s Spitzer Space Telescope was the only operating observatory that could confirm the distances and positions of the brown dwarfs they were interested in, and Spitzer was set to retire in January 2020. It was a frantic rush to find as many brown dwarfs as they could so Spitzer could reveal their locations more precisely.

Fortunately, citizen scientists helped save the day – they discovered dozens of new brown dwarfs.

“Without the citizen scientists, we couldn't have created such a complete sample in so short a time,” said J. Davy Kirkpatrick, scientist at Caltech/IPAC in Pasadena and lead author of the study. “Having the power of thousands of inquiring eyes on the data enabled us to find brown dwarf candidates much faster.”

Professional astronomers then used Spitzer to observe 361 local brown dwarfs of types L, T, and Y, and combined them with previous discoveries to make a 3D map of 525 brown dwarfs. Besides the citizen science discoveries, scientists made use of CatWise, a NASA-funded catalog of objects from WISE and NEOWISE, to complete their census.

And there's a surprise: One of our solar system's neighbors – the galaxy's coldest known Y dwarf, with temperatures likely below freezing – represents a rare resident in the cosmic neighborhood. Astronomers would have expected to find a lot more of them in the vicinity. But this may be because current telescopes aren't sensitive enough to find them, since these objects are so faint.

As previous research has found, of the seven objects nearest to our solar system, three are rare types of brown dwarfs. The rest are normal stars: red dwarfs Proxima Centauri and Barnard's Star, and Sun-like stars Alpha Centauri A and B.

"If you were to put the Sun at a random place within our 3D map and you were to ask, 'Typically, what do its neighbors look like?' We find that they would look very different from what our actual neighbors are," said Aaron Meisner, assistant scientist at the National Science Foundation's NOIRLab and co-author of the study.

So, is the Sun in an unusually diverse cosmic neighborhood, or is it just that nearby Y dwarfs are easiest to spot? Astronomers will need to investigate further to find out.

Some of these L, T, and Y dwarfs have masses and temperatures similar to exoplanets – planets beyond our solar system. Getting details about distant planets can be challenging because if they orbit other stars, starlight is a lot brighter than the planet. Since brown dwarfs in this study do not orbit stars, a telescope does not have to subtract starlight to look at them. This makes brown dwarfs a new kind of laboratory for understanding exoplanets.

Scientists will learn even more about brown dwarfs with NASA's forthcoming James Webb Space Telescope, which will examine these mysterious objects in detail in infrared light. NASA's upcoming SPHEREx mission, which will be an all-sky infrared survey, also presents new opportunities to characterize more brown dwarfs.

The Backyard Worlds: Planet 9 project is ongoing and open to anyone worldwide who wants to join the quest to find more mysterious objects in spacecraft data. In addition to a total of about 3,000 brown dwarfs, volunteers have helped find the oldest, coldest white dwarf surrounded by a disk of debris.

"I enjoy this project because the objects that we send to the researchers might get observed with a big telescope," said Melina Thévenot, a citizen scientist in Germany who is listed as a co-author of the new study. "I think we volunteers can really see the fruits of our efforts with this project and the publications by the science team."

Check out Backyard Worlds: Planet 9 at backyardworlds.org and more NASA citizen science projects at science.nasa.gov/citizen-science.

Media Contact

Elizabeth LandauHeadquarters, Washington202-358-0845elandau@nasa.gov

Discovery Alert: A Forgotten Planet Found in a Triple-Star System

NASA Science Editorial Team

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Selects 4 Concepts for Small Missions to Study Universe’s Secrets

4 min read

NASA has chosen four small-scale astrophysics missions for further concept development in a new program called Pioneers. Through small satellites and scientific balloons, these selections enable new platforms for exploring cosmic phenomena such as galaxy evolution, exoplanets, high-energy neutrinos, and neutron star mergers.

“The principal investigators of these concept studies bring innovative, out-of-the-box thinking to the problem of how to do high-impact astrophysics experiments on a small budget,” said Thomas H. Zurbuchen, associate administrator of NASA’s Science Mission Directorate. “Each of the proposed experiments would do something no other NASA telescope or mission can do, filling important gaps in our understanding of the universe as a whole.”

These are the four concepts chosen for further study:

Aspera is a SmallSat that will study galaxy evolution. Through observations in ultraviolet light, it will examine hot gas in the space between galaxies, called the intergalactic medium, and the inflow and outflow of gas from galaxies. The intergalactic medium is a major component of the universe, but is poorly measured; Aspera would close this gap. The principal investigator is Carlos Vargas at the University of Arizona.

Pandora is a SmallSat that will study 20 stars and their 39 exoplanets in visible and infrared light. It is aimed at disentangling the signals from stars and planetary atmospheres. Understanding how changes in starlight affects measurements of exoplanets is an outstanding problem in the search for habitable planets beyond the solar system. The principal investigator is Elisa Quintana of NASA Goddard Space Flight Center.

StarBurst is a SmallSat that will detect high-energy gamma rays from events such as the mergers of dense stellar remnants called neutron stars. This would provide valuable insight into such events, which are also detected through gravitational waves by observatories on Earth. These events are where most of the heavy metals in the universe, such as gold and platinum, are formed. To date, only one such event has been observed simultaneously in gravitational waves and gamma-rays; StarBurst would find up to 10 per year. The principal investigator is Daniel Kocevski of NASA Marshall Space Flight Center.

PUEO is a balloon mission designed to launch from Antarctica that will detect signals from ultra-high energy neutrinos, particles that contain valuable clues about the highest energy astrophysical processes, including the creation of black holes and neutron star mergers. Neutrinos travel across the universe undisturbed, carrying information about events billions of light years away. PUEO would be the most sensitive survey of cosmic ultra-high energy neutrinos ever conducted. The principal investigator is Abigail Vieregg of the University of Chicago.

After additional definition, these four concept studies will undergo a concept study review before being approved for flight.

The Pioneers program provides opportunities for early-to-mid-career researchers to propose innovative experiments and lead space or suborbital science investigations for the first time.

“Through this program designed to attract young professionals, we received two dozen great ideas from a diverse cohort of innovators at universities, research laboratories, and NASA centers,” said Paul Hertz, director of NASA’s astrophysics division at NASA Headquarters in Washington.

The principal investigators must be creative in designing missions to keep expenses down, as the cost cap for a Pioneers mission is $20 million. This low price point is enabled in part by the flourishing industry of small satellites for Earth observing and internet access, allowing researchers to purchase off-the-shelf spacecraft. In addition, telescopes developed by other government agencies can be used, rather than starting from scratch.

The program itself is an experiment for NASA. The agency has never solicited proposals for these kinds of astrophysics experiments at such low cost caps with such tight constraints. Some of the concepts may, upon further study, require a bigger budget, meaning they would not ultimately be approved for flight through the Pioneers program.

“We don’t know if there is great astrophysics that can be done in a $20 million satellite, but we challenged the community and they sent in a lot of innovative proposals,” Hertz said. “Now, we’re excited to see if they can deliver.”

Media Contact

Elizabeth LandauNASA Headquarters, Washington

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

In a surprise finding, astronomers using NASA’s Hubble Space Telescope have discovered that the blowtorch-like…

Overview Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way.…

Astronomers estimate that the universe could contain up to one septillion stars – that’s a one followed by 24 zeros.…

Galaxies consist of stars, planets, and vast clouds of gas and dust, all bound together by gravity. The largest contain…

Overview Our planetary system is located in an outer spiral arm of the Milky Way galaxy. We call it the…

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Detailing the Formation of Distant Solar Systems with NASA’s Webb Telescope

7 min read

We live in a mature solar system—eight planets and several dwarf planets (like Pluto) have formed, the latter within the rock- and debris-filled region known as the Kuiper Belt. If we could turn back time, what would we see as our solar system formed? While we can’t answer this question directly, researchers can study other systems that are actively forming—along with the mix of gas and dust that encircles their still-forming stars—to learn about this process.

A team led by Dr. Thomas Henning of the Max Planck Institute for Astronomy in Heidelberg, Germany, will employ NASA’s upcoming James Webb Space Telescope to survey more than 50 planet-forming disks in various stages of growth to determine which molecules are present and ideally pinpoint similarities, helping to shape what we know about how solar systems assemble.

Their research with Webb will specifically focus on the inner disks of relatively nearby, forming systems. Although information about these regions has been obtained by previous telescopes, none match Webb’s sensitivity, which means many more details will pour in for the first time. Plus, Webb’s space-based location about a million miles (1.5 million kilometers) from Earth will give it an unobstructed view of its targets. “Webb will provide unique data that we can’t get any other way,” said Inga Kamp of the Kapteyn Astronomical Institute of the University of Groningen in the Netherlands. “Its observations will provide molecular inventories of the inner disks of these solar systems.”

This research program will primarily gather data in the form of spectra. Spectra are like rainbows—they spread out light into its component wavelengths to reveal high-resolution information about the temperatures, speeds, and compositions of the gas and dust. This incredibly rich information will allow the researchers to construct far more detailed models of what is present in the inner disks—and where. “If you apply a model to these spectra, you can find out where molecules are located and what their temperatures are,” Henning explained.

These observations will be incredibly valuable in helping the researchers pinpoint similarities and differences among these planet-forming disks, which are also known as protoplanetary disks. “What can we learn from spectroscopy that we can’t learn from imaging? Everything!” Ewine van Dishoeck of Leiden University in the Netherlands exclaimed. “One spectrum is worth a thousand images.”

A ‘Mountain’ of New Data

Researchers have long studied protoplanetary disks in a variety of wavelengths of light, from radio to near-infrared. Some of the team’s existing data are from the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile, which collects radio light. ALMA excels at constructing images of the outer disks. If you were to compare the span of their outer disks to the size of our Solar System, this region is past Saturn’s orbit. Webb’s data will complete the picture by helping researchers model the inner disks.

Some data already exist about these inner disks—NASA’s retired Spitzer Space Telescope served as a pathfinder—but Webb’s sensitivity and resolution are required to identify the precise quantities of each molecule as well as the elemental compositions of the gas with its data, known as spectra. “What used to be a very blurry peak in the spectrum will consist of hundreds if not thousands of detailed spectral lines,” van Dishoeck said.

Webb’s specialty in mid-infrared light is particularly important. It will enable researchers to identify the “fingerprints” of molecules like water, carbon dioxide, methane, and ammonia—which can’t be identified with any other existing instruments. The observatory will also determine how starlight impacts the chemistry and physical structures of the disks.

Protoplanetary disks are complex systems. As they form, their mix of gas and dust is distributed into rings across the system. Their materials travel from the outer disk to the inner disk—but how? “The inner portion of the disk is a very dynamic place,” explains Tom Ray of the Dublin Institute for Advanced Studies in Ireland. “It’s not only where terrestrial-type planets form, but it’s also where supersonic jets are launched by the star.”

Jets emitted by the star lead to a mixing of elements in the inner and outer disks, both by sending out particles and permitting other particles to move inward. “We think that as material leaves, it loses its spin, or angular momentum, and that this allows other material to move inward,” Ray continued. “These exchanges of material will obviously impact the chemistry of the inner disk, which we’re excited to explore with Webb.”

Exciting Insights Await

PDS 70 is farther at 370 light-years away. It also has a large gap in its inner ring, plus data have revealed that two forming planets, known as protoplanets, are present and gathering material. “Webb’s mid-infrared measurements will help us refine what we know about them, as well as the material around them,” Kamp explained.

With dozens of targets on their list, it’s difficult for team members to play favorites. “I love them all,” Henning said. “One question I’d like to answer concerns the connection between the composition of planet-forming disks and the planets themselves. With Webb, we will observe far more detail about which types of material are available for a potential planet to accrete.”

After refining the data, his team will apply the discrete data points to models. “This will allow us to do a graphic reconstruction of these systems,” he continued. These models will be shared with the astronomical community, enabling other scientists to examine the data, and make their own projections or glean new findings. These studies will be conducted through a Guaranteed Time Observations (GTO) program.

The James Webb Space Telescope will be the world’s premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

Caption for the banner: PDS 70 is approximately 370 light-years away and features a large gap in its inner ring. The European Southern Observatory’s Very Large Telescope provided the first clear image of a planet forming around the central star in 2018. The planet is a bright point to the right of the center of the image. The central star is black since its light was blocked by an instrument known as a coronagraph. A second planet has also been detected. This system is a future target of NASA’s James Webb Space Telescope. Credit: ESO/A. Müller et al.

By Claire BlomeSpace Telescope Science Institute, Baltimore Md.

Media contact:

Laura BetzNASA’s Space Flight Center, Greenbelt, Md.Laura.e.betz@nasa.gov

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Assessing The Habitability Of Planets Around Old Red Dwarfs

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Planets orbiting close to the most abundant and longest-lasting stars in our Milky Way may be less hospitable to life than previously thought.

A new study using NASA's Chandra X-ray Observatory and Hubble Space Telescope examined the red dwarf called Barnard's Star, which is about 10 billion years old, more than twice the current age of the Sun. Red dwarf stars are much cooler and less massive than the Sun, and are expected to live much longer lives because they do not burn through their fuel as fast. Barnard's Star is one of the closest stars to Earth at a distance of only 6 light-years.

Young red dwarfs, with ages less than a few billion years, are known as strong sources of high-energy radiation, including blasts of ultraviolet light and X-rays. However, scientists know less about how much damaging radiation red dwarfs give off later in their lifetimes.

The new observations concluded that about 25% of the time, Barnard's Star unleashes scorching flares, which may damage the atmospheres of planets closely orbiting it. While its only known planet does not have habitable temperatures, this study adds to evidence that red dwarfs may present serious challenges for life on their planets.

“Red dwarfs are the most numerous types of stars, and their small sizes make them favorable for studying orbiting planets. Astronomers are interested in understanding what the prospects are for habitable planets around red dwarfs,” said Kevin France of University of Colorado in Boulder who led the study. “Barnard's Star is a great case study for learning about what happens around older red dwarfs in particular.”

The research team's Hubble observations of Barnard's Star taken in March 2019 revealed two ultraviolet high-energy flares, and Chandra observations in June 2019 uncovered an X-ray one. Both observations were about seven hours long.

“If these snapshots are representative of how active Barnard's Star is, then it is pumping out a lot of harmful radiation,” said study co-author Girish Duvvuri, also of the University of Colorado. “This amount of activity is surprising for an old red dwarf.”

The team then studied what these results mean for rocky planets orbiting in the habitable zone – the zone where liquid water could exist on a planet's surface -- of a red dwarf like Barnard's Star.

Any atmosphere formed early in the history of a habitable-zone planet was likely to have been eroded away by high-energy radiation from the star during its volatile youth. Later on, however, planet atmospheres might regenerate as the star becomes less active with age. This regeneration process may occur by gases released by impacts of solid material or gases being released by volcanic processes.

However, the onslaught of powerful flares like those reported here, repeatedly occurring over hundreds of millions of years, may erode any regenerated atmospheres on rocky planets in the habitable zone. This would reduce the chance of these worlds supporting life.

Because of these surprising flare findings, the team considered other possibilities for life on planets orbiting old red dwarfs like Barnard’s Star. Although planets in the traditional habitable zone may not be able to hold onto their atmospheres because of flares, astronomers can extend their searches for planets out to greater distances from the host star, where the doses of high-energy radiation are smaller. At these greater distances, it is possible that a greenhouse effect from gases other than carbon dioxide, such as hydrogen, allows liquid water to exist.

“It’s hard to say what the likelihood is of any one planet in any one system being habitable either today or in the future,” said the University of Colorado’s Allison Youngblood. “Our research shows one important factor that needs to be considered in the complicated question surrounding whether or not a planet can support life.”

Planets beyond the orbit of the Sun are also known as exoplanets. More than 4,000 exoplanets have been confirmed so far, and many of those identified orbit red dwarfs. Understanding what makes planets habitable is of interest to scientists in the field of astrobiology, which studies how life originated on Earth and where it might exist in the solar system and beyond.

The team is currently studying high-energy radiation from many more red dwarfs to determine whether Barnard’s Star is typical.

“It may turn out that most red dwarfs are hostile to life,” said co-author Tommi Koskinen of the University of Arizona in Tucson. “In that case the conclusion might be that planets around more massive stars, like our own Sun, might be the optimal location to search for inhabited worlds with the next generation of telescopes.”

Barnard’s Star is 16% the mass of the Sun and its known planet has a mass about three times that of Earth, orbiting at a distance roughly equal to the Mercury-Sun separation.

A paper describing these results was published on October 30 2020 in The Astronomical Journal and is available online [https://arxiv.org/abs/2009.01259]. NASA's Marshall Space Flight Center manages the Chandra program. The Smithsonian Astrophysical Observatory's Chandra X-ray Center controls science and flight operations from Cambridge and Burlington, Massachusetts.

Read more from NASA's Chandra X-ray Observatory.

For more Chandra images, multimedia and related materials, visit:

http://www.nasa.gov/chandra

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Life in Our Solar System? Meet the Neighbors

11 min read

Alicia Cermak

A tour of our solar system reveals a stunning diversity of worlds, from charbroiled Mercury and Venus to the frozen outer reaches of the Oort Cloud.

In between are a few tantalizing prospects for life beyond Earth – subterranean Mars, maybe, or the moons of giant planets with their hidden oceans – but so far, it’s just us.

“There’s nothing else in the solar system with lots of life on it,” said Mary Voytek, senior scientist for astrobiology at NASA Headquarters in Washington, D.C. “Otherwise, we would have likely detected it.”

Still, NASA continues searching the solar system for signs of life, past or present, and decades of investigation have begun to narrow down the possibilities. The broiling inner solar system seems unlikely (though the high-altitude clouds of Venus remain a possibility).

The same goes for the cloud-covered gas giants, with their crushing atmospheric pressures and seemingly bottomless depths – perhaps no solid surface at all, or if there is one, it’s no place for any living being.

The farthest provinces, with their dwarf planets and would-be comets locked in deep freeze, also seem a poor bet, though they can’t be ruled out. Same for dwarf planet Ceres in the asteroid belt, considered a possible “water world” either now or earlier in its history.

That brings us back to those tantalizing prospects. There’s Mars, now a cold, nearly airless desert, but once temperate and flowing with water.

And much hope remains out among the gas giants – not the big planets themselves, but their long list of moons. Jupiter’s Europa and Saturn’s Enceladus, despite their frozen, forbidding surfaces, are hiding vast oceans beneath the ice – among several moons with subsurface oceans.

Let’s begin the tour with our hottest planet.

Often called our “sister planet,” Venus, of similar size and structure to Earth, has critical differences: a surface hot enough to melt lead, a crushingly heavy atmosphere and an extremely volcanic geology. Venus began its existence much as Earth did, perhaps even with globe-spanning oceans. But the two planets took very different paths. A runaway greenhouse effect likely boiled off Venus’s oceans and turned the planet into a perpetual inferno – the hottest world in the solar system.

Yet Venus also exerts an irresistible pull for astrobiologists – scientists who study how life begins, its necessary ingredients and the planetary environments that it might require. Venus is a kind of negative to Earth’s positive; by studying what went so very wrong, we might learn what it takes to get life right.

“Venus gives us an example of an alternative evolution for planets,” said Vikki Meadows, an astrobiologist who heads the Virtual Planetary Laboratory in NASA’s Nexus for Exoplanet System Science.

The planet’s divergent path includes “loss of habitability, loss of water on the surface, sulfuric acid clouds, and a dense carbon-dioxide atmosphere,” Meadows said. “It’s also a warning – how terrestrial planets die.”

Venus has deep implications as well for the study of exoplanets – planets that orbit other stars. Many close to their stars are probably Venus-like worlds; Venus is a nearby laboratory showing how such planets might evolve.

Persistent, dark streaks in Venus's clouds, where temperatures and pressure are more congenial, also prompt intriguing speculation: Could they be wind-whipped bands of microbial lifeforms? A recent study even suggested the presence of one potential life sign, a gas called phosphine, in the Venusian atmosphere. Bacteria on Earth produce it. For now, this possibility remains in the "unlikely but possible" column, scientists say; only further investigation will offer a definite answer.

As we cruise past our sole example of a life-bearing world, we might take a page from an earlier era of planetary exploration, courtesy of Carl Sagan. The astronomer and prize-winning author also was a key member of science teams for a variety of NASA's solar system exploration missions, including Galileo.

In 1990, as the space probe zipped past Earth for a gravitational kick that would hurtle it toward the outer solar system, it turned its instruments on the home planet. Sagan's question: Could Galileo detect signs of life on Earth?

And it did. Oxygen. Methane. A spike in the infrared part of the light spectrum, called a "red edge," the telltale sign of reflective vegetation on the surface. Galileo even detected what today might be called a "technosignature" – a sign of intelligent life. In this case, powerful radio waves that were unlikely to come from natural sources.

"It's vital to think about what our own planet would look like to an alien," said Giada Arney, an astronomer and astrobiologist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "It's important to think about what signs of life they could actually see from space."

Arney, who says much of her work involves "thinking about Earth as an exoplanet," focuses on haze-shrouded worlds. As we search for signs of life around other stars, she reminds us that our own planet would have looked very different at various epochs in the deep past.

The Earth of billions of years ago, in the Archean era, might not even have been Sagan's "pale blue dot." Before the atmosphere became oxygen rich, Earth might occasionally have been a "pale orange dot," Arney says, its orange haze created by complex atmospheric chemistry involving methane generated by microbes. A similar haze is found today in the atmosphere of Saturn's moon, Titan, though in this case, not generated by life.

To find an analog of our own planet out among the stars, we must consider "not just modern Earth, but Earth through time," she said. "The kinds of planets that could be (considered) Earth-like may be very different from modern Earth."

In a sense, the Red Planet tells a tale echoing that of Venus, but from the other side of the temperature scale. Investigations by orbiters, and rovers on the surface, confirm that Mars was once wet, with rivers, lakes and perhaps even oceans, and like Earth potentially habitable.

"The most exciting thing about Mars is that, at some point in time, 3.5 billion years ago, it's clear the climate on Mars was more similar to Earth's and had liquid water on its surface," Voytek said.

Then solar wind and radiation stripped most of its atmosphere away. Its minimally active core ceased to generate a protective magnetic field. Its surface became forbiddingly cold and dry even as it was bombarded with radiation.

Is anything alive on Mars, perhaps beneath the surface, or in the frozen polar caps? Or might Earth's future robotic explorers – one day maybe human explorers – stumble upon evidence of extinct forms from early Mars?

Two strikes against Mars, Voytek said, are its lack of available water and the absence of plate tectonics – the process on Earth that moves continents over eons and recycles buried nutrients back up to the surface.

“A lot of people think the planet may be dead – no life now because it doesn’t have that recycling going on,” she said.

Strikes in its favor might include detection of methane in the Martian atmosphere. On Earth, methane, otherwise short-lived in the atmosphere, is replenished by the metabolic action of life forms. Methane also can be produced through reactions of water and rock, but microbial life beneath the surface is another possibility.

“While surface conditions are not suitable, we may find evidence of past life, or perhaps some life that’s still hanging on,” said Morgan Cable, a researcher with the Astrobiology and Ocean Worlds Group at NASA’s Jet Propulsion Laboratory.

A newly launched Mars rover, Perseverance, is designed to collect samples of Martian soil – called regolith – that would be returned to Earth later for analysis. And the European Space Agency’s Rosalind Franklin lander, expected to launch in 2022, will drill beneath the Mars surface to search for signs of life.

Our solar system’s majestic giants – Jupiter, Saturn, Uranus, Neptune – and their trains of moons might almost be considered solar systems in their own right. Some of these moons could well be habitable worlds; one of them, Titan, has a thick atmosphere, rain, rivers and lakes, though composed of methane and ethane instead of water.

We first glide toward Europa, a moon of Jupiter with an icy shell. Beneath the frozen surface, however, space probes have detected evidence of a vast ocean of liquid water. Two other Jovian moons, Ganymede and Callisto, also are likely to host subsurface oceans, though these might be sandwiched between layers of ice. That makes life less likely, Cable says.

“Europa, we think, has a nice contact between the liquid water ocean and the rocky interior,” she said. “That’s important because the energy you can generate through chemistry can be utilized by life.”

A potentially more accessible example can be found among the moons of Saturn, the next planet out. Enceladus, though tiny, also hides a liquid water ocean beneath an icy shell. But in this case, scientists know the little moon is doing something extraordinary.

“Luckily, it happens to be sending free samples from its ocean into space,” Cable says. “Enceladus is the only place in the solar system with guaranteed access to a subsurface ocean without the need to dig or drill.”

NASA’s Cassini spacecraft detected convincing evidence of hydrothermal vents on its sea floor, and jets of ocean water shoot through cracks in the moon’s surface, known as tiger stripes (Europa might have similar plumes). The material from Enceladus’s jets, in fact, forms one of Saturn’s rings.

Cassini flew through the plume, and although its instruments were not designed to analyze ocean-water samples – when it was built, the nature of these distant ocean worlds was unknown – it did pick up important clues.

These include complex organic molecules, salts similar to those in Earth’s oceans, and silicate “nanograins” and other evidence indicating the presence of hydrothermal activity.

Gases detected in the plume, hydrogen and methane, suggest enough energy is present to provide fuel for life.

“If there’s that much energy, why isn’t there life eating it?” Cable asks. So far, no one knows the answer.

“Hopefully a future mission will journey back to Enceladus and bring today’s modern sensitive instruments to this test,” she said.

Then there’s Titan.

Though smaller and with lighter gravity than Earth, Titan reminds us of our own world, if perhaps reflected through a fun-house mirror. Nitrogen dominates this moon’s atmosphere, as it does Earth’s. And Titan is the only other body in the solar system with rain, lakes and rivers – a whole hydrologic cycle in fact. Its flowing lakes and rivers are made of the hydrocarbons, methane and ethane.

Flowing water is not an option; Titan is nightmarishly cold, and water is essentially rock on its surface.

Titan also possesses a subsurface ocean of water, though deep down, and it’s unknown whether the ocean makes contact with anything from the surface. If it does, mixing with complex chemistry on the surface could provide fuel for life.

If it doesn’t, there’s another possibility. The chemical brew on the surface could power life as we don’t know it: exotic forms based on completely different components and chemical reactions.

“Titan allows us to test a completely separate hypothesis of life,” Cable said. “It has a completely different liquid on its surface.”

The extreme cold on Titan’s surface, of course, means chemistry happens very slowly if at all. That could make “weird life” far less likely.

NASA is planning a mission called “Dragonfly,” a rotary flier that will hop from place to place on the surface – and maybe solve some of Titan’s mysteries.

"The more we study our own cosmic backyard, the more surprises we find," Cable said. "And I'm excited. We'll be surprised more and more as we continue to extend our senses to the outer solar system and beyond."

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Pins Down Weird Exoplanet with Far-Flung Orbit

7 min read

NASA Hubble Mission Team

Goddard Space Flight Center

A planet in an unlikely orbit around a double star 336 light-years away may offer a clue to a mystery much closer to home: a hypothesized, distant body in our solar system dubbed "Planet Nine."

This is the first time that astronomers have been able to measure the motion of a massive Jupiter-like planet that is orbiting very far away from its host stars and visible debris disk. This disk is similar to our Kuiper Belt of small, icy bodies beyond Neptune. In our own solar system, the suspected Planet Nine would also lie far outside of the Kuiper Belt on a similarly strange orbit. Though the search for a Planet Nine continues, this exoplanet discovery is evidence that such oddball orbits are possible.

"This system draws a potentially unique comparison with our solar system," explained the paper's lead author, Meiji Nguyen of the University of California, Berkeley. "It's very widely separated from its host stars on an eccentric and highly misaligned orbit, just like the prediction for Planet Nine. This begs the question of how these planets formed and evolved to end up in their current configuration."

The system where this gas giant resides is only 15 million years old. This suggests that our Planet Nine — if it does exist — could have formed very early on in the evolution of our 4.6-billion-year-old solar system.

An Extreme Orbit

The 11-Jupiter-mass exoplanet called HD 106906 b was discovered in 2013 with the Magellan Telescopes at the Las Campanas Observatory in the Atacama Desert of Chile. However, astronomers did not know anything about the planet's orbit. This required something only the Hubble Space Telescope could do: collect very accurate measurements of the vagabond's motion over 14 years with extraordinary precision. The team used data from the Hubble archive that provided evidence for this motion.

The exoplanet resides extremely far from its host pair of bright, young stars — more than 730 times the distance of Earth from the Sun, or nearly 68 billion miles. This wide separation made it enormously challenging to determine the 15,000-year-long orbit in such a relatively short time span of Hubble observations. The planet is creeping very slowly along its orbit, given the weak gravitational pull of its very distant parent stars.

The Hubble team was surprised to find that the remote world has an extreme orbit that is very misaligned, elongated and external to the debris disk that surrounds the exoplanet's twin host stars. The debris disk itself is very unusual-looking, perhaps due to the gravitational tug of the wayward planet.

How Did It Get There?

So how did the exoplanet arrive at such a distant and strangely inclined orbit? The prevailing theory is that it formed much closer to its stars, about three times the distance that Earth is from the Sun. But drag within the system's gas disk caused the planet's orbit to decay, forcing it to migrate inward toward its stellar pair. The gravitational effects from the whirling twin stars then kicked it out onto an eccentric orbit that almost threw it out of the system and into the void of interstellar space. Then a passing star from outside the system stabilized the exoplanet's orbit and prevented it from leaving its home system.

Using precise distance and motion measurements from the European Space Agency's Gaia survey satellite, candidate passing stars were identified in 2019 by team members Robert De Rosa of the European Southern Observatory in Santiago, Chile, and Paul Kalas of the University of California.

A Messy Disk

In a study published in 2015, Kalas led a team that found circumstantial evidence for the runaway planet's behavior: the system's debris disk is strongly asymmetric, rather than being a circular "pizza pie" distribution of material. One side of the disk is truncated relative to the opposite side, and it is also disturbed vertically rather than being restricted to a narrow plane as seen on the opposite side of the stars.

"The idea is that every time the planet comes to its closest approach to the binary star, it stirs up the material in the disk," explains De Rosa. "So every time the planet comes through, it truncates the disk and pushes it up on one side. This scenario has been tested with simulations of this system with the planet on a similar orbit — this was before we knew what the orbit of the planet was."

"It's like arriving at the scene of a car crash, and you're trying to reconstruct what happened," explained Kalas. "Is it passing stars that perturbed the planet, then the planet perturbed the disk? Is it the binary in the middle that first perturbed the planet, and then it perturbed the disk? Or did passing stars disturb both the planet and disk at the same time? This is astronomy detective work, gathering the evidence we need to come up with some plausible storylines about what happened here."

A Planet Nine Proxy?

This scenario for HD 106906 b’s bizarre orbit is similar in some ways to what may have caused the hypothetical Planet Nine to end up in the outer reaches of our own solar system, well beyond the orbit of the other planets and beyond the Kuiper Belt. Planet Nine could have formed in the inner solar system and been kicked out by interactions with Jupiter. However, Jupiter — the proverbial 800-pound gorilla in our solar system — would very likely have flung Planet Nine far beyond Pluto. Passing stars may have stabilized the orbit of the kicked-out planet by pushing the orbit path away from Jupiter and the other planets in the inner solar system.

"It's as if we have a time machine for our own planetary system going back 4.6 billion years to see what may have happened when our young solar system was dynamically active and everything was being jostled around and rearranged," said Kalas.

To date, astronomers only have circumstantial evidence for Planet Nine. They've found a cluster of small celestial bodies beyond Neptune that move in unusual orbits compared with the rest of the solar system. This configuration, some astronomers say, suggests these objects were shepherded together by the gravitational pull of a huge, unseen planet. An alternative theory is that there is not one giant perturbing planet, but instead the imbalance is due to the combined gravitational influence of multiple, much smaller objects. Another theory is that Planet Nine does not exist at all and the clustering of smaller bodies may be just a statistical anomaly.

A Target for the Webb Telescope

Scientists using NASA's upcoming James Webb Space Telescope plan to get data on HD 106906 b to understand the planet in detail. "One question you could ask is: Does the planet have its own debris system around it? Does it capture material every time it goes close to the host stars? And you'd be able to measure that with the thermal infrared data from Webb," said De Rosa. "Also, in terms of helping to understand the orbit, I think Webb would be useful for helping to confirm our result."

Because Webb is sensitive to smaller, Saturn-mass planets, it may be able to detect other exoplanets that have been ejected from this and other inner planetary systems. "With Webb, we can start to look for planets that are both a little bit older and a little bit fainter," explained Nguyen. The unique sensitivity and imaging capabilities of Webb will open up new possibilities for detecting and studying these unconventional planets and systems.

The team's findings appear in the December 10, 2020, edition of The Astronomical Journal.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Media Contacts:Claire AndreoliNASA's Goddard Space Flight Center301-286-1940claire.andreoli@nasa.govAnn Jenkins / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4488 / 410-338-4514jenkins@stsci.edu / villard@stsci.edu

Science Contacts:Meiji Nguyen University of California, Berkeley, California meiji274@berkeley.eduRobert De Rosa European Southern Observatory, Santiago, Chile rderosa@eso.orgPaul KalasUniversity of California, Berkeley, Californiakalas@berkeley.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Easy Crafts from NASA: Make Your Own Exoplanets

2 min read

NASA Science Editorial Team

We’ve discovered thousands of exoplanets – worlds beyond our solar system – so far. Most of these faraway planets are unlike any of the worlds in our own solar system. They are so far from Earth that they’re really hard to see! Even the best pictures we have of them show little more than bright dots of light. We have to use our science to tell us more about what they might look like up close.

We know what colors planets might be, for instance, based on certain chemicals we observe in their atmospheres. You might say there’s an art to our science! Now NASA has an easy arts and crafts project where you can make your own exoplanets at home.

Now, what kind of exoplanet will you make? “Terrestrial” planets (that just means rocky) like Earth and Venus seem obvious; we are working with rocks after all! Gas giant exoplanets are also common, and those could have beautiful clouds like Jupiter.

We know of exoplanets smaller than Earth and bigger than Jupiter, the largest planet in our solar system. Our science tells us that some of these planets are puffy like Styrofoam, while others are dense and fiery with seas of lava. If you need inspiration, check out a few of the weirdest exoplanets found so far in our Strange New Worlds gallery.

Step 1: Lay out clean rocks on a clean, flat surface, preferably craft paper, though newspaper will work in a pinch.

Step 2: Pour a small amount of acrylic paint on the paper. You can use 2-4 colors for each planet rock. Separate paint pours far enough from each other to avoid color combinations mixing. Some planets are bathed in radiation, so you might choose green for them – or any other color! White could represent clouds or ice. We’ve seen blue, pink and even pitch black planets! Your planet can be whatever you imagine.

Step 3: Use chopstick/skewer/popsicle stick to mix desired color combinations into a swirl.

Step 4: Begin to slowly dip (flat side down) your rock into paint and press lightly.

Step 5: Lift rock up from paint to reveal your very own exoplanet!

Step 6: Let rocks dry for 1 hour.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New NASA Posters Feature Cosmic Frights for Halloween

3 min read

NASA Science Editorial Team

With Halloween just around the corner, NASA has released its latest Galaxy of Horrors posters. Presented in the style of vintage horror movie advertisements, the new posters feature a "dead" galaxy, an explosive gamma ray burst caused by colliding stellar corpses, and ever-elusive dark matter; the posters are also available in Spanish.

As fun and creative as all three posters are, they're based on real phenomena. In a dead galaxy, new star birth has ceased and most remaining stars are the long-lived variety, which are small and red, giving the galaxy a crimson glow. Likewise, when dead stars collide, they sometimes create a gamma ray burst, or the brightest type of explosion in the universe. And while dark matter may sound like it's right out of a Halloween tale, its gravity keeps stars inside galaxies and hold groups of galaxies together in clusters – yet scientists don't know what this invisible stuff is made of.

Free to download, the posters were produced by NASA's Exoplanet Exploration Program Office, located at NASA's Jet Propulsion Laboratory in Southern California, with the input of astrophysicists. The posters are also available in Spanish: Cementerio Galáctico, Materia Oscura, and Demonions de Rayos Gamma.

"One of the things I really like about these posters is that if you spend some time studying the art and then maybe go learn a little more about each of these topics, you'll see there was a lot of thought by the artists about the choices they made to highlight the science," said Jason Rhodes, an astrophysicist at JPL who consulted on the project.

Take that dark matter poster, which carries the tagline "Something Else Is Out There." The massive spider seen crawling across the sky on a glowing web is pure fiction, but the concept alludes to something called the cosmic web, which is the large-scale organization of matter and dark matter in the universe: Thin filaments of matter and dark matter connect clusters of galaxies, like roadways between major cities. In fact, scientific visualizations of the cosmic web look similar to the spider web featured in the poster.

Similarly, the two narrow energy beams seen in the gamma ray burst poster reflect how they occur in real life, traveling in opposite directions from the colliding stellar corpses. The bursts are so intense that if such an event occurred "close" to the Earth, causing a beam to fire directly at our planet, the beam of radiation and particles could do harm. But the rarity of these events makes that extremely unlikely, according Judy Racusin, an astrophysicist at NASA's Goddard Space Flight Center who also consulted on the posters. In fact, astronomers estimate that a gamma ray burst goes off in our galaxy only about once every 10,000 years, but they are only visible to us about every 10,000,000 to 100,000,000 years. Even then, one of these events wouldn't necessarily pose a threat to our planet.

While gamma ray bursts are real, the space travelers observing the event in the Galaxy of Horrors image are, of course, the product of creative license.

"The poster art is a really fun way to imagine one of these happening," said Racusin. "But I wouldn't want to be those space travelers!"

To learn more about these posters and download both the Spanish and English versions for free, visit the Galaxy of Horrors!

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

About Half of Sun-Like Stars Could Host Rocky, Potentially Habitable Planets

6 min read

NASA Science Editorial Team

Since astronomers confirmed the presence of planets beyond our solar system, called exoplanets, humanity has wondered how many could harbor life. Now, we’re one step closer to finding an answer. According to new research using data from NASA’s retired planet-hunting mission, the Kepler space telescope, about half the stars similar in temperature to our Sun could have a rocky planet capable of supporting liquid water on its surface.

Our galaxy holds an estimated 300 million of these potentially habitable worlds, based on results in a study released today and to be published in The Astronomical Journal. Some of these exoplanets could even be our interstellar neighbors, with four potentially within 30 light-years of our Sun and the closest likely to be about 20 light-years from us.

This research helps us understand the potential for these planets to have the elements to support life. This is an essential part of astrobiology, the study of life’s origins and future in our universe.

The study is authored by NASA scientists who worked on the Kepler mission alongside collaborators from around the world. NASA retired the space telescope in 2018 after it ran out of fuel. Nine years of the telescope’s observations revealed that there are billions of planets in our galaxy – more planets than stars.

"Kepler already told us there were billions of planets, but now we know a good chunk of those planets might be rocky and habitable," said the lead author Steve Bryson, a researcher at NASA's Ames Research Center in California's Silicon Valley. "Though this result is far from a final value, and water on a planet's surface is only one of many factors to support life, it's extremely exciting that we calculated these worlds are this common with such high confidence and precision."

For the purposes of calculating this occurrence rate, the team looked at exoplanets between a radius of 0.5 and 1.5 times that of Earth's, narrowing in on planets that are most likely rocky. They also focused on stars similar to our Sun in age and temperature, plus or minus up to 1,500 degrees Fahrenheit.

That's a wide range of different stars, each with its own particular properties impacting whether the rocky planets in its orbit are capable of supporting liquid water. These complexities are partly why it is so difficult to calculate how many potentially habitable planets are out there, especially when even our most powerful telescopes can just barely detect these small planets. That's why the research team took a new approach.

This new finding is a significant step forward in Kepler's original mission to understand how many potentially habitable worlds exist in our galaxy. Previous estimates of the frequency, also known as the occurrence rate, of such planets ignored the relationship between the star's temperature and the kinds of light given off by the star and absorbed by the planet.

The new analysis accounts for these relationships, and provides a more complete understanding of whether or not a given planet might be capable of supporting liquid water, and potentially life. That approach is made possible by combining Kepler's final dataset of planetary signals with data about each star's energy output from an extensive trove of data from the European Space Agency's Gaia mission.

"We always knew defining habitability simply in terms of a planet's physical distance from a star, so that it's not too hot or cold, left us making a lot of assumptions," said Ravi Kopparapu, an author on the paper and a scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "Gaia's data on stars allowed us to look at these planets and their stars in an entirely new way."

Gaia provided information about the amount of energy that falls on a planet from its host star based on a star's flux, or the total amount of energy that is emitted in a certain area over a certain time. This allowed the researchers to approach their analysis in a way that acknowledged the diversity of the stars and solar systems in our galaxy.

"Not every star is alike," said Kopparapu. "And neither is every planet."

Though the exact effect is still being researched, a planet's atmosphere figures into how much light is needed to allow liquid water on a planet's surface as well. Using a conservative estimate of the atmosphere's effect, the researchers estimated an occurrence rate of about 50% — that is, about half of Sun-like stars have rocky planets capable of hosting liquid water on their surfaces. An alternative optimistic definition of the habitable zone estimates about 75%.

This result builds upon a long legacy of work of analyzing Kepler data to obtain an occurrence rate and sets the stage for future exoplanet observations informed by how common we now expect these rocky, potentially habitable worlds to be. Future research will continue to refine the rate, informing the likelihood of finding these kinds of planets and feeding into plans for the next stages of exoplanet research, including future telescopes.

"Knowing how common different kinds of planets are is extremely valuable for the design of upcoming exoplanet-finding missions," said co-author Michelle Kunimoto, who worked on this paper after finishing her doctorate on exoplanet occurrence rates at the University of British Columbia, and recently joined the Transiting Exoplanet Survey Satellite, or TESS, team at the Massachusetts Institute of Technology in Cambridge, Massachusetts. "Surveys aimed at small, potentially habitable planets around Sun-like stars will depend on results like these to maximize their chance of success."

After revealing more than 2,800 confirmed planets outside our solar system, the data collected by the Kepler space telescope continues to yield important new discoveries about our place in the universe. Though Kepler's field of view covered only 0.25% of the sky, the area that would be covered by your hand if you held it up at arm's length towards the sky, its data has allowed scientists to extrapolate what the mission's data means for the rest of the galaxy. That work continues with TESS, NASA's current planet hunting telescope.

"To me, this result is an example of how much we've been able to discover just with that small glimpse beyond our solar system," said Bryson. "What we see is that our galaxy is a fascinating one, with fascinating worlds, and some that may not be too different from our own."

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Search for New Worlds at Home With NASA's Planet Patrol Project

5 min read

Help NASA find exoplanets, worlds beyond our solar system, through a newly launched website called Planet Patrol. This citizen science platform allows members of the public to collaborate with professional astronomers as they sort through a stockpile of star-studded images collected by NASA's Transiting Exoplanet Survey Satellite (TESS).

"Automated methods of processing TESS data sometimes fail to catch imposters that look like exoplanets," said project leader Veselin Kostov, a research scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and the SETI Institute in Mountain View, California. "The human eye is extremely good at spotting such imposters, and we need citizen scientists to help us distinguish between the look-alikes and genuine planets."

Volunteers will help determine which TESS snapshots include signals from potential planets and which ones show planet impersonators.

TESS uses its four cameras to take full images of one patch of sky, called a sector, every 10 minutes for a month at a time. This long stare allows TESS to see when planets pass in front of their stars, or transit, and dim their light. Over the course of a year, TESS collects hundreds of thousands of snapshots, each containing thousands of possible planets – too many for scientists to examine without help.

Computers are very good at analyzing such data sets, but they're not perfect, Kostov said. Even the most carefully crafted algorithms can fail when the signal from a planet is weak. Some of the most interesting exoplanets, like small worlds with long orbits, can be especially challenging. Planet Patrol volunteers will help discover such worlds and will contribute to scientists' understanding of how planetary systems form and evolve throughout the universe.

Planets aren't the only source of changes in starlight, though. Some stars naturally change brightness over time, for example. In other cases, a star could actually be an eclipsing binary, where two orbiting stars alternately transit or eclipse each other. Or there may be an eclipsing binary in the background that creates the illusion of a planet transiting a target star. Instrumental quirks can also cause brightness variations. All these false alarms can trick automated planet-hunting processes.

On the new website, participants will help Kostov and his team sift through TESS images of potential planets by answering a set of questions for each – like whether it contains multiple bright sources or if it resembles stray light rather than light from a star. These questions help the researchers narrow down the list of possible planets for further follow-up study.

Citizen scientists can dive even deeper by learning more about the star in each image and by engaging with the Planet Patrol community.

A Goddard summer intern recently helped discover the TESS mission's first planet orbiting two stars through another citizen science program called Planet Hunters TESS, run by the University of Oxford.

"We're all swimming through the same sea of data, just using different strokes," said Marc Kuchner, the citizen science officer for NASA's Science Mission Directorate. "Planet Hunters TESS asks volunteers to look at light curves, which are graphs of stars' brightness over time. Planet Patrol asks them to look at the TESS image directly, although we plan to also include light curves for those images in the future.”

Planet Patrol is a collaboration between NASA, the SETI Institute in Mountain View, California, the Space Telescope Science Institute in Baltimore, and Zooniverse, a collaboration of scientists, software developers, and educators who collectively develop and manage citizen science projects on the internet. It is funded by the Sellers Exoplanet Environments Collaboration at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

For more information about Planet Patrol, visit: http://exoplanetpatrol.org

For more information about citizen science at NASA, visit: https://science.nasa.gov/citizenscience

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Creates a Cosmic Vista of the Northern Sky

4 min read

Familiar stars shine, nebulae glow, and nearby galaxies tantalize in a new panorama of the northern sky assembled from 208 pictures captured by NASA’s Transiting Exoplanet Survey Satellite (TESS). The planet hunter imaged about 75% of the sky in a two-year-long survey and is still going strong.

TESS has discovered 74 exoplanets, or worlds beyond our solar system. Astronomers are sifting through some 1,200 additional exoplanet candidates, where potential new worlds await confirmation. More than 600 of these candidates lie in the northern sky.

TESS locates planets by simultaneously monitoring many stars over large regions of the sky and watching for tiny changes in their brightness. When a planet passes in front of its host star from our perspective, it blocks some of the star’s light, causing it to temporarily dim. This event is called a transit, and it repeats with every orbit of the planet around the star. This technique has proven to be the most successful planet-finding strategy so far, accounting for about three quarters of the nearly 4,300 exoplanets now known. The data collected also allow for the study of other phenomena such as stellar variations and supernova explosions in unprecedented detail.

The northern mosaic covers less of the sky than its southern counterpart, which was imaged during the mission’s first year of operations. For about half of the northern sectors, the team decided to angle the cameras further north to minimize the impact of scattered light from Earth and the Moon. This results in a prominent gap in coverage.

The northern panorama represents only a glimpse of the data TESS has returned. The mission splits each celestial hemisphere into 13 sectors. TESS imaged each sector for nearly a month using four cameras, which carry a total of 16 sensors called charge-coupled devices (CCDs). During its primary mission, the cameras captured a full sector of the sky every 30 minutes. This means each CCD acquired nearly 30,800 full science images. Adding in other measurements, TESS has beamed back more than 40 terabytes so far – equivalent to streaming some 12,000 high-definition movies.

Remarkably, these numbers will rise sharply over the next year. TESS has now begun its extended mission, during which it will spend another year imaging the southern sky. The satellite will revisit planets discovered in its first year, find new ones, and fill in coverage gaps from its initial survey. Improvements to the satellite’s data collection and processing now allow TESS to return full sector images every 10 minutes and measure the brightness of thousands of stars every 20 seconds – all while continuing its previous strategy of measuring the brightness of tens of thousands of stars every two minutes.

“These changes promise to make TESS’s extended mission even more fruitful,” said Padi Boyd, the mission’s project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Making high-precision measurements of stellar brightness at these frequencies makes TESS an extraordinary new resource for studying flaring and pulsating stars and other transient phenomena, as well as for exploring the science of transiting exoplanets.”

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire Andreoli■NASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Search for New Worlds at Home With NASA’s Planet Patrol Project

4 min read

NASA Science Editorial Team

By Jeanette Kazmierczak

Help NASA find exoplanets, worlds beyond our solar system, through a newly launched website called Planet Patrol. This citizen science platform allows members of the public to collaborate with professional astronomers as they sort through a stockpile of star-studded images collected by NASA’s Transiting Exoplanet Survey Satellite (TESS).

“Automated methods of processing TESS data sometimes fail to catch imposters that look like exoplanets,” said project leader Veselin Kostov, a research scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and the SETI Institute in Mountain View, California. “The human eye is extremely good at spotting such imposters, and we need citizen scientists to help us distinguish between the look-alikes and genuine planets.”

Volunteers will help determine which TESS snapshots include signals from potential planets and which ones show planet impersonators.

TESS uses its four cameras to take full images of one patch of sky, called a sector, every 10 minutes for a month at a time. This long stare allows TESS to see when planets pass in front of their stars, or transit, and dim their light. Over the course of a year, TESS collects hundreds of thousands of snapshots, each containing thousands of possible planets – too many for scientists to examine without help.

Computers are very good at analyzing such data sets, but they’re not perfect, Kostov said. Even the most carefully crafted algorithms can fail when the signal from a planet is weak. Some of the most interesting exoplanets, like small worlds with long orbits, can be especially challenging. Planet Patrol volunteers will help discover such worlds and will contribute to scientists’ understanding of how planetary systems form and evolve throughout the universe.

Planets aren’t the only source of changes in starlight, though. Some stars naturally change brightness over time, for example. In other cases, a star could actually be an eclipsing binary, where two orbiting stars alternately transit or eclipse each other. Or there may be an eclipsing binary in the background that creates the illusion of a planet transiting a target star. Instrumental quirks can also cause brightness variations. All these false alarms can trick automated planet-hunting processes.

On the new website, participants will help Kostov and his team sift through TESS images of potential planets by answering a set of questions for each – like whether it contains multiple bright sources or if it resembles stray light rather than light from a star. These questions help the researchers narrow down the list of possible planets for further follow-up study.

Citizen scientists can dive even deeper by learning more about the star in each image and by engaging with the Planet Patrol community.

A Goddard summer intern recently helped discover the TESS mission’s first planet orbiting two stars through another citizen science program called Planet Hunters TESS, run by the University of Oxford.

“We’re all swimming through the same sea of data, just using different strokes,” said Marc Kuchner, the citizen science officer for NASA’s Science Mission Directorate. “Planet Hunters TESS asks volunteers to look at light curves, which are graphs of stars’ brightness over time. Planet Patrol asks them to look at the TESS image directly, although we plan to also include light curves for those images in the future.”

Planet Patrol is a collaboration between NASA, the SETI Institute in Mountain View, California, the Space Telescope Science Institute in Baltimore, and Zooniverse, a collaboration of scientists, software developers, and educators who collectively develop and manage citizen science projects on the internet. It is funded by the Sellers Exoplanet Environments Collaboration at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

For more information about Planet Patrol, visit http://exoplanetpatrol.org

For more information about citizen science at NASA, visit: https://science.nasa.gov/citizenscience

Media contact:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Primary Mirror for NASA’s Roman Space Telescope Completed

5 min read

The Nancy Grace Roman Space Telescope’s primary mirror, which will collect and focus light from cosmic objects near and far, has been completed. Using this mirror, Roman will capture stunning space vistas with a field of view 100 times greater than Hubble images.

“Achieving this milestone is very exciting,” said Scott Smith, Roman telescope manager at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Success relies on a team with each person doing their part, and it’s especially true in our current challenging environment. Everyone plays a role in collecting that first image and answering inspiring questions.”

Roman will peer through dust and across vast stretches of space and time to study the universe using infrared light, which human eyes can’t see. The amount of detail these observations will reveal is directly related to the size of the telescope’s mirror, since a larger surface gathers more light and measures finer features.

Roman’s primary mirror is 7.9 feet (2.4 meters) across. While it’s the same size as the Hubble Space Telescope’s main mirror, it is less than one-fourth the weight. Roman’s mirror weighs only 410 pounds (186 kilograms) thanks to major improvements in technology.

The primary mirror, in concert with other optics, will send light to Roman’s two science instruments – the Wide Field Instrument and Coronagraph Instrument. The first is essentially a giant 300-megapixel camera that provides the same sharp resolution as Hubble across nearly 100 times the field of view. Using this instrument, scientists will be able to map the structure and distribution of invisible dark matter, study planetary systems around other stars, and explore how the universe evolved to its present state.

The coronagraph demonstrates technology that blocks out the glare of stars and allows astronomers to directly image planets in orbit around them. If the coronagraph technology performs as anticipated, it will see planets that are almost a billion times fainter than their host star and enable detailed studies of giant planets around other suns.

Roman will observe from a vantage point about 930,000 miles (1.5 million km) away from Earth in the direction opposite the Sun. Roman’s barrel-like shape will help block out unwanted light from the Sun, Earth, and Moon, and the spacecraft’s distant location will help keep the instruments cool, ensuring that it will be able to detect faint infrared signals.

Because it will experience a range of temperatures between manufacture and testing on Earth and operations in space, the primary mirror is made of a specialty ultralow-expansion glass. Most materials expand and contract when temperatures change, but if the primary mirror changed shape it would distort the images from the telescope. Roman’s mirror and its support structure are designed to reduce flexing, which will preserve the quality of its observations.

Development of the mirror is much further along than it would typically be at this stage since the mission leverages a mirror that was transferred to NASA from the National Reconnaissance Office. The team modified the mirror’s shape and surface to meet Roman’s science objectives.

The newly resurfaced mirror sports a layer of silver less than 400 nanometers thick – about 200 times thinner than a human hair. The silver coating was specifically chosen for Roman because of how well it reflects near-infrared light. By contrast, Hubble’s mirror is coated with layers of aluminum and magnesium fluoride to optimize visible and ultraviolet light reflectivity. Likewise, the James

Webb Space Telescope’s mirrors have a gold coating to suit its longer wavelength infrared observations.

Roman’s mirror is so finely polished that the average bump on its surface is only 1.2 nanometers tall – more than twice as smooth as the mission requires. If the mirror were scaled to be Earth’s size, these bumps would be just a quarter of an inch high.

“The mirror was precisely finished to the Roman Space Telescope’s optical prescription,” said Bonnie Patterson, program manager at L3Harris Technologies in Rochester, New York. “Since it’s so much smoother than required, it will provide even greater scientific benefit than originally planned.”

Next, the mirror will be mounted for additional testing at L3Harris. It has already been extensively tested at both cold and ambient temperatures. The new tests will be done with the mirror attached to its support structure.

“Roman’s primary mirror is complete, yet our work isn’t over,” said Smith. “We’re excited to see this mission through to launch and beyond, and eager to witness the wonders it will reveal.”

The Nancy Grace Roman Space Telescope is managed at Goddard, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Pasadena, California, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from research institutions across the United States.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Among Trillions of Planets, Are We ‘Home Alone?’

4 min read

Pat Brennan

Once seen as the center of the universe, Earth has suffered a series of demotions over the past few hundred years. Now, in an age of fast-paced discovery, we’ve learned we’re likely just one of trillions of planets in the Milky Way galaxy – and among the smaller ones at that.

Yet Earth remains a standout, and so far, one of a kind. Of the thousands of exoplanets – planets around other stars – confirmed by our increasingly powerful telescopes, and despite extensive probing of the solar system, ours is still the only planet known to host life.

In some ways it’s an embarrassment of riches. Earth’s abundant, persistent, and pervasive lifeforms seem to fill almost every nook and cranny, from the boiling, caustic pools of Yellowstone National Park to the Dry Valleys of Antarctica. Life might well have gotten its start only a few hundred million years after Earth formed from a swirling disk of gas and dust – an eyeblink in geologic time.

But Earth hasn’t always looked like the blue orb we know so well. The variety of contending creatures that have come and gone over billions of years, in a sense, paints a picture of the many planets Earth has been: a lava-covered rock with a poisonous atmosphere, an ocean world with the bare beginnings of microbial life, a steaming tropical riot of earth-shaking dinosaurs, or an Ice Age expanse where cave-dwelling humans hunted mammoths.

“We tend to talk about Earth-like planets as a planet like ours is today,” said Doug Hudgins, program scientist for NASA’s Exoplanet Exploration Program at NASA Headquarters in Washington. “The planet has been radically different at times in the past.”

Compare Earth’s lively past to a dazzling cosmos stretching endlessly in all directions, so far silent on the question of life. Not even crickets.

So, are we really alone?

Finding an answer is a high priority for NASA, but even posing the question – that is, interrogating the universe – quickly becomes an inventory of ingredients from astrobiology: chemistry, planetary science, and cosmology, strongly seasoned with statistics.

The odds seem a bit better now that we’ve confirmed more than 4,000 exoplanets in our galaxy, about a fifth of them in Earth’s size-range. We know the building blocks of life are present throughout the solar system and the cosmos, and that includes water.

We don’t know how readily life begins, whether it’s common or rare, how long it endures. Up the ante to intelligent life, and the questions only multiply.

That includes one of the most famous questions of all: Where is everybody? Physicist Enrico Fermi posed it back in 1950 during lunch with fellow physicists, igniting decades of debate. Even at a leisurely, slower-than-light pace, the reasoning went, our galaxy could be easily crossed by a spacefaring civilization within a few million years. The Milky Way galaxy is presently pushing 14 billion. And while it took 4-billion-plus- years for technological intelligence to develop on our planet, the galaxy contains plenty of planetary systems of comparable age, as well as others much older.

We hope you’ll join us for a trip through our solar system, and the planets and stars beyond. Through stories and visuals, we’ll take stock of where the search for life stands and get a glimpse of the future – the space telescopes, instruments, probes, landers, rovers and advanced technology NASA plans to deploy in coming decades. The goal is to find that hidden blue and white marble, or perhaps even an orange one – another living, breathing planet.

“We only have our planet’s example to follow,” said Nancy Kiang of the NASA Goddard Institute for Space Studies, who studies how plants might adapt to exoplanet environments. “There could be a similar evolutionary pathway (on other worlds) – convergent evolution on a planetary scale.”

Maybe not quite like looking in a mirror, but not too far from looking like home.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Unveiling Rogue Planets With NASA’s Roman Space Telescope

6 min read

New simulations show that NASA’s Nancy Grace Roman Space Telescope will be able to reveal myriad rogue planets – freely floating bodies that drift through our galaxy untethered to a star. Studying these island worlds will help us understand more about how planetary systems form, evolve, and break apart.

Astronomers discovered planets beyond our solar system, known as exoplanets, in the 1990s. We quickly went from knowing of only our own planetary system to realizing that planets likely outnumber the hundreds of billions of stars in our galaxy. Now, a team of scientists is finding ways to improve our understanding of planet demographics by searching for rogue worlds.

“As our view of the universe has expanded, we’ve realized that our solar system may be unusual,” said Samson Johnson, a graduate student at Ohio State University in Columbus who led the research effort. “Roman will help us learn more about how we fit in the cosmic scheme of things by studying rogue planets.”

The findings, published in the Astronomical Journal, center on the Roman Space Telescope’s ability to locate and characterize isolated planets. Astronomers have only tentatively discovered a few of these nomad worlds so far because they are so difficult to detect.

Roman will find rogue planets by conducting a large microlensing survey. Gravitational lensing is an observational effect that occurs because the presence of mass warps the fabric of space-time. The effect is extreme around very massive objects, like black holes and entire galaxies. Even solitary planets cause a detectable degree of warping, called microlensing.

If a rogue planet aligns closely with a more distant star from our vantage point, the star’s light will bend as it travels through the curved space-time around the planet. The result is that the planet acts like a natural magnifying glass, amplifying light from the background star. Astronomers see the effect as a spike in the star’s brightness as the star and planet come into alignment. Measuring how the spike changes over time reveals clues to the rogue planet’s mass.

“The microlensing signal from a rogue planet only lasts between a few hours and a couple of days and then is gone forever,” said co-author Matthew Penny, an assistant professor of physics and astronomy at Louisiana State University in Baton Rouge. “This makes them difficult to observe from Earth, even with multiple telescopes. Roman is a game-changer for rogue planet searches.”

Microlensing offers the best way to systematically search for rogue planets – especially those with low masses. They don’t shine like stars and are often very cool objects, emitting too little heat for infrared telescopes to see. These vagabond worlds are essentially invisible, but Roman will discover them indirectly thanks to their gravitational effects on the light of more distant stars.

Johnson and co-authors showed that Roman will be able to detect rogue planets with masses as small as Mars. Studying these planets will help narrow down competing models of planetary formation.

The planet-building process can be chaotic, since smaller objects collide with one another and sometimes stick together to form larger bodies. It’s similar to using a piece of playdough to pick up other pieces. But occasionally collisions and close encounters can be so violent that they fling a planet out of the gravitational grip of its parent star. Unless it manages to drag a moon along with it, the newly orphaned world is doomed to wander the galaxy alone.

Rogue planets may also form in isolation from clouds of gas and dust, similar to how stars grow. A small cloud of gas and dust could collapse to form a central planet instead of a star, with moons instead of planets surrounding it.

Roman will test planetary formation and evolution models that predict different numbers of these isolated worlds. Determining the abundance and masses of rogue planets will offer insight into the physics that drives their formation. The research team found that the mission will provide a rogue planet count that is at least 10 times more precise than current estimates, which range from tens of billions to trillions in our galaxy. These estimates mainly come from observations by ground-based telescopes.

Since Roman will observe above the atmosphere, nearly a million miles away from Earth in the direction opposite the Sun, it will yield far superior microlensing results. In addition to providing a sharper view, Roman's perspective will allow it to stare at the same patch of sky continuously for months at a time. Johnson and his colleagues showed that Roman's microlensing survey will detect hundreds of rogue planets, even though it will search only a relatively narrow strip of the galaxy.

Part of the study involved determining how to analyze the mission's future data to obtain a more accurate census. Scientists will be able to extrapolate from Roman's rogue planet count to estimate how common these objects are throughout the entire galaxy.

"The universe could be teeming with rogue planets and we wouldn't even know it," said Scott Gaudi, a professor of astronomy at Ohio State University and a co-author of the paper. "We would never find out without undertaking a thorough, space-based microlensing survey like Roman is going to do."

The Nancy Grace Roman Space Telescope is managed at Goddard, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Pasadena, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from research institutions across the United States.

Download high resolution images and videos from NASA Goddard's Scientific Visualization Studio

By Ashley BalzerNASA's Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940

Battered, Blasted: a Giant Planet Core Laid Bare?

4 min read

Pat Brennan

The cores of gas giant planets, like our own Jupiter, are shrouded in dense, turbulent atmospheres – and so are shrouded in mystery. A newly discovered world called TOI 849 b could be the exposed, naked core of a gas giant whose atmosphere was blasted away by its star.

Every day is a bad day on planet TOI 849 b. About half the mass of our own Saturn, this planet orbits a Sun-like star more than 700 light-years from Earth. It hugs its star so tightly that a year – one trip around the star – takes less than a day. And it pays a high price for this close embrace: an estimated surface temperature of nearly 2,800 degrees Fahrenheit, which is 1,500 degrees Celsius. It's a scorcher even compared to Venus, which is 880 degrees Fahrenheit (471 degrees Celsius).

But for TOI 849 b, recently discovered by NASA's Transiting Exoplanet Survey Satellite (TESS), the price of closeness to its star might have been even higher. Though about the size of Neptune, the planet appears to have little or no atmosphere. Scientists aren't sure why, but the possibilities include photoevaporation – the stripping away of a planet's atmosphere by intense radiation from its star.

Compared to other exoplanets that orbit very close to their stars, this planet is quite unusual because it is 40 times the mass of Earth but only about three times as big around. The gravity of such massive worlds should attract large amounts of gas from the disk of material out of which planets form. And planets with similarly large masses are five to 10 times as wide as Earth. But TOI 849 b is a lot less puffy than that, leading scientists to conclude that it lacks a substantial atmosphere.

The planet's discoverers say TOI 849 b likely was deprived of its atmosphere in one of two ways: Either it was prevented from gathering enough gas for an atmosphere to form in the first place, or that gaseous atmosphere was torn away. Several planet formation scenarios put forth by scientists suggest that such large, remnant cores are unlikely. It might be a relatively rare, very large planet core that somehow survived blasting, baking or having its atmosphere stripped away by such close proximity to the gravitational influence of its star.

The planet might even have lost its atmosphere after colliding with another giant planet.

One more possibility: a bit of bad luck. TOI 849 b might simply have formed inside a gap in the disk of material surrounding the star, depriving it of the chance to cloak itself in atmospheric gases.

TOI 849 b offers tantalizing opportunities to find out just what lurks deep inside gas giants like Jupiter. Future observations could nail down the composition of evaporated material in whatever wisp of an atmosphere might still exist on the planet. That might be something like peeling back Jupiter's gaseous layers and seeing what lies beneath.

This planet also inhabits what astronomers call the "hot Neptunian desert." In this exclusive club, planets in the size-range of Neptune that are super-heated because their orbits are scorchingly close to their stars. It's a "desert" because such objects are spectacularly rare. TOI 849 b is only the second such object to be published in a scientific journal.

A large, international team led by David J. Armstrong of the University of Warwick, United Kingdom, and including NASA scientists, discovered the new planet using TESS, which was launched in 2018. The planet was entered into NASA's Exoplanet Archive on July 9.

Missions like TESS help contribute to the field of astrobiology, the interdisciplinary research on the variables and conditions of distant worlds that could harbor life as we know it.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Planet Hunter Completes Its Primary Mission

4 min read

On July 4, NASA’s Transiting Exoplanet Survey Satellite (TESS) finished its primary mission, imaging about 75% of the starry sky as part of a two-year-long survey. In capturing this giant mosaic, TESS has found 66 new exoplanets, or worlds beyond our solar system, as well as nearly 2,100 candidates astronomers are working to confirm.

“TESS is producing a torrent of high-quality observations providing valuable data across a wide range of science topics,” said Patricia Boyd, the project scientist for TESS at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “As it enters its extended mission, TESS is already a roaring success.”

TESS monitors 24-by-96-degree strips of the sky called sectors for about a month using its four cameras. The mission spent its first year observing 13 sectors comprising the southern sky and then spent another year imaging the northern sky.

Now in its extended mission, TESS has turned around to resume surveying the south. In addition, the TESS team has introduced improvements to the way the satellite collects and processes data. Its cameras now capture a full image every 10 minutes, three times faster than during the primary mission. A new fast mode allows the brightness of thousands of stars to be measured every 20 seconds, along with the previous method of collecting these observations from tens of thousands of stars every two minutes. The faster measurements will allow TESS to better resolve brightness changes caused by stellar oscillations and to capture explosive flares from active stars in greater detail.

These changes will remain in place for the duration of the extended mission, which will be completed in September 2022. After spending a year imaging the southern sky, TESS will take another 15 months to collect additional observations in the north and to survey areas along the ecliptic – the plane of Earth’s orbit around the Sun – that the satellite has not yet imaged.

TESS looks for transits, the telltale dimming of a star caused when an orbiting planet passes in front of it from our point of view. Among the mission’s newest planetary discoveries are its first Earth-size world, named TOI 700 d, which is located in the habitable zone of its star, the range of distances where conditions could be just right to allow liquid water on the surface. TESS revealed a newly minted planet around the young star AU Microscopii and found a Neptune-size world orbiting two suns.

In addition to its planetary discoveries, TESS has observed the outburst of a comet in our solar system, as well as numerous exploding stars. The satellite discovered surprise eclipses in a well-known binary star system, solved a mystery about a class of pulsating stars, and explored a world experiencing star-modulated seasons. Even more remarkable, TESS watched as a black hole in a distant galaxy shredded a Sun-like star.

Missions like TESS help contribute to the field of astrobiology, the interdisciplinary research on the variables and conditions of distant worlds that could harbor life as we know it, and what form that life could take.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts;

MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes, and observatories worldwide are participants in the mission.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire Andreoli■NASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Citizen Scientists Discover Dozens of New Cosmic Neighbors in NASA Data

6 min read

We’ve never met some of the Sun’s closest neighbors until now. In a new study, astronomers report the discovery of 95 objects known as brown dwarfs, many within a few dozen light-years of the Sun. They’re well outside the solar system, so don’t experience heat from the Sun, but still inhabit a region astronomers consider our cosmic neighborhood. This collection represents some of the coldest known examples of these objects, which are between the sizes of planets and stars.

Members of the public helped make these discoveries through Backyard Worlds: Planet 9, a NASA-funded citizen science project that is a collaboration between volunteers and professional scientists. Backyard Worlds incorporates data from NASA’s Near-Earth Object Wide-Field Infrared Survey Explorer (NEOWISE) satellite along with all-sky observations collected between 2010 and 2011 under its previous moniker, WISE. Data from NASA’s retired Spitzer Space Telescope and the facilities of the National Science Foundation’s NOIRLab were also instrumental in the analysis.

“■Vast modern datasets can unlock landmark discoveries, and it’s exciting that these could be spotted first by citizen scientists■,” said Aaron Meisner, assistant scientist at NSF’s NOIRLab and the lead author of the study describing the brown dwarfs. “■These Backyard Worlds discoveries show that members of the public can play an important role in reshaping our scientific understanding of our solar neighborhood.■”

Why these brown dwarfs are important

Brown dwarfs are not massive enough to power themselves like stars but are still many times heavier than planets. Despite their name, brown dwarfs would actually appear magenta or orange-red to the human eye if seen close up. While brown dwarfs can be extremely hot, even thousands of degrees Fahrenheit, many of the newly discovered ones are colder than the boiling point of water. Some even approach the temperature of Earth and are cool enough to harbor water clouds.

Brown dwarfs with low temperatures are also small in diameter and therefore faint in visible light. Still, they give off heat in the form of infrared light, which is invisible to the human eye yet detectable by telescopes such as NEOWISE and Spitzer. For cold brown dwarfs like those in this study, the infrared signal is also faint, so they are easier to find the closer they are to our solar system.

Discovering and characterizing astronomical objects near the Sun is fundamental to our understanding of our place in, and the history of, the universe. With their relatively cold temperatures, these newly discovered brown dwarfs represent a long sought missing link within the brown dwarf population.

In 2014, scientists discovered the coldest-known brown dwarf, called WISE 0855, using data from NASA’s WISE mission in infrared light. WISE 0855 is about minus 10 degrees Fahrenheit, or minus 23 degrees Celsius. No other brown dwarf came close to this object’s low temperature. Some researchers wondered if 0855 was actually a rogue exoplanet – a planet that originated in a star system but was kicked out of its orbit. This new batch of brown dwarfs, together with others recently discovered using NEOWISE and Spitzer, puts 0855 in context.

“Our new discoveries help connect the dots between 0855 and the other known brown dwarfs,” said astrophysicist Marc Kuchner, the principal investigator of Backyard Worlds and the Citizen Science Officer for NASA’s Science Mission Directorate. Kuchner is also an astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

Since the same physical processes may form both planets and brown dwarfs, the new findings offer prospects for research into worlds beyond our solar system.

“This paper is evidence that the solar neighborhood is still uncharted territory and citizen scientists are excellent astronomical cartographers,” said coauthor Jackie Faherty of the American Museum of Natural History in New York. “Mapping the coldest brown dwarfs down to the lowest masses gives us key insights into the low-mass star-formation process while providing a target list for detailed studies of the atmospheres of Jupiter analogs.”

How professional scientists and citizen scientists collaborated

To help find our Sun’s coldest, nearest neighbors, the professional astronomers of the Backyard Worlds project turned to a worldwide network of more than 100,000 citizen scientists. These volunteers diligently inspect trillions of pixels of telescope images to identify the subtle movements of brown dwarfs. Despite the abilities of machine learning and supercomputers, there’s no substitute for the human eye when it comes to scouring telescope images for moving objects. For this new group of brown dwarfs, 20 citizen scientists across 10 different countries are listed as coauthors of the study.

“Being that this will be the first scientific paper that I’m a coauthor on, its publication will definitely be the highlight of working with Backyard Worlds so far,” said Les Hamlet, a citizen scientist in Springfield, Missouri, who has worked on Backyard Worlds since 2017. “Also, being connected in some way with the now-retired Spitzer Space Telescope through this paper is kind of special to me.”

Backyard Worlds volunteers primarily examine sky maps produced from observations by WISE and NEOWISE. Participants then scour additional archival data sets, like those from the ■Nicholas U. Mayall 4-meter Telescope at Kitt Peak National Observatory and ■Víctor M. Blanco 4-meter Telescope■ at Cerro Tololo Inter-American Observatory, programs of NSF’s NOIRLab. Spitzer, which NASA retired in January 2020, provided the crucial brown dwarf temperature estimates. The results will be published in ■The■ ■Astrophysical Journal.

Backyard Worlds volunteers have already discovered more than 1,500 cold worlds near the Sun. The new discovery of 95 brown dwarfs is the largest published sample of these objects ever discovered through a citizen science project.

Alongside the dedicated efforts of the Backyard Worlds volunteers, NOIRLab’s Astro Data Lab science platform was instrumental in this research.

The approach of the Backyard Worlds project – searching for rare objects in large datasets – is also one of the goals for the Vera C. Rubin Observatory, an NSF/Department of Energy facility currently under construction on Cerro Pachón in Chile’s Atacama Desert. The Rubin Observatory will image the entire southern sky every three nights over 10 years, providing a vast amount of data which will enable new ways of doing astrophysical research.

The new Backyard Worlds discoveries also underscore Spitzer’s pioneering legacy of revealing the Sun’s coolest neighbors. NASA’s forthcoming James Webb Space Telescope will also be a powerful tool for examining brown dwarfs for more insights into these mysterious objects and what they can reveal about the formation of planets and their atmospheres.

About Backyard Worlds: Planet 9

The ongoing Backyard Worlds: Planet 9 project, funded by NASA, lets anyone join the quest to find more mysterious objects in spacecraft data. Check it out at backyardworlds.org.

Media Contacts

Elizabeth LandauHeadquarters, Washington202-923-0167elandau@nasa.gov

Amanda KoczNational Science Foundation’s NOIRLab626-524-5884akocz@aura-astronomy.org

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

In a surprise finding, astronomers using NASA’s Hubble Space Telescope have discovered that the blowtorch-like…

Overview Our planetary system is located in an outer spiral arm of the Milky Way galaxy. We call it the…

Overview Asteroids, comets, and meteors are chunks of rock, ice, and metal left over from the formation of our solar…

Webb is the premier observatory of the next decade, serving thousands of astronomers worldwide. It studies every phase in the…

NASA Images

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Uses Earth as a Proxy for Identifying Oxygen on Potentially Habitable Planets Around Other Stars

7 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Taking advantage of a total lunar eclipse, astronomers using NASA's Hubble Space Telescope have detected Earth's own brand of sunscreen – ozone – in our atmosphere. This method simulates how astronomers and astrobiology researchers will search for evidence of life beyond Earth by observing potential "biosignatures" on exoplanets (planets around other stars).

Hubble did not look at Earth directly. Instead, the astronomers used the Moon as a mirror to reflect sunlight, which had passed through Earth's atmosphere, and then reflected back towards Hubble. Using a space telescope for eclipse observations reproduces the conditions under which future telescopes would measure atmospheres of transiting exoplanets. These atmospheres may contain chemicals of interest to astrobiology, the study of and search for life.

Though numerous ground-based observations of this kind have been done previously, this is the first time a total lunar eclipse was captured at ultraviolet wavelengths and from a space telescope. Hubble detected the strong spectral fingerprint of ozone, which absorbs some of the sunlight. Ozone is important to life because it is the source of the protective shield in Earth's atmosphere.

On Earth, photosynthesis over billions of years is responsible for our planet's high oxygen levels and thick ozone layer. That's one reason why scientists think ozone or oxygen could be a sign of life on another planet, and refer to them as biosignatures.

"Finding ozone is significant because it is a photochemical byproduct of molecular oxygen, which is itself a byproduct of life," explained Allison Youngblood of the Laboratory for Atmospheric and Space Physics in Boulder, Colorado, lead researcher of Hubble's observations.

Although ozone in Earth's atmosphere had been detected in previous ground-based observations during lunar eclipses, Hubble's study represents the strongest detection of the molecule to date because ozone – as measured from space with no interference from other chemicals in the Earth's atmosphere – absorbs ultraviolet light so strongly.

Hubble recorded ozone absorbing some of the Sun's ultraviolet radiation that passed through the edge of Earth's atmosphere during a lunar eclipse that occurred on January 20 to 21, 2019. Several other ground-based telescopes also made spectroscopic observations at other wavelengths during the eclipse, searching for more of Earth's atmospheric ingredients, such as oxygen and methane.

"One of NASA's major goals is to identify planets that could support life," Youngblood said. "But how would we know a habitable or an uninhabited planet if we saw one? What would they look like with the techniques that astronomers have at their disposal for characterizing the atmospheres of exoplanets? That's why it's important to develop models of Earth's spectrum as a template for categorizing atmospheres on extrasolar planets."

Her paper is available online in The Astronomical Journal.

The atmospheres of some extrasolar planets can be probed if the alien world passes across the face of its parent star, an event called a transit. During a transit, starlight filters through the backlit exoplanet's atmosphere. (If viewed close up, the planet's silhouette would look like it had a thin, glowing "halo" around it caused by the illuminated atmosphere, just as Earth does when seen from space.)

Chemicals in the atmosphere leave their telltale signature by filtering out certain colors of starlight. Astronomers using Hubble pioneered this technique for probing exoplanets. This is particularly remarkable because extrasolar planets had not yet been discovered when Hubble was launched in 1990 and the space observatory was not initially designed for such experiments.

So far, astronomers have used Hubble to observe the atmospheres of gas giant planets and super-Earths (planets several times Earth's mass) that transit their stars. But terrestrial planets about the size of Earth are much smaller objects and their atmospheres are thinner, like the skin on an apple. Therefore, teasing out these signatures from Earth-sized exoplanets will be much harder.

That's why researchers will need space telescopes much larger than Hubble to collect the feeble starlight passing through these small planets' atmospheres during a transit. These telescopes will need to observe planets for a longer period, many dozens of hours, to build up a strong signal.

To prepare for these bigger telescopes, astronomers decided to conduct experiments on a much closer and only known inhabited terrestrial planet: Earth. Our planet's perfect alignment with the Sun and Moon during a total lunar eclipse mimics the geometry of a terrestrial planet transiting its star.

But the observations were also challenging because the Moon is very bright, and its surface is not a perfect reflector because it is mottled with bright and dark areas. The Moon is also so close to Earth that Hubble had to try and keep a steady eye on one select region, despite the Moon's motion relative to the space observatory. So, Youngblood's team had to account for the Moon's drift in their analysis.

Finding ozone in the skies of a terrestrial extrasolar planet does not guarantee that life exists on the surface. "You would need other spectral signatures in addition to ozone to conclude that there was life on the planet, and these signatures cannot necessarily be seen in ultraviolet light," Youngblood said.

On Earth, ozone is formed naturally when oxygen in the Earth's atmosphere is exposed to strong concentrations of ultraviolet light. Ozone forms a blanket around Earth, protecting it from harsh ultraviolet rays.

"Photosynthesis might be the most productive metabolism that can evolve on any planet, because it is fueled by energy from starlight and uses cosmically abundant elements like water and carbon dioxide," said Giada Arney of NASA's Goddard Space Flight Center in Greenbelt, Maryland, a co-author of the science paper. "These necessary ingredients should be common on habitable planets."

Seasonal variability in the ozone signature also could indicate seasonal biological production of oxygen, just as it does with the growth seasons of plants on Earth.

But ozone can also be produced without the presence of life when nitrogen and oxygen are exposed to sunlight. To increase confidence that a given biosignature is truly produced by life, astronomers must search for combinations of biosignatures. A multiwavelength campaign is needed because each of the many biosignatures are more easily detected at wavelengths specific to those signatures.

"Astronomers will also have to take the developmental stage of the planet into account when looking at younger stars with young planets. If you wanted to detect oxygen or ozone from a planet similar to the early Earth, when there was less oxygen in our atmosphere, the spectral features in optical and infrared light aren't strong enough," Arney explained. "We think Earth had low concentrations of ozone before the mid-Proterozoic geological period (between roughly 2.0 billion to 0.7 billion years ago) when photosynthesis contributed to the build up of oxygen and ozone in the atmosphere to the levels we see today. But because the ultraviolet-light signature of ozone features is very strong, you would have a hope of detecting small amounts of ozone. The ultraviolet may therefore be the best wavelength for detecting photosynthetic life on low-oxygen exoplanets."

NASA has a forthcoming observatory called the James Webb Space Telescope that could make similar kinds of measurements in infrared light, with the potential to detect methane and oxygen in exoplanet atmospheres. Webb is currently scheduled to launch in 2021.

Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore410-338-4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

Allison YoungbloodLaboratory for Atmospheric and Space Physics, Boulder, Colo.allison.youngblood@colorado.edu

Discovery Alert: See the Image – 2 Planets Orbit a Sun-like Star

3 min read

Alicia Cermak

The planet: TYC 8998-760-1 c

The discovery: This hot, very large planet is the second to be directly imaged – that is, pixels of light captured by telescope from the planet itself – as it orbits a Sun-like star some 300 light-years away. An international team of scientists published its discovery of the star's first directly imaged companion in February 2020.

Key facts: These two planets – TYC 8998-760-1 b and now, c – are considered the first multi-planet system to be directly imaged around a Sun-like star. The star is a baby version of our Sun, only 17 million years old. The extreme youth of this system is a big part of why astronomers were able to capture direct images: The planets are so hot from their recent formation that they still glow brightly enough to be seen from our vantage point, even though they're hundreds of light-years away.

Details: Planets b and c are much farther away from their star than, say, Jupiter and Saturn are from the Sun. Planet b is 160 times the Earth-Sun distance, planet c is about 320 times. Just for comparison, Jupiter is 5 times the Earth-Sun distance, Saturn 10 times.

And these planets are bruisers. The inner planet, b, is about 14 times the mass, or heft, of Jupiter, c about 6 times. Planet b, in fact, might even be a brown dwarf, a kind of failed star considered neither a star nor a planet, but somewhere in between.

Fun facts: Thousands of planets around other stars – exoplanets – have been confirmed so far in our galaxy, which likely holds trillions. But the vast majority are found through indirect means – measuring wobbles in the star's motion caused by the gravity of orbiting planets, or the tiny dip in starlight as a planet crosses its star's face. Only a few dozen of the exoplanets found so far have been directly imaged. And direct images of multi-planet systems are rarer still: only two others so far, both with stars very different from our Sun. The new system, with its Sun-like star, might have some characteristics in common with the very early history of our own solar system. It offers an exciting opportunity for scientists to learn more about the formation of such systems, including our own.

The discoverers: Both planets in this system were discovered by an international team of scientists led by Alexander J. Bohn of Leiden University in the Netherlands. They used the SPHERE instrument on the Very Large Telescope (VLT) at the European Southern Observatory in Chile to observe the star and its planets in February 2020. The planet was entered into NASA's Exoplanet Archive on July 23.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Ground System for NASA's Roman Space Telescope Completes Major Review

7 min read

When it launches in the mid-2020s, NASA's Nancy Grace Roman Space Telescope will create enormous panoramic pictures of space in unprecedented detail. The mission's wide field of view will enable scientists to conduct sweeping cosmic surveys, yielding a wealth of new information about the universe.

The Roman mission's ground system, which will make data from the spacecraft available to scientists and the public, has just successfully completed its preliminary design review. The plan for science operations has met all of the design, schedule, and budget requirements, and will now proceed to the next phase: building the newly designed data system.

"This is an exciting milestone for the mission," said Ken Carpenter, the Roman ground system project scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "We are on track to complete the data system in time for launch, and we look forward to the ground-breaking science it will enable."

Roman will have the same resolution as the Hubble Space Telescope but capture a field of view nearly 100 times larger. Scientists expect the spacecraft to collect more data than any of NASA's other astrophysics missions.

Using Hubble's observations, astronomers have revolutionized our view of the universe and unleashed a flood of discoveries. Hubble has gathered 172 terabytes of data since its launch in 1990. If all of this data were printed as text and the pages were placed on top of each other, the stack would reach about 5,000 miles (8,000 kilometers) high. That's far enough to reach about 15 times higher than Hubble's orbit, or about 2% of the distance to the Moon.

Roman will gather data about 500 times faster than Hubble, adding up to 20,000 terabytes (20 petabytes) over the course of its five-year primary mission. If this data were printed, the stack of papers would tower 330 miles (530 kilometers) high after a single day. By the end of Roman's primary mission, the stack would extend well beyond the Moon. Untold cosmic treasures will be brought to light by Roman's rich observations.

Such a vast volume of information will require NASA to rely on new processing and archival techniques. Scientists will access and analyze Roman's data using cloud-based remote services and more sophisticated tools than those used by previous missions.

All of Roman's data will be publicly available within days of the observations – a first for a NASA astrophysics flagship mission. This is significant because Roman's colossal images will often contain far more than the primary target of observation.

Since scientists everywhere will have rapid access to the data, they will be able to quickly discover short-lived phenomena, such as supernova explosions. Detecting these phenomena quickly will allow other telescopes to perform follow-up observations.

One of the science areas that will benefit from the mission's vast data is the microlensing survey. Gravitational lensing is an observational effect that occurs because the presence of mass warps the fabric of space-time. The effect is extreme around very massive objects, like black holes and entire galaxies. But even relatively small objects like stars and planets cause a detectable degree of warping, called microlensing.

Any time two stars align closely from our vantage point, light from the more distant star curves as it travels through the warped space-time around the nearer star. The nearer star acts like a natural cosmic lens, focusing and intensifying light from the background star.

Scientists see this as a spike in brightness. Planets orbiting the foreground star may also modify the lensed light, acting as their own tiny lenses. These small signatures drive the design of Roman's microlensing survey.

"With such a large number of stars and frequent observations, Roman's microlensing survey will see thousands of planetary events," said Rachel Akeson, task lead for the Roman Science Support Center at IPAC/Caltech in Pasadena, California. "Each one will have a unique signature which we can use to determine the planet's mass and distance from its star."

Roman's microlensing survey will also detect hundreds of other bizarre and interesting cosmic objects. Roman will discover starless planets that roam the galaxy as rogue worlds; brown dwarfs, which are too massive to be characterized as planets but not massive enough to ignite as stars; and stellar corpses, including neutron stars and black holes, which are left behind when stars exhaust their fuel.

Microlensing events are extremely rare and require extensive observations. Roman will monitor hundreds of millions of stars every 15 minutes for months at a time – something no other space telescope can do, generating an unprecedented stream of new information.

While the microlensing survey will look toward the heart of our galaxy, where stars are most densely concentrated, Roman's cosmological surveys will peer far beyond our stars to study hundreds of millions of other galaxies. These observations will help illuminate two of the biggest cosmic puzzles: dark matter and dark energy.

Visible matter accounts for only about five percent of the contents of the universe. Nearly 27 percent of the universe comes in the form of dark matter, which doesn't emit or absorb light. Dark matter is only detectable through its gravitational effects on visible matter.

Roman will help us figure out what dark matter is made of by exploring the structure and distribution of regular matter and dark matter across space and time. This investigation can only be done effectively using precise measurements from many galaxies.

The remaining approximately 68 percent of the universe is made up of dark energy. This mysterious cosmic pressure is causing the expansion of the universe to accelerate, but so far we don't know much more about it.

Roman will study dark energy through multiple observational strategies, including surveys of galaxy clusters and supernovae. Scientists will create a 3D map of the universe to help us understand how the universe grew over time under the influence of dark energy.

Since Roman will have such a large field of view, it will dramatically reduce the amount of time needed to gather data. The Cosmic Assembly Near-infrared Deep Extragalactic Survey (CANDELS) is one of the largest projects ever done with Hubble, designed to study the development of galaxies over time. While it took Hubble nearly 21 days, Roman would complete a similar survey in less than half an hour – 1,000 times faster than Hubble. Using Roman, scientists will be able to extend these observations in ways that would be impractical with other telescopes.

"With its incredibly fast survey speeds, Roman will observe planets by the thousands, galaxies by the millions, and stars by the billions," said Karoline Gilbert, mission scientist for the Roman Science Operations Center at the Space Telescope Science Institute in Baltimore. "These vast datasets will allow us to address cosmic mysteries that hint at new fundamental physics."

The Nancy Grace Roman Space Telescope is managed at Goddard, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Pasadena, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from research institutions across the United States.

Download high-resolution video and images from NASA's Scientific Visualization Studio

By Ashley BalzerNASA's Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Finding Disks Where Planets Form: ‘Disk Detective’ Needs Your Help

5 min read

NASA Science Editorial Team

Planets form from gas and dust particles swirling around baby stars in enormous spinning disks. But because this process takes millions of years, scientists can only learn about these disks by finding and studying a lot of different examples.

Through a project called Disk Detective, you can help. Anyone, regardless of background or prior knowledge, can assist scientists in figuring out the mysteries of planet formation. Disk Detective is an example of citizen science, a collaboration between professional scientists and members of the public.

Get the Latest JPL News: Subscribe to the Newsletter »

"We're trying to understand how long it takes for planets to form," said astrophysicist Marc Kuchner, the Disk Detective project lead at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and the Citizen Science Officer for NASA's Science Mission Directorate. "Tracing the evolution of these disks is the main way that we know how long planet formation takes."

Disk Detective has just relaunched with a new website and a new dataset of about 150,000 stars. This new version of the project focuses on M dwarfs, which represent the most common type of star in the Milky Way galaxy. It also concentrates on brown dwarfs, which are balls of gas that don't burn hydrogen the way stars do and often more closely resemble giant planets like Jupiter.

After reading the instructions, participants can start identifying disks right away in Disk Detective. The interface presents a series of real astronomical images and asks visitors questions that will help determine more definitively if a disk is present. The images come from NASA's Wide-Field Infrared Survey Explorer (WISE), which now operates as NEOWISE, as well as the ground-based Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) in Hawaii and the NASA-funded Two Micron All-Sky Survey (2MASS), which operated from 1997 to 2001.

"We have multiple citizen scientists look at each object, give their own independent opinion, and trust the wisdom of the crowd to decide what things are probably galaxies and what things are probably stars with disks around them," said Disk Detective's director, Steven Silverberg, a postdoctoral researcher at Massachusetts Institute of Technology's Kavli Institute for Astrophysics and Space Research.

Advanced users learn more about the objects they're studying using professional data archives. Those who contribute substantial insight receive credit on scientific papers describing the discoveries made through Disk Detective's efforts. Professional scientists then follow up on citizen scientists' input using more sophisticated tools and new observations. Fifteen citizen scientists have already become named co-authors on peer-reviewed scientific papers through Disk Detective.

One enthusiastic Disk Detective "superuser" is Hugo Durantini Luca, a computer technician in Córdoba, Argentina. He began classifying disks with the project in 2014 and since then has taken on additional responsibilities: writing tutorials, moderating discussions, and even helping use telescopes in South America to follow up on interesting targets. While he became involved because of his interest in detecting planetary systems and analyzing images, he says he highly values "the way you are able to work with the science team directly." He is in frequent communication with Kuchner and other professional astronomers, and he participates in a weekly video call for superusers.

"I think we are going to have an interesting new season," Durantini Luca said. "The new way we are processing the data will allow us to analyze the image[s] with better detail."

Citizen scientists at Disk Detective made an important discovery in 2016: a new class of disks, called Peter Pan disks. Most disks around young, low-mass stars should lose their gas, due to planet formation and natural dissipation into space, after 5 million years. Yet Disk Detective citizen scientists discovered a disk with plenty of gas orbiting a star that is roughly 45 million years old.

Since then, seven similar mysteriously young-looking disks have been found, each at least 20 million years old. Scientists are still puzzling out why planet formation goes on for so long in these disks. They predict that citizen scientists may find as many as 15 new Peter Pan disks through the newly revamped Disk Detective.

"To figure out how disks evolve, we need a big sample of different kinds of disks of different ages," Kuchner said.

More recently, Disk Detective's efforts resulted in a discovery announced on June 2 at the American Astronomical Society's (AAS) 236th meeting, which was held virtually. With the help of citizen scientists, astronomers identified the closest young brown dwarf disk yet, one that may have the capability to form planets. This 3.7-million-year-old brown dwarf, called W1200-7845, is about 333 light-years away. A light-year is the distance light travels in one year; the closest star beyond the Sun is over 4 light-years away.

"There are not many examples of young brown dwarfs so close to the Sun, so W1200-7845 is an exciting discovery," said Maria Schutte, a predoctoral graduate student at the University of Oklahoma, who led the study and presented the findings at the AAS meeting. Durantini Luca and other citizen scientists were included as coauthors.

Since the last Disk Detective data release, ESA's (European Space Agency's) Gaia satellite has delivered an unprecedented bounty of information about the locations, movements, and types of stars in the Milky Way. The Disk Detective science team used the new data from Gaia to identify M dwarfs of interest to the project. A second improvement to the project is that the new images from the surveys listed above have higher resolution than the previous batch of data, making more background objects visible.

"NASA needs your help," Kuchner said. "Come discover these disks with us!"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Two Bizarre Brown Dwarfs Found With Citizen Scientists’ Help

5 min read

With the help of citizen scientists, astronomers have discovered two highly unusual brown dwarfs, balls of gas that are not massive enough to power themselves the way stars do.

Participants in the NASA-funded Backyard Worlds: Planet 9 project helped lead scientists to these bizarre objects, using data from NASA’s Near-Earth Object Wide-Field Infrared Survey Explorer (NEOWISE) satellite along with all-sky observations collected between 2009 and 2011 under its previous moniker, WISE. Backyard Worlds: Planet 9 is an example of “citizen science,” a collaboration between professional scientists and members of the public.

Scientists call the newly discovered objects “the first extreme T-type subdwarfs.” They weigh about 75 times the mass of Jupiter and clock in at roughly 10 billion years old. These two objects are the most planet-like brown dwarfs yet seen among the Milky Way’s oldest population of stars.

Astronomers hope to use these brown dwarfs to learn more about exoplanets, which are planets outside of our solar system. The same physical processes may form both planets and brown dwarfs.

“These surprising, weird brown dwarfs resemble ancient exoplanets closely enough that they will help us understand the physics of the exoplanets,” said astrophysicist Marc Kuchner, the principal investigator of Backyard Worlds: Planet 9 and the Citizen Science Officer for NASA’s Science Mission Directorate. Kuchner is also an astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

These two special brown dwarfs have highly unusual compositions. When viewed in particular wavelengths of infrared light, they look like other brown dwarfs, but at others they do not resemble any other stars or planets that have been observed so far.

Scientists were surprised to see they have very little iron, meaning that, like ancient stars, they have not incorporated iron from star births and deaths in their environments. A typical brown dwarf would have as much as 30 times more iron and other metals than these newly discovered objects. One of these brown dwarfs seems to have only about 3% as much iron as our Sun. Scientists expect very old exoplanets would have a low metal content, too.

“A central question in the study of brown dwarfs and exoplanets is how much does planet formation depend on the presence of metals like iron and other elements formed by multiple earlier generations of stars,” Kuchner said. “The fact that these brown dwarfs seem to have formed with such low metal abundances suggests that maybe we should be searching harder for ancient, metal-poor exoplanets, or exoplanets orbiting ancient metal-poor stars.”

A study in The Astrophysical Journal details these discoveries and the potential implications. Six citizen scientists are listed as co-authors of the study.

How volunteers found these extreme brown dwarfs

The study’s lead author, Adam Schneider of Arizona State University’s School of Earth and Space Exploration in Tempe, first noticed one of the unusual brown dwarfs, called WISE 1810, in 2016, but it was in a crowded area of the sky and was difficult to confirm.

With the help of a tool called WiseView, created by Backyard Worlds: Planet 9 citizen scientist Dan Caselden, Schneider confirmed that the object he had seen years earlier was moving quickly, which is a good indication that an object is a nearby celestial body like a planet or brown dwarf.

“WiseView scrolls through data like a short movie,” Schneider said, “so you can see more easily see if something is moving or not.”

The second unusual brown dwarf, WISE 0414, was discovered by a group of citizen scientists including Backyard Worlds participants Paul Beaulieu, Sam Goodman, William Pendrill, Austin Rothermich, and Arttu Sainio.

The citizen scientists who found WISE 0414 combed through hundreds of images taken by WISE looking for moving objects, which are best detected with the human eye.

“The discovery of these two brown dwarfs shows that science enthusiasts can contribute to the scientific process,” Schneider said. “Through Backyard Worlds, thousands of people can work together to find unusual objects in the solar neighborhood.”

Astronomers followed up to determine their physical properties and confirm that they are indeed brown dwarfs. The discovery of these two unusual brown dwarfs suggests astronomers may be able to find more of these objects in the future.

About Backyard Worlds: Planet 9

The ongoing Backyard Worlds: Planet 9 project lets anyone join the quest to find more mysterious objects in spacecraft data. Citizen scientists using this project have discovered a wealth of astronomical treasures, including more than 1,600 brown dwarfs and the oldest, coldest white dwarf surrounded by a disk of debris.

About 150,000 people have participated so far. Check it out at backyardworlds.org.

About WISE and NEOWISE

The WISE spacecraft was placed in hibernation in February 2011 after completing its primary astrophysics mission, but in late 2013, the spacecraft was reactivated, renamed NEOWISE, and assigned a second mission dedicated to identifying and characterizing the population of near-Earth objects while also providing information about the size and composition of more distant asteroids and comets.

NASA’s Jet Propulsion Laboratory in Pasadena, California, manages and operates the NEOWISE mission for NASA’s Planetary Defense Coordination Office within the Science Mission Directorate in Washington. The principal investigator, Amy Mainzer, is at the University of Arizona. The Space Dynamics Laboratory in Logan, Utah, built the science instrument. Ball Aerospace & Technologies Corp. of Boulder, Colorado, built the spacecraft. Science data processing takes place at IPAC at Caltech in Pasadena. Caltech manages JPL for NASA.

JPL managed and operated WISE for NASA’s Science Mission Directorate. Edward Wright at UCLA was the principal investigator. The mission was selected competitively under NASA’s Explorers Program managed by the agency’s Goddard Space Flight Center in Greenbelt, Maryland.

For more information about NEOWISE, visit:

For more information about WISE, visit:

Elizabeth LandauNASA Headquarterselandau@nasa.gov202-923-0167

Karin ValentineMedia RelationsSchool of Earth and Space ExplorationArizona State Universitykarin.valentine@asu.edu480-965-9345

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

‘Disk Detective’ Needs Your Help Finding Disks Where Planets Form

6 min read

Planets form from gas and dust particles swirling around baby stars in enormous spinning disks. But because this process takes millions of years, scientists can only learn about these disks by finding and studying a lot of different examples.

Through a project called Disk Detective, you can help. Anyone, regardless of background or prior knowledge, can assist scientists in figuring out the mysteries of planet formation. Disk Detective is an example of citizen science, a collaboration between professional scientists and members of the public.

“We’re trying to understand how long it takes for planets to form,” said astrophysicist Marc Kuchner, the Disk Detective project lead at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and the Citizen Science Officer for NASA’s Science Mission Directorate. “Tracing the evolution of these disks is the main way that we know how long planet formation takes.”

Disk Detective has just relaunched with a new website and a new dataset of about 150,000 stars. This new version of the project focuses on M dwarfs, which represent the most common type of star in the Milky Way galaxy. It also concentrates on brown dwarfs, which are balls of gas that don’t burn hydrogen the way stars do and often more closely resemble giant planets like Jupiter.

After reading the instructions, participants can start identifying disks right away in Disk Detective. The interface presents a series of real astronomical images and asks visitors questions that will help determine more definitively if a disk is present. The images come from NASA’s Wide-Field Infrared Survey Explorer (WISE), which now operates as NEOWISE, as well as the ground-based Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) in Hawaii and the NASA-funded Two Micron All-Sky Survey (2MASS), which operated from 1997 to 2001.

“We have multiple citizen scientists look at each object, give their own independent opinion, and trust the wisdom of the crowd to decide what things are probably galaxies and what things are probably stars with disks around them,” said Disk Detective’s director, Steven Silverberg, a postdoctoral researcher at Massachusetts Institute of Technology’s Kavli Institute for Astrophysics and Space Research.

Advanced users learn more about the objects they’re studying using professional data archives. Those who contribute substantial insight receive credit on scientific papers describing the discoveries made through Disk Detective’s efforts. Professional scientists then follow up on citizen scientists’ input using more sophisticated tools and new observations. Fifteen citizen scientists have already become named co-authors on peer-reviewed scientific papers through Disk Detective.

One enthusiastic Disk Detective “superuser” is Hugo Durantini Luca, a computer technician in Córdoba, Argentina. He began classifying disks with the project in 2014 and since then has taken on additional responsibilities: writing tutorials, moderating discussions, and even helping use telescopes in South America to follow up on interesting targets. While he became involved because of his interest in detecting planetary systems and analyzing images, he says he highly values “the way you are able to work with the science team directly.” He is in frequent communication with Kuchner and other professional astronomers, and he participates in a weekly video call for superusers.

“I think we are going to have an interesting new season,” Durantini Luca said. “The new way we are processing the data will allow us to analyze the image[s] with better detail.”

Citizen scientists at Disk Detective made an important discovery in 2016: a new class of disks, called Peter Pan disks. Most disks around young, low-mass stars should lose their gas, due to planet formation and natural dissipation into space, after 5 million years. Yet Disk Detective citizen scientists discovered a disk with plenty of gas orbiting a star that is roughly 45 million years old.

Since then, seven similar mysteriously young-looking disks have been found, each at least 20 million years old. Scientists are still puzzling out why planet formation goes on for so long in these disks. They predict that citizen scientists may find as many as 15 new Peter Pan disks through the newly revamped Disk Detective.

“To figure out how disks evolve, we need a big sample of different kinds of disks of different ages,” Kuchner said.

More recently, Disk Detective’s efforts resulted in a discovery announced on June 2 at the American Astronomical Society’s (AAS) 236th meeting, which was held virtually. With the help of citizen scientists, astronomers identified the closest young brown dwarf disk yet, one that may have the capability to form planets. This 3.7-million-year-old brown dwarf, called W1200-7845, is about 333 light-years away. A light-year is the distance light travels in one year; the closest star beyond the Sun is over 4 light-years away.

“There are not many examples of young brown dwarfs so close to the Sun, so W1200-7845 is an exciting discovery,” said Maria Schutte, a predoctoral graduate student at the University of Oklahoma, who led the study and presented the findings at the AAS meeting. Durantini Luca and other citizen scientists were included as co-authors.

Since the last Disk Detective data release, ESA’s (European Space Agency’s) Gaia satellite has delivered an unprecedented bounty of information about the locations, movements, and types of stars in the Milky Way. The Disk Detective science team used the new data from Gaia to identify M dwarfs of interest to the project. A second improvement to the project is that the new images from the surveys listed above have higher resolution than the previous batch of data, making more background objects visible.

“NASA needs your help,” Kuchner said. “Come discover these disks with us!”

About Disk Detective

Disk Detective is a NASA-funded citizen science project that is part of the NASA-sponsored Zooniverse citizen science platform.

Check out the revamped Disk Detective project at https://diskdetective.org.

Learn more about NASA Citizen Science at https://science.nasa.gov/citizenscience.

About WISE and NEOWISE

NASA’s Jet Propulsion Laboratory in Southern California managed and operated WISE for NASA’s Science Mission Directorate from 2009 to 2011. Edward Wright at the University of California, Los Angeles was the principal investigator. The mission was selected competitively under NASA’s Explorers Program managed by the agency’s Goddard Space Flight Center in Greenbelt, Maryland. In late 2013, the spacecraft was reactivated and renamed NEOWISE. For more information about NEOWISE, visit:

https://www.nasa.gov/neowise

http://neowise.ipac.caltech.edu/

For more information about WISE, visit:

https://www.nasa.gov/wise

https://www.jpl.nasa.gov/wise/

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

In a surprise finding, astronomers using NASA's Hubble Space Telescope have discovered that the blowtorch-like…

Scientists and engineers tested NASA's LEMS (Lunar Environment Monitoring Station) instrument suite in a "sandbox" of…

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Delivers New Insights Into an Ultrahot World

5 min read

Measurements from NASA’s Transiting Exoplanet Survey Satellite (TESS) have enabled astronomers to greatly improve their understanding of the bizarre environment of KELT-9 b, one of the hottest planets known.

“The weirdness factor is high with KELT-9 b,” said John Ahlers, an astronomer at Universities Space Research Association in Columbia, Maryland, and NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “It’s a giant planet in a very close, nearly polar orbit around a rapidly rotating star, and these features complicate our ability to understand the star and its effects on the planet.”

The new findings appear in a paper led by Ahlers published on June 5 in The Astronomical Journal.

Located about 670 light-years away in the constellation Cygnus, KELT-9 b was discovered in 2017 because the planet passed in front of its star for a part of each orbit, an event called a transit. Transits regularly dim the star’s light by a small but detectable amount. The transits of KELT-9 b were first observed by the KELT transit survey, a project that collected observations from two robotic telescopes located in Arizona and South Africa.

Between July 18 and Sept. 11, 2019, as part of the mission’s yearlong campaign to observe the northern sky, TESS observed 27 transits of KELT-9 b, taking measurements every two minutes. These observations allowed the team to model the system’s unusual star and its impact on the planet.

KELT-9 b is a gas giant world about 1.8 times bigger than Jupiter, with 2.9 times its mass. Tidal forces have locked its rotation so the same side always faces its star. The planet swings around its star in just 36 hours on an orbit that carries it almost directly above both of the star’s poles.

KELT-9 b receives 44,000 times more energy from its star than Earth does from the Sun. This makes the planet’s dayside temperature around 7,800 degrees Fahrenheit (4,300 C), hotter than the surfaces of some stars. This intense heating also causes the planet’s atmosphere to stream away into space.

Its host star is an oddity, too. It’s about twice the size of the Sun and averages about 56 percent hotter. But it spins 38 times faster than the Sun, completing a full rotation in just 16 hours. Its rapid spin distorts the star’s shape, flattening it at the poles and widening its midsection. This causes the star’s poles to heat up and brighten while its equatorial region cools and dims — a phenomenon called gravity darkening. The result is a temperature difference across the star’s surface of almost 1,500 F (800 C).

With each orbit, KELT-9 b twice experiences the full range of stellar temperatures, producing what amounts to a peculiar seasonal sequence. The planet experiences “summer” when it swings over each hot pole and “winter” when it passes over the star’s cooler midsection. So KELT-9 b experiences two summers and two winters every year, with each season about nine hours.

“It’s really intriguing to think about how the star’s temperature gradient impacts the planet,” said Goddard’s Knicole Colón, a co-author of the paper. “The varying levels of energy received from its star likely produce an extremely dynamic atmosphere.”

KELT-9 b’s polar orbit around its flattened star produces distinctly lopsided transits. The planet begins its transit near the star’s bright poles and then blocks less and less light as it travels over the star’s dimmer equator. This asymmetry provides clues to the temperature and brightness changes across the star’s surface, and they permitted the team to reconstruct the star’s out-of-round shape, how it’s oriented in space, its range of surface temperatures, and other factors impacting the planet.

“Of the planetary systems that we’ve studied via gravity darkening, the effects on KELT-9 b are by far the most spectacular,” said Jason Barnes, a professor of physics at the University of Idaho and a co-author of the paper. “This work goes a long way toward unifying gravity darkening with other techniques that measure planetary alignment, which in the end we hope will tease out secrets about the formation and evolutionary history of planets around high-mass stars.”

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS, Spitzer Missions Discover a World Orbiting a Unique Young Star

7 min read

For more than a decade, astronomers have searched for planets orbiting AU Microscopii, a nearby star still surrounded by a disk of debris left over from its formation. Now scientists using data from NASA’s Transiting Exoplanet Survey Satellite (TESS) and retired Spitzer Space Telescope report the discovery of a planet about as large as Neptune that circles the young star in just over a week.

The system, known as AU Mic for short, provides a one-of-a-kind laboratory for studying how planets and their atmospheres form, evolve and interact with their stars.

“AU Mic is a young, nearby M dwarf star. It’s surrounded by a vast debris disk in which moving clumps of dust have been tracked, and now, thanks to TESS and Spitzer, it has a planet with a direct size measurement,” said Bryson Cale, a doctoral student at George Mason University in Fairfax, Virginia. “There is no other known system that checks all of these important boxes.”

The new planet, AU Mic b, is described in a paper co-authored by Cale and led by his advisor Peter Plavchan, an assistant professor of physics and astronomy at George Mason. Their report was published on Wednesday, June 24, in the journal Nature.

AU Mic b is featured in a new NASA poster available in English and Spanish, part of a Galaxy of Horrors series. The fun but informative series resulted from a collaboration of scientists and artists and was produced by NASA’s Exoplanet Exploration Program Office.

AU Mic is a cool red dwarf star with an age estimated at 20 million to 30 million years, making it a stellar infant compared to our Sun, which is at least 150 times older. The star is so young that it primarily shines from the heat generated as its own gravity pulls it inward and compresses it. Less than 10% of the star’s energy comes from the fusion of hydrogen into helium in its core, the process that powers stars like our Sun.

The system is located 31.9 light-years away in the southern constellation Microscopium. It’s part of a nearby collection of stars called the Beta Pictoris Moving Group, which takes its name from a bigger, hotter A-type star that harbors two planets and is likewise surrounded by a debris disk.

Although the systems have the same age, their planets are markedly different. The planet AU Mic b almost hugs its star, completing an orbit every 8.5 days. It weighs less than 58 times Earth’s mass, placing it in the category of Neptune-like worlds. Beta Pictoris b and c, however, are both at least 50 times more massive than AU Mic b and take 21 and 3.3 years, respectively, to orbit their star.

“We think AU Mic b formed far from the star and migrated inward to its current orbit, something that can happen as planets interact gravitationally with a gas disk or with other planets,” said co-author Thomas Barclay, an associate research scientist at the University of Maryland, Baltimore County and an associate project scientist for TESS at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “By contrast, Beta Pictoris b’s orbit doesn’t appear to have migrated much at all. The differences between these similarly aged systems can tell us a lot about how planets form and migrate.”

Detecting planets around stars like AU Mic poses a particular challenge. These stormy stars possess strong magnetic fields and can be covered with starspots — cooler, darker and highly magnetic regions akin to sunspots — that frequently erupt powerful stellar flares. Both the spots and their flares contribute to the star’s brightness changes.

In July and August 2018, when TESS was observing AU Mic, the star produced numerous flares, some of which were more powerful than the strongest flares ever recorded on the Sun. The team performed a detailed analysis to remove these effects from the TESS data.

When a planet crosses in front of its star from our perspective, an event called a transit, its passage causes a distinct dip in the star's brightness. TESS monitors large swaths of the sky, called sectors, for 27 days at a time. During this long stare, the mission's cameras regularly capture snapshots that allow scientists to track changes in stellar brightness.

Regular dips in a star's brightness signal the possibility of a transiting planet. Usually, it takes at least two observed transits to recognize a planet's presence.

"As luck would have it, the second of three TESS transits occurred when the spacecraft was near its closest point to Earth. At such times, TESS is not observing because it is busy downlinking all of the stored data," said co-author Diana Dragomir, a research assistant professor at the University of New Mexico in Albuquerque. "To fill the gap, our team was granted observing time on Spitzer, which caught two additional transits in 2019 and enabled us to confirm the orbital period of AU Mic b."

Spitzer was a multipurpose infrared observatory operating from 2003 until its decommissioning on Jan. 30, 2020. The mission proved especially adept at detecting and studying exoplanets around cool stars. Spitzer returned the AU Mic observations during its final year.

Because the amount of light blocked by a transit depends on the planet's size and orbital distance, the TESS and Spitzer transits provide a direct measure of AU Mic b's size. Analysis of these measurements show that the planet is about 8% larger than Neptune.

Observations from instruments on ground-based telescopes provide upper limits for the planet's mass. As a planet orbits, its gravity tugs on its host star, which moves slightly in response. Sensitive instruments on large telescopes can detect the star's radial velocity, its motion to-and-fro along our line of sight. Combining observations from the W. M. Keck Observatory and NASA's InfraRed Telescope Facility in Hawaii and the European Southern Observatory in Chile, the team concluded that AU Mic b has a mass smaller than 58 Earths.

This discovery shows the power of TESS to provide new insights into well-studied stars like AU Mic, where more planets may be waiting to be found.

"There is an additional candidate transit event seen in the TESS data, and TESS will hopefully revisit AU Mic later this year in its extended mission," Plavchan said. "We are continuing to monitor the star with precise radial velocity measurements, so stay tuned."

For decades, AU Mic has intrigued astronomers as a possible home for planets thanks to its proximity, youth and bright debris disk. Now that TESS and Spitzer have found one there, the story comes full circle. AU Mic is a touchstone system, a nearby laboratory for understanding the formation and evolution of stars and planets that will be studied for decades to come.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Center in California's Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT's Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

NASA's Jet Propulsion Laboratory (JPL) in Southern California managed the Spitzer mission for the agency's Science Mission Directorate in Washington. Spitzer science data continue to be analyzed by the science community via the Spitzer data archive located at the Infrared Science Archive housed at IPAC at Caltech in Pasadena. Science operations were conducted at the Spitzer Science

Center at Caltech. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado. Caltech manages JPL for NASA.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

Hubble Sees Cosmic Flapping ‘Bat Shadow’

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

En español

Sometimes nicknames turn out to be closer to reality than you might imagine.

NASA’s Hubble Space Telescope captured a striking image of a fledgling star’s unseen, planet-forming disk casting a huge shadow across a more distant cloud in a star-forming region – like a fly wandering into the beam of a flashlight shining on a wall.

The young star is called HBC 672, and the shadow feature was nicknamed the “Bat Shadow” because it resembles a pair of wings. The nickname turned out to be surprisingly appropriate: Now, the team reports that they see the Bat Shadow flapping!

“The shadow moves. It’s flapping like the wings of a bird!” described lead author Klaus Pontoppidan, an astronomer at the Space Telescope Science Institute (STScI) in Baltimore. The phenomenon may be caused by a planet pulling on the disk and warping it. The team witnessed the flapping over 404 days.

But what created the Bat Shadow in the first place?

“You have a star that is surrounded by a disk, and the disk is not like Saturn’s rings – it’s not flat. It’s puffed up. And so that means that if the light from the star goes straight up, it can continue straight up – it’s not blocked by anything. But if it tries to go along the plane of the disk, it doesn’t get out, and it casts a shadow,” explained Pontoppidan.

He suggests imagining a lamp with a shade that casts a shadow on the wall. In this case, the lightbulb is the star, the lampshade is the disk, and the cloud is the wall. Based on the shadow’s shape, the disk must be flared, with an angle that increases with distance – like bell-bottom pants, or a trumpet.

The disk – a circling structure of gas, dust, and rock – might be roughly saddle-shaped, with two peaks and two dips, which would explain the “flapping” of the shadow. The team speculates that a planet is embedded in the disk, with an orbit inclined to the disk’s plane. This planet would be the cause of the doubly warped shape of the orbiting disk and the resulting movement in its shadow.

“If there were just a simple bump in the disk, we'd expect both sides of the shadow to tilt in opposite directions, like airplane wings during a turn,” said team member Colette Salyk of Vassar College in Poughkeepsie, New York.

The shadow, extending from the star across the surrounding cloud, is so large – about 200 times the length of our solar system – that light doesn’t travel instantaneously across it. In fact, the time it takes for the light to travel from the star out to the perceivable edge of the shadow is about 40 to 45 days. Pontoppidan and his team calculate a planet warping the disk would orbit its star in no fewer than 180 days. They estimate that this planet would be about the same distance from its star as Earth is from the Sun.

If not a planet, an alternative explanation for the shadow motion is a lower-mass stellar companion orbiting HBC 672 outside the plane of the disk, causing HBC 672 to “wobble” relative to its shadowing disk. But Pontoppidan and his team doubt this is the case, based on the thickness of the disk. There is also no current evidence for a binary companion.

The disk is too small and too distant to be seen, even by Hubble. The star HBC 672 resides in a stellar nursery called the Serpens Nebula, about 1,400 light-years away. It is only one or two million years old, which is young in cosmic terms.

This finding was serendipitous. The first image of the Bat Shadow was taken by another team. Later, the image was slated for use in NASA’s Universe of Learning, a program that creates materials and experiences to enable learners to explore the universe for themselves. The goal was to illustrate how shadows can convey information about phenomena invisible to us. However, the original team only observed the Bat Shadow in one light filter, which did not provide enough data for the color image desired by NASA’s Universe of Learning.

To get the color image, Pontoppidan and his team had to observe the shadow in additional filters. When they combined the old and new images, the shadow appeared to have moved. At first, they thought the problem was in the image processing, but they quickly realized the images were properly aligned and the phenomenon was real.

The team’s paper will appear in an upcoming edition of the Astrophysical Journal.

NASA’s Universe of Learning materials are based upon work supported by NASA under award number NNX16AC65A. For more information about NASA’s Universe of Learning, see: https://www.universe-of-learning.org/

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA’s Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

For images, video, and more information about this study and Hubble, visit:

https://www.nasa.gov/hubble

https://hubblesite.org/contents/news-releases/2020/news-2020-22

Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Ann Jenkins / Ray VillardSpace Telescope Science Institute, Baltimore410-338-4488 / 410-338-4514jenkins@stsci.edu / villard@stsci.edu

Klaus PontoppidanSpace Telescope Science Institute, Baltimorepontoppi@stsci.edu

Colette SalykVassar College, Poughkeepsie, New Yorkcosalyk@vassar.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Scientist Simulates Sunsets on Other Worlds

3 min read

Have you ever wondered what a sunset on Uranus might look like?

As you can see in the animation above, a Uranian sunset is a rich azure that fades into royal blue with hints of turquoise. This blue-green color comes from the interaction of sunlight with the planet's atmosphere. When sunlight — which is made up of all the colors of the rainbow — reaches Uranus's atmosphere, hydrogen, helium and methane absorb the longer-wavelength red portion of the light. The shorter-wavelength blue and green portions of light get scattered as photons bounce off the gas molecules and other particles in the atmosphere. A similar phenomenon makes Earth's sky appear blue on a clear day.

Geronimo Villanueva, a planetary scientist from NASA's Goddard Space Flight Center in Greenbelt, Maryland, created the sunset simulations while building a computer modeling tool for a possible future mission to Uranus, an icy-cold planet in the outer solar system. One day, a probe could descend through the Uranian atmosphere, with Villanueva's tool helping scientists interpret the measurements of light that will reveal its chemical makeup.

To validate the accuracy of his tool, Villanueva simulated known sky colors of Uranus and other worlds, some of which are shown above. The animations show the Sun appearing to set from the perspective of someone on these worlds. As these worlds rotate away from the light of the Sun, which is what happens during a sunset, photons get scattered in different directions depending on the energy of the photons and the types of molecules in the atmospheres. The result is a lovely palette of colors that would be visible to those standing on these worlds.

The animations show all-sky views as if you were looking up at the sky through a super wide camera lens from Earth, Venus, Mars, Uranus, and Titan. The white dot represents the location of the Sun. The halo of light seen towards the end of the sunset on hazy Earth is produced because of the way light is scattered by particles, including dust or fog, that are suspended in the clouds. The same is true of the Martian halo. Also on Mars, the sunset turns from a brownish color to a blueish because the Martian dust particles scatter the blue color more effectively.

These sky simulations are now a new feature of a widely used online tool called the Planetary Spectrum Generator, which was developed by Villanueva and his colleagues at NASA Goddard. The generator helps scientists replicate how light is transferred through the atmospheres of planets, exoplanets, moons, and comets in order to understand what their atmospheres and surfaces are made of.

For a less technical and more contemplative perspective on alien sunsets, check out this short movie:

By Lonnie ShekhtmanNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Young Giant Planet Offers Clues to Formation of Exotic Worlds

6 min read

Jupiter-size planets orbiting close to their stars have upended ideas about how giant planets form. Finding young members of this planet class could help answer key questions.

For most of human history our understanding of how planets form and evolve was based on the eight (or nine) planets in our solar system. But over the last 25 years, the discovery of more than 4,000 exoplanets, or planets outside our solar system, changed all that.

Among the most intriguing of these distant worlds is a class of exoplanets called hot Jupiters. Similar in size to Jupiter, these gas-dominated planets orbit extremely close to their parent stars, circling them in as few as 18 hours. We have nothing like this in our own solar system, where the closest planets to the Sun are rocky and orbiting much farther away. The questions about hot Jupiters are as big as the planets themselves: Do they form close to their stars or farther away before migrating inward? And if these giants do migrate, what would that reveal about the history of the planets in our own solar system?

To answer those questions, scientists will need to observe many of these hot giants very early in their formation. Now, a new study in the Astronomical Journal reports on the detection of the exoplanet HIP 67522 b, which appears to be the youngest hot Jupiter ever found. It orbits a well-studied star that is about 17 million years old, meaning the hot Jupiter is likely only a few million years younger, whereas most known hot Jupiters are more than a billion years old. The planet takes about seven days to orbit its star, which has a mass similar to the Sun's. Located only about 490 light-years from Earth, HIP 67522 b is about 10 times the diameter of Earth, or close to that of Jupiter. Its size strongly indicates that it is a gas-dominated planet.

HIP 67522 b was identified as a planet candidate by NASA's Transiting Exoplanet Survey Satellite (TESS), which detects planets via the transit method: Scientists look for small dips in the brightness of a star, indicating that an orbiting planet has passed between the observer and the star. But young stars tend to have a lot of dark splotches on their surfaces — starspots, also called sunspots when they appear on the Sun — that can look similar to transiting planets. So scientists used data from NASA's recently retired infrared observatory, the Spitzer Space Telescope, to confirm that the transit signal was from a planet and not a starspot. (Other methods of exoplanet detection have yielded hints at the presence of even younger hot Jupiters, but none have been confirmed.)

The discovery offers hope for finding more young hot Jupiters and learning more about how planets form throughout the universe — even right here at home.

“We can learn a lot about our solar system and its history by studying the planets and other things orbiting the Sun,” said Aaron Rizzuto, an exoplanet scientist at the University of Texas at Austin who led the study. “But we will never know how unique or how common our solar system is unless we're out there looking for exoplanets. Exoplanet scientists are finding out how our solar system fits in the bigger picture of planet formation in the universe.”

There are three main hypotheses for how hot Jupiters get so close to their parent stars. One is that they simply form there and stay put. But it's hard to imagine planets forming in such an intense environment. Not only would the scorching heat vaporize most materials, but young stars frequently erupt with massive explosions and stellar winds, potentially dispersing any newly emerging planets.

It seems more likely that gas giants develop farther from their parent star, past a boundary called the snow line, where it's cool enough for ice and other solid materials to form. Jupiter-like planets are composed almost entirely of gas, but they contain solid cores. It would be easier for those cores to form past the snow line, where frozen materials could cling together like a growing snowball.

The other two hypotheses assume this is the case, and that hot Jupiters then wander closer to their stars. But what would be the cause and timing of the migration?

One idea posits that hot Jupiters begin their journey early in the planetary system's history while the star is still surrounded by the disk of gas and dust from which both it and the planet formed. In this scenario, the gravity of the disk interacting with the mass of the planet could interrupt the gas giant's orbit and cause it to migrate inward.

The third hypothesis maintains that hot Jupiters get close to their star later, when the gravity of other planets around the star can drive the migration. The fact that HIP 67522 b is already so close to its star so early after its formation indicates that this third hypothesis probably doesn't apply in this case. But one young hot Jupiter isn't enough to settle the debate on how they all form.

"Scientists would like to know if there is a dominant mechanism that forms most hot Jupiters," said Yasuhiro Hasegawa, an astrophysicist specializing in planet formation at NASA's Jet Propulsion Laboratory who was not involved in the study. "In the community right now there is no clear consensus about which formation hypothesis is most important for reproducing the population we have observed. The discovery of this young hot Jupiter is exciting, but it's only a hint at the answer. To solve the mystery, we will need more."

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Center in California's Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT's Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

NASA's Spitzer Space Telescope was retired on Jan. 30, 2020. Science data continues to be analyzed by the science community via the Spitzer data archive located at the Infrared Science Archive housed at IPAC at Caltech in Pasadena, California. JPL managed Spitzer mission operations for NASA's Science Mission Directorate in Washington. Science operations were conducted at the Spitzer Science Center at IPAC at Caltech. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado. Caltech manages JPL for NASA.

Rizzuto is a 51 Pegasi b Fellow which is funded by the Heising-Simons Foundation.

For more information about TESS visit:

https://www.nasa.gov/tess-transiting-exoplanet-survey-satellite

For more information on Spitzer, visit:

www.nasa.gov/spitzer

www.spitzer.caltech.edu/

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

2020-115

Young Giant Planet Offers Clues to Formation of Exotic Worlds

6 min read

NASA Science Editorial Team

For most of human history our understanding of how planets form and evolve was based on the eight (or nine) planets in our solar system. But over the last 25 years, the discovery of more than 5,500 exoplanets, or planets outside our solar system, changed all that.

Among the most intriguing of these distant worlds is a class of exoplanets called hot Jupiters. Similar in size to Jupiter, these gas-dominated planets orbit extremely close to their parent stars, circling them in as few as 18 hours. We have nothing like this in our own solar system, where the closest planets to the Sun are rocky and orbiting much farther away. The questions about hot Jupiters are as big as the planets themselves: Do they form close to their stars or farther away before migrating inward? And if these giants do migrate, what would that reveal about the history of the planets in our own solar system?

To answer those questions, scientists will need to observe many of these hot giants very early in their formation. Now, a new study in the Astronomical Journal reports on the detection of the exoplanet HIP 67522 b, which appears to be the youngest hot Jupiter ever found. It orbits a well-studied star that is about 17 million years old, meaning the hot Jupiter is likely only a few million years younger, whereas most known hot Jupiters are more than a billion years old. The planet takes about seven days to orbit its star, which has a mass similar to the Sun's. Located only about 490 light-years from Earth, HIP 67522 b is about 10 times the diameter of Earth, or close to that of Jupiter. Its size strongly indicates that it is a gas-dominated planet.

HIP 67522 b was identified as a planet candidate by NASA's Transiting Exoplanet Survey Satellite (TESS), which detects planets via the transit method: Scientists look for small dips in the brightness of a star, indicating that an orbiting planet has passed between the observer and the star. But young stars tend to have a lot of dark splotches on their surfaces - starspots, also called sunspots when they appear on the Sun - that can look similar to transiting planets. So scientists used data from NASA's recently retired infrared observatory, the Spitzer Space Telescope, to confirm that the transit signal was from a planet and not a starspot. (Other methods of exoplanet detection have yielded hints at the presence of even younger hot Jupiters, but none have been confirmed.)

The discovery offers hope for finding more young hot Jupiters and learning more about how planets form throughout the universe - even right here at home.

"We can learn a lot about our solar system and its history by studying the planets and other things orbiting the Sun," said Aaron Rizzuto, an exoplanet scientist at the University of Texas at Austin who led the study. "But we will never know how unique or how common our solar system is unless we're out there looking for exoplanets. Exoplanet scientists are finding out how our solar system fits in the bigger picture of planet formation in the universe."

There are three main hypotheses for how hot Jupiters get so close to their parent stars. One is that they simply form there and stay put. But it's hard to imagine planets forming in such an intense environment. Not only would the scorching heat vaporize most materials, but young stars frequently erupt with massive explosions and stellar winds, potentially dispersing any newly emerging planets.

It seems more likely that gas giants develop farther from their parent star, past a boundary called the snow line, where it's cool enough for ice and other solid materials to form. Jupiter-like planets are composed almost entirely of gas, but they contain solid cores. It would be easier for those cores to form past the snow line, where frozen materials could cling together like a growing snowball.

The other two hypotheses assume this is the case, and that hot Jupiters then wander closer to their stars. But what would be the cause and timing of the migration?

One idea posits that hot Jupiters begin their journey early in the planetary system's history while the star is still surrounded by the disk of gas and dust from which both it and the planet formed. In this scenario, the gravity of the disk interacting with the mass of the planet could interrupt the gas giant's orbit and cause it to migrate inward.

The third hypothesis maintains that hot Jupiters get close to their star later, when the gravity of other planets around the star can drive the migration. The fact that HIP 67522 b is already so close to its star so early after its formation indicates that this third hypothesis probably doesn't apply in this case. But one young hot Jupiter isn't enough to settle the debate on how they all form.

"Scientists would like to know if there is a dominant mechanism that forms most hot Jupiters," said Yasuhiro Hasegawa, an astrophysicist specializing in planet formation at NASA's Jet Propulsion Laboratory who was not involved in the study. "In the community right now there is no clear consensus about which formation hypothesis is most important for reproducing the population we have observed. The discovery of this young hot Jupiter is exciting, but it's only a hint at the answer. To solve the mystery, we will need more."

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Center in California's Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT's Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

NASA's Spitzer Space Telescope was retired on Jan. 30, 2020. Science data continues to be analyzed by the science community via the Spitzer data archive located at the Infrared Science Archive housed at IPAC at Caltech in Pasadena, California. JPL managed Spitzer mission operations for NASA's Science Mission Directorate in Washington. Science operations were conducted at the Spitzer Science Center at IPAC at Caltech. Spacecraft operations were based at Lockheed Martin Space in Littleton, Colorado. Caltech manages JPL for NASA.

Rizzuto is a 51 Pegasi b Fellow which is funded by the Heising-Simons Foundation.

For more information about TESS visit:

https://www.nasa.gov/tess-transiting-exoplanet-survey-satellite

For more information on Spitzer, visit:

www.nasa.gov/spitzer

www.spitzer.caltech.edu/

Anne McClain

NASA Astronaut

Anne McClain

NASA Astronaut

Anne McClain

NASA Astronaut

Anne McClain

NASA Astronaut

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

In Planet Formation, It’s Location, Location, Location

6 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers using NASA's Hubble Space Telescope are finding that planets have a tough time forming in the rough-and-tumble central region of the massive, crowded star cluster Westerlund 2. Located 20,000 light-years away, Westerlund 2 is a unique laboratory to study stellar evolutionary processes because it's relatively nearby, quite young, and contains a large stellar population.

A three-year Hubble study of stars in Westerlund 2 revealed that the precursors to planet-forming disks encircling stars near the cluster's center are mysteriously devoid of large, dense clouds of dust that in a few million years could become planets.

However, the observations show that stars on the cluster's periphery do have the immense planet-forming dust clouds embedded in their disks. Researchers think our solar system followed this recipe when it formed 4.6 billion years ago.

So why do some stars in Westerlund 2 have a difficult time forming planets while others do not? It seems that planet formation depends on location, location, location. The most massive and brightest stars in the cluster congregate in the core, which is verified by observations of other star-forming regions. The cluster's center contains at least 30 extremely massive stars, some weighing up to 80 times the mass of the Sun. Their blistering ultraviolet radiation and hurricane-like stellar winds of charged particles blowtorch disks around neighboring lower-mass stars, dispersing the giant dust clouds.

"Basically, if you have monster stars, their energy is going to alter the properties of the disks around nearby, less massive stars," explained Elena Sabbi, of the Space Telescope Science Institute in Baltimore and lead researcher of the Hubble study. "You may still have a disk, but the stars change the composition of the dust in the disks, so it's harder to create stable structures that will eventually lead to planets. We think the dust either evaporates away in 1 million years, or it changes in composition and size so dramatically that planets don't have the building blocks to form."

The Hubble observations represent the first time that astronomers analyzed an extremely dense star cluster to study which environments are favorable to planet formation. Scientists, however, are still debating whether bulky stars are born in the center or whether they migrate there. Westerlund 2 already has massive stars in its core, even though it is a comparatively young, 2-million-year-old system.

Using Hubble's Wide Field Camera 3, the researchers found that of the nearly 5,000 stars in Westerlund 2 with masses between 0.1 to 5 times the Sun's mass, 1,500 of them show fluctuations in their light as the stars accrete material from their disks. Orbiting material clumped within the disk would temporarily block some of the starlight, causing brightness fluctuations.

However, Hubble detected the signature of such orbiting material only around stars outside the cluster's packed central region. The telescope witnessed large drops in brightness for as much as 10 to 20 days around 5% of the stars before they returned to normal brightness. They did not detect these dips in brightness in stars residing within four light-years of the center. These fluctuations could be caused by large clumps of dust passing in front of the star. The clumps would be in a disk tilted nearly edge-on to the view from Earth. "We think they are planetesimals or structures in formation," Sabbi explained. "These could be the seeds that eventually lead to planets in more evolved systems. These are the systems we don't see close to very massive stars. We see them only in systems outside the center."

Thanks to Hubble, astronomers can now see how stars are accreting in environments that are like the early universe, where clusters were dominated by monster stars. So far, the best known nearby stellar environment that contains massive stars is the starbirth region in the Orion Nebula. However, Westerlund 2 is a richer target because of its larger stellar population.

"Hubble's observations of Westerlund 2 give us a much better sense of how stars of different masses change over time, and how powerful winds and radiation from very massive stars affect nearby lower-mass stars and their disks," Sabbi said. "We see, for example, that lower-mass stars, like our Sun, that are near extremely massive stars in the cluster still have disks and still can accrete material as they grow. But the structure of their disks (and thus their planet-forming capability) seems to be very different from that of disks around stars forming in a calmer environment farther away from the cluster core. This information is important for building models of planet formation and stellar evolution."

This cluster will be an excellent laboratory for follow-up observations with NASA's upcoming James Webb Space Telescope, an infrared observatory. Hubble has helped astronomers identify the stars that have possible planetary structures. With Webb, researchers can study which disks around stars are not accreting material and which disks still have material that could build up into planets. This information on 1,500 stars will allow astronomers to map a path on how star systems grow and evolve. Webb also can study the chemistry of the disks in different evolutionary phases and watch how they change, and help astronomers determine what influence environment plays in their evolution.

NASA's Nancy Grace Roman Space Telescope, another planned infrared observatory, will be able to perform Sabbi's study on a much larger area.■ Westerlund 2 is just a small slice of an immense star-formation region. These vast regions contain clusters of stars with different ages and different densities. Astronomers could use Roman Space Telescope observations to start to build up statistics on how a star's characteristics, like its mass or outflows, affect its own evolution or the nature of stars that form nearby. The observations could also provide more information on how planets form in tough environments.

Sabbi's team's results appeared in The Astrophysical Journal.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore410-338-4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

Elena SabbiSpace Telescope Science Institute, Baltimoresabbi@stsci.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Are Planets with Oceans Common in the Galaxy? It’s Likely, NASA Scientists Find

7 min read

Several years ago, planetary scientist Lynnae Quick began to wonder whether any of the more than 4,000 known exoplanets, or planets beyond our solar system, might resemble some of the watery moons around Jupiter and Saturn. Though some of these moons don’t have atmospheres and are covered in ice, they are still among the top targets in NASA’s search for life beyond Earth. Saturn’s moon Enceladus and Jupiter’s moon Europa, which scientists classify as “ocean worlds,” are good examples.

“Plumes of water erupt from Europa and Enceladus, so we can tell that these bodies have subsurface oceans beneath their ice shells, and they have energy that drives the plumes, which are two requirements for life as we know it,” says Quick, a NASA planetary scientist who specializes in volcanism and ocean worlds. “So if we’re thinking about these places as being possibly habitable, maybe bigger versions of them in other planetary systems are habitable too.”

Quick, of NASA’s Goddard Space Flight Center in Greenbelt, Maryland, decided to explore whether — hypothetically — there are planets similar to Europa and Enceladus in the Milky Way galaxy. And, could they, too, be geologically active enough to shoot plumes through their surfaces that could one day be detected by telescopes.

Through a mathematical analysis of several dozen exoplanets, including planets in the nearby TRAPPIST-1 system, Quick and her colleagues learned something significant: More than a quarter of the exoplanets they studied could be ocean worlds, with a majority possibly harboring oceans beneath layers of surface ice, similar to Europa and Enceladus. Additionally, many of these planets could be releasing more energy than Europa and Enceladus.

Scientists may one day be able to test Quick’s predictions by measuring the heat emitted from an exoplanet or by detecting volcanic or cryovolcanic (liquid or vapor instead of molten rock) eruptions in the wavelengths of light emitted by molecules in a planet’s atmosphere. For now, scientists cannot see many exoplanets in any detail. Alas, they are too far away and too drowned out by the light of their stars. But by considering the only information available — exoplanet sizes, masses and distances from their stars — scientists like Quick and her colleagues can tap mathematical models and our understanding of the solar system to try to imagine the conditions that could be shaping exoplanets into livable worlds or not.

While the assumptions that go into these mathematical models are educated guesses, they can help scientists narrow the list of promising exoplanets to search for conditions favorable to life so that NASA’s upcoming James Webb Space Telescope or other space missions can follow up.

“Future missions to look for signs of life beyond the solar system are focused on planets like ours that have a global biosphere that’s so abundant it’s changing the chemistry of the whole atmosphere,” says Aki Roberge, a NASA Goddard astrophysicist who collaborated with Quick on this analysis. “But in the solar system, icy moons with oceans, which are far from the heat of the Sun, still have shown that they have the features we think are required for life.”

To look for possible ocean worlds, Quick’s team selected 53 exoplanets with sizes most similar to Earth, though they could have up to eight times more mass. Scientists assume planets of this size are more solid than gaseous and, thus, more likely to support liquid water on or below their surfaces. At least 30 more planets that fit these parameters have been discovered since Quick and her colleagues began their study in 2017, but they were not included in the analysis, which was published on June 18 in the journal Publications of the Astronomical Society of the Pacific.

With their Earth-size planets identified, Quick and her team sought to determine how much energy each one could be generating and releasing as heat. The team considered two primary sources of heat. The first, radiogenic heat, is generated over billions of years by the slow decay of radioactive materials in a planet's mantle and crust. That rate of decay depends on a planet's age and the mass of its mantle. Other scientists already had determined these relationships for Earth-size planets. So, Quick and her team applied the decay rate to their list of 53 planets, assuming each one is the same age as its star and that its mantle takes up the same proportion of the planet's volume as Earth's mantle does.

Next, the researchers calculated heat produced by something else: tidal force, which is energy generated from the gravitational tugging when one object orbits another. Planets in stretched out, or elliptical, orbits shift the distance between themselves and their stars as they circle them. This leads to changes in the gravitational force between the two objects and causes the planet to stretch, thereby generating heat. Eventually, the heat is lost to space through the surface.

One exit route for the heat is through volcanoes or cryovolcanoes. Another route is through tectonics, which is a geological process responsible for the movement of the outermost rocky or icy layer of a planet or moon. Whichever way the heat is discharged, knowing how much of it a planet pushes out is important because it could make or break habitability.

For instance, too much volcanic activity can turn a livable world into a molten nightmare. But too little activity can shut down the release of gases that make up an atmosphere, leaving a cold, barren surface. Just the right amount supports a livable, wet planet like Earth, or a possibly livable moon like Europa.

In the next decade, NASA's Europa Clipper will explore the surface and subsurface of Europa and provide insights about the environment beneath the surface. The more scientists can learn about Europa and other potentially habitable moons of our solar system, the better they'll be able to understand similar worlds around other stars — which may be plentiful, according to today's findings.

"Forthcoming missions will give us a chance to see whether ocean moons in our solar system could support life," says Quick, who is a science team member on both the Clipper mission and the Dragonfly mission to Saturn's moon Titan. "If we find chemical signatures of life, we can try to look for similar signs at interstellar distances."

When Webb launches, scientists will try to detect chemical signatures in the atmospheres of some of the planets in the TRAPPIST-1 system, which is 39 light years away in the constellation Aquarius. In 2017, astronomers announced that this system has seven Earth-size planets. Some have suggested that some of these planets could be watery, and Quick's estimates support this idea. According to her team's calculations, TRAPPIST-1 e, f, g and h could be ocean worlds, which would put them among the 14 ocean worlds the scientists identified in this study.

The researchers predicted that these exoplanets have oceans by considering the surface temperatures of each one. This information is revealed by the amount of stellar radiation each planet reflects into space. Quick's team also took into account each planet's density and the estimated amount of internal heating it generates compared to Earth.

"If we see that a planet's density is lower than Earth's, that's an indication that there might be more water there and not as much rock and iron," Quick says. And if the planet's temperature allows for liquid water, you've got an ocean world.

"But if a planet's surface temperature is less than 32 degrees Fahrenheit (0 degrees Celsius), where water is frozen," Quick says, "then we have an icy ocean world, and the densities for those planets are even lower."

Other scientists who participated in this analysis with Quick and Roberge are Amy Barr Mlinar from the Planetary Science Institute in Tucson, Arizona, and Matthew M. Hedman from the University of Idaho in Moscow.

By Lonnie ShekhtmanNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Cosmic Baby Is Discovered, and It’s Brilliant

6 min read

Astronomers tend to have a slightly different sense of time than the rest of us. They regularly study events that happened millions or billions of years ago, and objects that have been around for just as long. That’s partly why the recently discovered neutron star known as Swift J1818.0–1607 is remarkable: A new study in the journal Astrophysical Journal Letters estimates that it is only about 240 years old — a veritable newborn by cosmic standards.

NASA’s Neil Gehrels Swift Observatory spotted the young object on March 12, when it released a massive burst of X-rays. Follow-up studies by the European Space Agency’s XMM-Newton observatory and NASA’s NuSTAR telescope, which is led by Caltech and managed by the agency’s Jet Propulsion Laboratory, revealed more of the neutron star’s physical characteristics, including those used to estimate its age.

A neutron star is an incredibly dense nugget of stellar material left over after a massive star goes supernova and explodes. In fact, they’re some of the densest objects in the universe (second only to black holes): A teaspoon of neutron star material would weigh 4 billion tons on Earth. The atoms inside a neutron star are smashed together so tightly, they behave in ways not found anywhere else. Swift J1818.0–1607 packs twice the mass of our Sun into a volume more than one trillion times smaller.

With a magnetic field up to 1,000 times stronger than a typical neutron star — and about 100 million times stronger than the most powerful magnets made by humans — Swift J1818.0–1607 belongs to a special class of objects called magnetars, which are the most magnetic objects in the universe. And it appears to be the youngest magnetar ever discovered. If its age is confirmed, that means light from the stellar explosion that formed it would have reached Earth around the time that George Washington became the first president of the United States.

“This object is showing us an earlier time in a magnetar’s life than we’ve ever seen before, very shortly after its formation,” said Nanda Rea, a researcher at the Institute of Space Sciences in Barcelona and principal investigator on the observation campaigns by XMM Newton and NuSTAR (short for Nuclear Spectroscopic Telescope Array).

While there are over 3,000 known neutron stars, scientists have identified just 31 confirmed magnetars — including this newest entry. Because their physical properties can’t be re-created on Earth, neutron stars (including magnetars) are natural laboratories for testing our understanding of the physical world.

“Maybe if we understand the formation story of these objects, we’ll understand why there is such a huge difference between the number of magnetars we’ve found and the total number of known neutron stars,” Rea said.

Swift J1818.0–1607 is located in the constellation Sagittarius and is relatively close to Earth — only about 16,000 light-years away. (Because light takes time to travel these cosmic distances, we are seeing light that the neutron star emitted about 16,000 years ago, when it was about 240 years old.) Many scientific models suggest that the physical properties and behaviors of magnetars change as they age and that magnetars may be most active when they are younger. So finding a younger sample close by like this will help refine those models.

Though neutron stars are only about 10 to 20 miles (15 to 30 kilometers) wide, they can emit huge bursts of light on par with those of much larger objects. Magnetars in particular have been linked to powerful eruptions bright enough to be seen clear across the universe. Considering the extreme physical characteristics of magnetars, scientists think there are multiple ways that they can generate such huge amounts of energy.

The Swift mission spotted Swift J1818.0–1607 when it began outbursting. In this phase, its X-ray emission became at least 10 times brighter than normal. Outbursting events vary in their specifics, but they usually begin with a sudden increase in brightness over the course of days or weeks that is followed by a gradual decline over months or years as the magnetar returns to its normal brightness.

That's why astronomers have to act fast if they want to observe the period of peak activity from one of these events. The Swift mission alerted the global astronomy community to the event, and XMM-Newton (which has NASA participation) and NuSTAR performed quick follow-up studies.

In addition to X-rays, magnetars have been known to release great bursts of gamma rays, the highest energy form of light in the universe. They can also emit steady beams of radio waves, the lowest energy form of light in the universe. (Neutron stars that emit long-lived radio beams are called radio pulsars; Swift J1818.0–1607 is one of five known magnetars that are also radio pulsars.)

"What's amazing about [magnetars] is they're quite diverse as a population," said Victoria Kaspi, director of the McGill Space Institute at McGill University in Montreal and a former member of the NuSTAR team, who was not involved with the study. "Each time you find one it's telling you a different story. They're very strange and very rare, and I don't think we've seen the full range of possibilities."

The new study was led by Paolo Esposito with the School for Advanced Studies (IUSS) in Pavia, Italy.

NuSTAR recently celebrated eight years in space, having launched on June 13, 2012. A Small Explorer mission led by Caltech and managed by JPL for NASA's Science Mission Directorate in Washington, NuSTAR was developed in partnership with the Danish Technical University and the Italian Space Agency (ASI). The spacecraft was built by Orbital Sciences Corp. in Dulles, Virginia. NuSTAR's mission operations center is at the University of California, Berkeley, and the official data archive is at NASA's High Energy Astrophysics Science Archive Research Center. ASI provides the mission's ground station and a mirror archive. Caltech manages JPL for NASA.

ESA's XMM-Newton observatory was launched in December 1999 from Kourou, French Guiana. NASA funded elements of the XMM-Newton instrument package and provides the NASA Guest Observer Facility at Goddard, which supports use of the observatory by U.S. astronomers.

NASA's Goddard Space Flight Center manages the Swift mission in collaboration with Penn State in University Park, the Los Alamos National Laboratory in New Mexico and Northrop Grumman Innovation Systems in Dulles, Virginia. Other partners include the University of Leicester and Mullard Space Science Laboratory of the University College London in the United Kingdom, Brera Observatory and ASI.

For more information on NuSTAR, visit:

https://www.nasa.gov/mission_pages/nustar/main/index.html

https://www.nustar.caltech.edu/

For more information on Swift, visit:

https://www.nasa.gov/mission_pages/swift/main

https://swift.gsfc.nasa.gov/

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

2020-113

Know the Star, Know the Planet

6 min read

Alicia Cermak

Not only do apples fall close to the tree, but the tree’s history can strongly influence the taste of the apple.

Something similar can be said for planets. If you want to get to know a faraway planet better, say a small, rocky world tens or hundreds of light-years away, you’d best start by getting to know its star.

In reality, we can’t even find most planets outside our solar system — exoplanets — without help from their stars. Every planet detection method known requires a detailed dossier on the star, with very few exceptions: finding “rogue planets” that mysteriously wander the galaxy without stellar companions, and planets that are directly imaged – capturing pixels of light from the planets themselves. These directly imaged planets represent only a tiny fraction of the thousands of exoplanets discovered in our galaxy so far — and even they require, first, the detection of the star itself.

“We’re now entering this era of really trying to understand the structure and composition of the planets, trying to understand what kinds of systems planets can exist in,” said astronomer David Ciardi of NASA’s Exoplanet Science Institute (NExScI) at Caltech. “The star is the most dominant part of a solar system; it has the most mass, the most energy influence. We’re studying these systems holistically — not just an individual rock.”

If you put the question to Karl Stapelfeldt, chief scientist for NASA’s Exoplanet Exploration Program, he’ll simply run down the list of exoplanet detection methods that require intimate knowledge of the host star:

Such star measurements are indispensable for NASA’s newest space-based planet hunter, TESS (the Transiting Exoplanet Survey Satellite). They can reveal even more about planets when combined with asteroseismology, or the measurement of “star quakes.”

“The [starlight measurements] we get from TESS can help provide precise stellar radii for the brightest stars via asteroseismology,” said Knicole Colón, an astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and a member of the TESS team. “Knowing the sizes of stars lets us measure sizes of planets precisely. TESS data can also help us measure ages of stars, in turn providing an estimate of the ages of planets.”

Want to know an exoplanet’s temperature? Unless it is so hot that it’s emitting its own light, you’ll need to know its orbital distance from the star (see the transit method) and the star’s luminosity, or how much sheer power the star radiates (think light-bulb wattage).

Learning how big around the planet is, what it’s made of, even the composition of its atmosphere — you guessed it. Knowledge of the star is critical. Planets generally form from the same cloud of gas and dust as their host star. So elements found in a star’s atmosphere have direct bearing on its planets.

“It’s interesting to have stellar elemental abundances to go along with those of the planet, as the combination informs theories of planet formation and evolution,” Stapelfeldt said. “In both cases, the abundances are derived from taking a spectrum” — that is, analyzing the spectrum of light from stars and planets to reveal elements in their atmospheres.

Or we can view the other side of the question: Without needed measurements, can the star fool us into thinking it has a planet that isn’t really there?

Many stars move in orbital duets with companion stars, which can look a lot like planets. Others play host to giant objects called brown dwarfs, a kind of “failed star” that is considered neither a star nor a planet.

And failure to properly account for a star’s pulses, jitters and other variations can lead to a vexing problem: phantom planets.

“The star itself is often also exhibiting variability that can masquerade as a planet signal,” said Jennifer Burt, a postdoctoral exoplanet researcher at NASA’s Jet Propulsion Laboratory in Pasadena, California.

Among these variations: star spots (our Sun’s version are called sunspots). “The star’s rotation period dictates how star spots rotate on and off the side of the star we can see from Earth,” Burt said.

Especially in the early days of exoplanet discovery, insufficient understanding of stellar rotation led to “false positives” – signals that at first appeared to be planets, but actually came from other sources upon closer inspection. Those exoplanet announcements were then withdrawn.

It’s a major problem for one of the most intriguing classes of exoplanets: rocky, Earth-sized worlds that orbit within the “habitable zone” of red-dwarf stars, also called M-dwarfs. If such planets possess atmospheres, some could be at just the right temperature for liquid water to pool on the surface. The seven planets of TRAPPIST-1 form a system with multiple Earth-size worlds in this special zone.

However, the rotation period of the star can be similar to the orbital period of planets in the habitable zones, according to Eric Mamajek, deputy program scientist for NASA’s Exoplanet Exploration Program.

A year on such planets — once around the star — might take 10 days, and "10 days is not unusual for the rotation period of an M-dwarf," he said.

If a star's rotation takes about the same time as a planet's orbit, it's difficult to tell the two apart. It's still possible to confirm the planet is there; it just takes a lot more work.

Bottom line: The star is in charge. It's why even careful study of our own sttar, the Sun, can help us better understand exoplanets.

"Everything we derive with regard to the characteristics of the planet — the size of the planet, the mass, the atmosphere — is all done relative to the star," Ciardi says. "You need to know the star in order to know the planet."

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Explore Exoplanets at Home with NASA

4 min read

NASA Science Editorial Team

So far, we've discovered more than 4,000 exoplanets. Many of these planets beyond our own solar system are … weird. Super-Earths (bigger than Earth and smaller than Neptune) and hot Jupiters (gas giants that orbit really close to their stars) abound. You can visit some of these real worlds and see what conditions might be like — based on NASA science — at our Exoplanet Travel Bureau. We have 360-degree visualizations of planet surfaces, like one of the seven rocky worlds of the TRAPPIST-1 system and the lava-covered planet called 55 Cancri e. What would the view be from a potential moon of Kepler-16b? You'd have two shadows from the planet's two suns! Viewable on desktop and mobile, and optimized for VR viewers like Google cardboard. While you're there, download the free travel posters.

Visit each and every one of the 4,000-plus exoplanets discovered (so far) in our Eyes on Exoplanets app. How many planets has TESS, NASA's latest exoplanet-hunting spacecraft, found? You can check out known planets and TESS candidates awaiting confirmation. Zoom through the galaxy. View by mission, planet type or just browse some of the weirdest worlds. Happy exploring!

Now that you've spent some time exploring Eyes on Exoplanets, take the quiz! Are you a junior explorer or a rocket scientist? Earn your downloadable certificate and share your ranking on social media to challenge your friends.

NASA studies exoplanets – the planets beyond our solar system – with telescopes on the ground and in space, but our best idea of what they might look like comes from artists' illustrations based on real science, like our Exoplanet Travel Bureau posters. These posters are now available as coloring pages for you to add your own creative vision to exoplanet art. Grab crayons, markers, paint or colored pencils and shade in the hues of rocky terrain, lava oceans, planetary systems and more. Download our coloring books in English and in Spanish.

We want to see your creations! Post photos of your colored pages on social media and be sure to tag us on Twitter with @NASAExoplanets and use the hashtag #ColorWithNASA so we see your creations on Instagram and Facebook, too.

When we talk about the enormity of the cosmos, it's easy to toss out big numbers — but far more difficult to wrap our minds around just how large, how far and how numerous celestial bodies really are. (And what does a light-year, the distance light travels in one year, or about 5.8 trillion miles, look like anyway?) To get a better sense of the true distances to exoplanets, we might start with the theater in which we find them, the Milky Way galaxy. Check out the feature story here.

The planets beyond our solar system are far away. Even the closest known exoplanet, Proxima b, is 4.2 light-years from Earth. Most are much, much farther. How do we find planets around much brighter stars that are hard to see, even with telescopes? In many cases, we study the stars, looking for dips in light or slight wobbles. And sometimes the light of a distant star is bent and focused as a planet passes between it and Earth — an event called microlensing. Check out five ways astronomers discover faraway worlds.

Our real-time exoplanetary encyclopedia combines interactive visualizations with detailed data on all known exoplanets. Click on a planet's name to see a 3D model of each planet and its home star system, along with vital statistics. Sort by planet type, or search for planets around stars visible to the naked eye, along with other fun options in our Exoplanet Catalog.

How did we get here? How do stars and planets come into being? What happens during a star's life, and what fate will its planets meet when it dies? Come along on this interstellar journey through time.

NASA’s Spitzer Space Telescope helped unveil the cosmos, witnessing stars being born, exploring exoplanets and studying our universe. During its 16-year mission, Spitzer took more than 36.5 million raw images. Some of our favorite images from Spitzer are featured in the NASA Selfies app for iOS and Android mobile devices. You can explore the universe in Spitzer’s images — and you can see how you look in a spacesuit floating among them. Download for free from your App store.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: A New Giant, Directly Imaged

3 min read

Alicia Cermak

Planet-like object: TYC 8998-760-1 b

The discovery: This object, a brown dwarf or perhaps a large planet, joins an exclusive club: those that have been directly imaged.

Key facts: Capturing pixels of light directly from planets beyond our solar system -- exoplanets -- is extremely difficult because the light from these worlds is overwhelmed by the glare from their stars. The new object joins the thin ranks of such detections. It might be a brown dwarf -- a kind of "failed star" -- that is considered neither a star nor a planet, but somewhere in between.

Details: TYC 8998-760-1 b orbits a very young, Sun-like star some 300 light-years away. The star, about the same size as our Sun, is only about 17 million years old -- a baby among stars. That means the star's companion formed only recently, and is still so hot that it gives off a powerful glow detectable by ground-based telescopes.

Fun facts: Brown dwarfs are mysterious worlds, with many unanswered questions about their properties and appearance. They're too massive to be planets, but not quite massive enough to be stars because they're unable to trigger nuclear burning in their cores. The new directly imaged object is immense, about 14 times the mass, or heft, of our own planet Jupiter, and likely three times as big around. The estimated temperature at its surface is about 2,600 degrees Fahrenheit (1,400 degrees Celsius). This object's extreme girth is unusual for brown dwarfs, and could indicate that its youthful atmosphere is highly inflated. Another possibility, which can't yet be ruled out, is that it's really two objects orbiting each other, these in turn orbiting the star. Last, the object is right on the borderline between brown dwarf and planet -- and, with further observation, could turn out to be a planet after all.

Although thousands of exoplanets have been detected in our galaxy using ground and space-based telescopes, astronomers find the overwhelming majority of them through indirect means -- watching for wobbles a star makes as it's tugged back and forth by the gravity of an orbiting planet, or tracing the tiny dip in starlight as a planet crosses the face of its star. Far fewer such objects, including large, young exoplanets and brown dwarfs, have been found by direct imaging.

The discoverers: An international team of astronomers led by Alexander Bohn of Leiden University in the Netherlands discovered the new object, TYC 8998-760-1 b, using the Very Large Telescope (VLT), operated by the European Southern Observatory in Chile. The observations of this sub-stellar (smaller than star-sized) companion were carried out using the VLT's SPHERE exoplanet imager and its NACO adaptive optics system. The object was entered into NASA's Exoplanet Archive in April.

The discovery is part of the Young Suns Exoplanet Survey of 70 young stars about the same mass as our Sun in a huge, relatively nearby stellar group, called Scorpius-Centaurus, which contains thousands of stars.

Read the paper, "The Young Suns Exoplanet Survey: Detection of a wide-orbit planetary mass companion to a solar-type Sco-Cen member"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s

other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Nine Reasons We’re Grateful to Live on Earth

13 min read

Earth can sometimes feel like the last place you’d want to be. Indeed, a number of explorers have devised inventive ways to move civilization off this planet.

It’s no surprise: The promise of a better life in the mysterious beyond can be seductive. But the fact is the more we learn about out there the more we realize how special it is here. The first astronauts to look from space back at Earth, a “pale blue dot, the only home we’ve ever known,” as scientist Carl Sagan once wrote, saw a beautiful, delicate world that is perfectly suited to the bounty of life it supports.

“When I looked up and saw the Earth coming up on this very stark, beat up lunar horizon, an Earth that was the only color that we could see, a very fragile looking Earth, a very delicate looking Earth, I was immediately almost overcome by the thought that here we came all this way to the Moon, and yet the most significant thing we’re seeing is our own home planet, the Earth,” said William Anders, a crew member on Apollo 8, the first crewed mission to the Moon.

On this 50th anniversary of Earth Day on April 22, we reflect on nine reasons Earth is the best place to live:

Known as the Red Planet because of the rust particles in its soil that give it a reddish hue, Mars has always fascinated the human mind. What would it be like to live on this not-so-distant world, many have wondered? One day, astronauts will find out. But we know already that living there would require some major adjustments. No longer would we be able to take long, deep breaths of nitrogen- and oxygen-rich air while a gentle spring breeze grazes the skin. Without a spacesuit providing essential life support, humans would have to inhale carbon dioxide, a toxic gas we typically exhale as a waste product. On top of that, the thin Martian atmosphere (100 times thinner than Earth’s) and lack of a global magnetic field would leave us vulnerable to harmful radiation that damages cells and DNA; the low gravity (38% of Earth’s) would weaken our bones. Besides the hardships our bodies would endure, it would simply be less fun to live on Mars. Summer trips to the beach? Forget them. On Mars, there’s plenty of sand, but not a single swimming hole, much less a lake or ocean, and the average temperature is around minus 81 degrees Fahrenheit (minus 63 degrees Celsius). Even the hardiest humans would find the Martian climate to be a drag. —Staci Tiedeken, planetary science outreach coordinator, NASA’s Goddard Space Flight Center

Earth has grassy fields, rugged mountains and icy glaciers. But to live on the Sun, we’d have to kiss all solid ground goodbye. The Sun is a giant ball of plasma, or super-heated gas. If you tried to stand on the Sun’s visible surface, called the photosphere, you’d fall right through, about 205,000 miles (330,000 kilometers) until you reached a layer of plasma so compressed, it’s as thick as water. But you wouldn’t float, because you’d be crushed by the pressure there: 4.5 million times stronger than the deepest point in the ocean. Get ready for a quick descent, too. The Sun’s gravity is 28 times stronger than Earth’s. Thus, a 170-pound (77-kilogram) adult on Earth would weigh an extra 4,590 pounds (2,245 kilograms) at the Sun. That would feel like wearing an SUV on your back! If a person managed to hover in the photosphere, though, it might get a little warm. The temperature there is around 10,000 degrees Fahrenheit (5,500 Celsius), about five to 10 times hotter than lava — yet, not nearly the hottest temperature on the Sun. Don’t worry, though, there would be a break of 3,000 degrees Fahrenheit (1,600 degrees Celsius) if you stumbled on a sunspot, which is a “cool” region formed by intense magnetic fields. These conditions would have even the most intrepid adventurers longing for the comforts of home. —Miles Hatfield, science writer, NASA’s Goddard Space Flight Center

Since the beginning of recorded history, people have tracked and celebrated nature’s transition from the desolate days of winter, to the brilliant radiance of spring, to the endless days of summer, and so on. Seasons come from a planet's tilt on its axis (Earth's is 23.5 degrees), which tips each hemisphere either toward or away from the heat of the Sun throughout the year. Venus, barely tilted on its axis, has no seasons, though there are hints that it may have once looked and behaved much like Earth, including having oceans covering its rocky surface. But these days, our neighboring planet has an atmosphere so thick (55 times denser than Earth's) it helps keep Venus at a searing 900 degrees Fahrenheit (465 degrees Celsius) year round — that's hotter than the hottest home oven. This oppressive atmosphere also blots out the sky, making it impossible to stargaze from the surface. But Venus isn't all bad. Despite the low quality of life, there is one benefit of living there: The Venusian year (225 Earth days) is shorter than its day (243 Earth days). That means you can celebrate your birthday every day on Venus! —Lonnie Shekhtman, science writer, NASA's Goddard Space Flight Center

Capturing the imaginations of scientists and sci-fi writers alike, black holes are extremely compact objects that do not let any light escape. The surface of a black hole is an area called the "event horizon," a boundary beyond which nothing can ever return. Even if we were fortunate enough to have a spaceship that could travel to a relatively nearby black hole, its gravity is so strong that approaching too close would stretch and compress the spacecraft and everyone inside it into a noodle shape — a fate scientists call "spaghettification." Making matters even weirder, time ticks by more slowly around a black hole. To someone watching from far away as a spaceship fell into the event horizon, the vehicle would appear to slow down more the closer it got — and never quite get there. Fortunately, there are no known black holes in the vicinity of Earth or anywhere in the solar system, so we're safe for now. And we're lucky that Earth has just the right amount of gravity — enough so we don't go flying away, but not so much that we can't stand up and run around. If you still think traveling to a black hole would be a good idea, check out this black hole safety video. —Elizabeth Landau, writer, NASA Headquarters

Jupiter's breathtaking swirls of colorful cloud bands might make this planet an appealing vacation destination … for skydivers. They'd need to bring along their own oxygen, since Jupiter's atmosphere is made mostly of hydrogen and helium (same as our Sun), with clouds of mostly ammonia. Descending through Jupiter's clouds is for the most extreme thrill seekers. Given the planet's strong gravity and super-fast rotation on its axis compared to Earth (10 hours vs. 24 hours), a skydiver would tumble 2.5 times faster than they would on Earth, while getting knocked around by winds raging between 270 and 425 miles per hour (430 to 680 kilometers per hour). Jupiter's winds make Earth's highest category hurricane feel like a breeze, and its lightning strikes are up to 1,000 times more powerful than ours. Even if a skydiver does make it through the hundreds of miles, or kilometers, of atmosphere, plus crushing air pressure and extreme heat, it's not clear they'll reach a solid surface. Scientist don't know yet whether Jupiter, a giant planet that can fit 1,300 Earths inside of it, has a solid core. Having solid ground to stand is starting to sound like a luxury. —Staci Tiedeken, planetary science outreach coordinator, NASA's Goddard Space Flight Center

In places where ocean tides are highest on Earth, the difference between low and high tide is about 50 feet (15 meters). Compare that to Io. This moon of Jupiter is caught in a tug-of-war between the planet's massive gravity and the pulling of two neighboring moons, Europa and Ganymede. These forces cause Io's surface to regularly bulge up and down by as much as 330 feet (100 meters) — and we're talking about rock, not water. All this motion has consequences: Io's interior is very hot, making this moon the most volcanically active world in the solar system. Io, which from space looks like a moldy cheese pizza, has hundreds of volcanoes. Some erupt lava fountains dozens of miles (or kilometers) high. Between all the lava, a thin sulfur dioxide atmosphere and intense radiation from nearby Jupiter, Io doesn't offer much of a beach vacation for humans. —Bill Dunford, writer and web producer, NASA's Jet Propulsion Laboratory

If there is one place in the universe we know of that could compete with Earth as a home for humans, Titan is it. This satellite of Saturn is the second largest moon in our solar system after Ganymede. Titan is in some ways the most similar world to ours that we have found. Its thick atmosphere would remind us of home, though the air pressure there is slightly higher than Earth's. The atmosphere would defend humans against harmful radiation. Like Earth, Titan also has clouds, rain, lakes and rivers, and even a subsurface ocean of salty water. Even the moon's terrain and landscape look eerily similar to some parts of Earth. While Titan sounds promising, it has major flaws. Chief among them is oxygen — there isn't any in the atmosphere. And those lovely rivers and lakes? They're made of liquid methane. So don't pack your bathing suit just yet; our bodies are denser than the methane, so they'd sink like boulders. Another thing you'd miss on Titan is seeing the Sun above your head, dazzling against an azure sky. Not only is Titan much farther from the Sun than is Earth, its hazy atmosphere dims the sunlight, making daytime appear like twilight on Earth. —Lonnie Shekhtman, science writer, NASA's Goddard Space Flight Center

Jupiter's moon Europa is one of the best places to search for life beyond Earth. It may harbor more liquid water than all of Earth's oceans combined. Just picture yourself standing on a warm, sandy beach, admiring the sunlight glimmering on an ocean that reaches from horizon to horizon. And then prepare to be disappointed. Europa's ocean is global. It has no beach. No shore. Only ocean, all the way around. Sunlight doesn't glimmer on the water and there are no waves because Europa's ocean is hidden beneath miles — perhaps tens of miles — of ice that encases the entire moon. Europa is also tidally locked, meaning if a person stood on its Jupiter-facing side (like our Moon, one hemisphere always faces its parent planet), the solar system's largest planet would loom overhead and never set. A sublime setting for a romantic stroll? No. Europa has a practically nonexistent atmosphere and brutally cold temperatures ranging from about minus 210 to minus 370 degrees Fahrenheit (minus 134 to minus 223 degrees Celsius). A spacesuit might help with the temperature and pressure, but it can't protect against those pesky atomic particles captured in Jupiter's magnetic field, endlessly lashing Europa with such energy that they can blast apart molecules and ionize atoms. Europa's ionizing radiation would damage or destroy cells in the human body, leading to radiation sickness. —Jay R. Thompson, writer, NASA's Jet Propulsion Laboratory

With more than 4,000 planets discovered so far outside our solar system, called "exoplanets," we don't know of any that offers the comforts of Earthly living — and many would be downright nightmares. Take Kepler-7b, for example, a gas giant with roughly the same density as foam board. That means it could actually float in a bathtub (fun fact: so could Saturn). Like other exoplanets called "hot Jupiters," this one is really close to its star — a "year," one orbit, takes just five Earth days. One side always faces the star, just like one side of the Moon always faces Earth. That means it's always hot and light on one half of this planet; on the other, night never ends. If you're bummed out by cloudy days on Earth, consider that one side of Kepler-7b always has thick, unmoving clouds, and those clouds may even be made of evaporated rock and iron. And at more than 2,400 degrees Fahrenheit (1,316 degrees Celsius), Kepler-7b would be a real roaster to visit, especially on the dayside. It's amazing to learn about how different exoplanets can be from Earth, but we're glad we don't live on Kepler-7b. —Kristen Walbolt, digital and social media producer/strategist, NASA's Jet Propulsion Laboratory

More information here.

Last Updated: Apr 22, 2020

Editor: Svetlana Shekhtman

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: The Rhythmic Dance of a 5-planet System

3 min read

Alicia Cermak

The planets: HD 158259 b, c, d, e, f, and (maybe) g

The discovery: A “super-Earth” and at least four “mini-Neptunes” orbit a Sun-like star 88 light-years away. A sixth, outermost planet also is likely, though its presence could not be fully confirmed. Perhaps this system’s most haunting quality: All the planets are locked in rhythmic harmony, like a waltz in a cosmic ballroom.

Key facts: Each planet in this system makes three orbits for every two orbits of the next planet out. While such “orbital resonance” has been seen in other systems of planets beyond our own — that is, systems of exoplanets — this offers one of the most striking examples. The planets very closely match this “3:2” resonance, though not quite perfectly.

Details: In our own solar system, orbital resonance is found mainly among the moons of Jupiter and Saturn, as well as between Pluto and Neptune. The gravitational influence of one body on the next creates this rhythmic dance, but their orbits must be in close proximity. And this new planetary system fits the bill. The innermost planet, HD 158259 b, hugs its star so tightly that a year — once around the star — takes only 2 days. Planet c takes 3.4 days, planet d, 5, planet e about 8 and planet f, 12. The likely outermost planet, g, appears to have about a 17-day orbit.

Fun facts: The other systems known to be in orbital resonance include the famous TRAPPIST-1 family of seven planets, all roughly the size of Earth, about 40 light-years away. They, too, are packed tightly around their star, in this case a small red dwarf. Several of these worlds fall within their star’s habitable zone, where temperatures could be mild enough to allow liquid water on the surface. In some ways, the innermost planet in the new system, HD 158259 b, is also comparable to Earth: a bit bigger around, but likely to be terrestrial — rocky — just like our planet. This planet also orbits a star very much like our Sun. But the planet and its siblings orbit their star so closely they’re almost certainly extremely hot — for planet b, far too hot to be habitable.

The discoverers: An international team led by researcher Nathan C. Hara, of the University of Geneva, relied on observations of the star HD 158259 that were made over a seven-year period. The data came from the SOPHIE spectrograph, an instrument installed on a telescope at the Haute-Provence Observatory, in the South of France. SOPHIE measures the wobbling motions — “radial velocities” — of stars, caused by gravitational tugs from orbiting planets, which reveal the planets' "heft," or mass. The research team also used data from a NASA space telescope, TESS (the Transiting Exoplanet Survey Satellite), to detect the innermost planet, though by a different method. TESS watches for tiny dips in starlight as a planet crosses the face of its star. That reveals the planet's size and how long it takes to make an orbit. Data from SOPHIE helped confirm the finding by TESS. And by combining findings from both, the science team determined that HD 158259 b is about 1.2 times as big around as Earth and more than twice its mass.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

No Blue Skies for Super-Hot Planet WASP-79b

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

The weather forecast for the giant, super-hot, Jupiter-size planet WASP-79b is steamy humidity, scattered clouds, iron rain and yellow skies.

NASA's Hubble Space Telescope teamed up with the Magellan Consortium's Magellan II Telescope in Chile to analyze the atmosphere of this planet, which orbits a star that is hotter and brighter than our Sun, and is located at a distance of 780 light-years from Earth in the constellation Eridanus. Among exoplanets, planets that encircle stars beyond our Sun, WASP-79b is among the largest ever observed.

The surprise in recently published results is that the planet's sky doesn't have any evidence for an atmospheric phenomenon called Rayleigh scattering, where certain colors of light are dispersed by very fine dust particles in the upper atmosphere. Rayleigh scattering is what makes Earth's skies blue by scattering the shorter (bluer) wavelengths of sunlight.

Because WASP-79b doesn't seem to have this phenomenon, the daytime sky would likely be yellowish, researchers say.

"This is a strong indication of an unknown atmospheric process that we're just not accounting for in our physical models. I've shown the WASP-79b spectrum to a number of colleagues, and their consensus is 'that's weird,'" said Kristin Showalter Sotzen of the Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland.

The team would like to find other planets with a similar condition to learn more.

"Because this is the first time we've see this, we're really not sure what the cause is," Sotzen said. "We need to keep an eye out for other planets like this because it could be indicative of unknown atmospheric processes that we don't currently understand. Because we only have one planet as an example, we don't know if it's an atmospheric phenomenon linked to the evolution of the planet."

Hot Jupiters orbit so close to their stars that the conventional wisdom is that they migrated inward toward a tight orbit about their star, after bulking up on cold gas in the frigid outer reaches of a planetary system. WASP-79b completes an orbit in just 3 1/2 days. But this planet is in an unusual polar orbit about the star, which goes against scientists' theories about how planets form — especially for hot Jupiters.

The new results might potentially give additional clues to the history of similar planets. Some hot Jupiters appear to have hazy or cloudy atmospheres while others appear to have clear atmospheres. If it's like other hot Jupiters, WASP-79b may have scattered clouds, and iron lifted to high altitudes could precipitate as rain.

WASP-79b is twice the mass of Jupiter and is so hot it has an extended atmosphere, which is ideal for studying starlight that is filtered through and grazes the atmosphere on its way toward Earth.

To study the planet, the team used a spectrograph — an instrument that analyzes wavelengths of light in order to look at chemical compositions — on the Magellan II Telescope at Las Campanas Observatory in Chile. They expected to see a decrease in the amount of blue starlight due to Rayleigh scattering. Instead, they saw the opposite trend. The shorter, bluer wavelengths of light appear to be more transparent, indicating less absorption and scattering by the atmosphere. This result was consistent among independent observations of WASP-79b made with NASA's Transiting Exoplanet Survey Satellite (TESS).

WASP-79b also was observed as part of the Hubble Space Telescope's Panchromatic Comparative Exoplanet Treasury (PanCET) program, and those observations showed that there is water vapor in WASP-79b's atmosphere. Based on this finding, the giant planet was selected as an Early Release Science target for NASA's upcoming James Webb Space Telescope. Webb is expected to provide much more spectral data over longer infrared wavelengths. These observations may reveal more evidence for water vapor in the planet's atmosphere, and will provide a detailed view of the planet's chemical makeup, which could help reveal the underlying source of the peculiar spectrum.

The results were published in January 2020 in The Astronomical Journal.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore410-338-4514villard@stsci.edu

Kristin SotzenJohns Hopkins University Applied Physics Laboratory, Laurel, Md.kristin.sotzen@jhuapl.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Tale of Two Telescopes: WFIRST and Hubble

9 min read

Editor’s note, Sept. 23, 2020: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

NASA’s Wide Field Infrared Survey Telescope (WFIRST), planned for launch in the mid-2020s, will create enormous cosmic panoramas. Using them, astronomers will explore everything from our solar system to the edge of the observable universe, including planets throughout our galaxy and the nature of dark energy.

Though it’s often compared to the Hubble Space Telescope, which turns 30 years old this week, WFIRST will study the cosmos in a unique and complementary way.

“WFIRST will enable incredible scientific progress on a broad range of topics, from stellar populations and distant planets to dark energy and the structure of galaxies,” said Ken Carpenter, the WFIRST ground system project scientist and Hubble operations project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Hubble contributed tremendously to our understanding in these areas, but WFIRST will propel us forward by studying far more objects in the sky.”

Thirty years after its launch, Hubble continues to provide us with stunning, detailed images of the universe. When WFIRST opens its eyes to the cosmos, it will generate much larger images while matching Hubble’s crisp infrared resolution.

Hubble adds to our picture of the universe in ways WFIRST can’t by using ultraviolet vision that captures the high-resolution details, and by providing more specialized features for in-depth study of the light emitted by individual objects. WFIRST provides a more general capability in covering wide areas at visible and infrared wavelengths.

Each WFIRST image will capture a patch of the sky bigger than the apparent size of a full Moon. Hubble’s widest exposures, taken with its Advanced Camera for Surveys, are nearly 100 times smaller. Over the first five years of observations, WFIRST will image over 50 times as much sky as Hubble has covered so far in 30 years.

Since the quality will be the same, WFIRST will function like a fleet of 100 Hubbles operating in sync. Its large field of view will enable WFIRST to conduct sweeping cosmic surveys that would take hundreds of years using Hubble. Scientists will use these surveys to study some of the most compelling mysteries in the universe, including dark energy — a strange force that is accelerating the expansion of the universe.

Hubble played a major role in discovering dark energy. In 1998, astronomers measured how fast the universe is expanding by using ground-based telescopes to study relatively nearby exploding stars, called supernovae. They made the surprising discovery that the expansion of the universe is speeding up. Astronomers using Hubble confirmed this result by measuring supernovae over a longer period of time. The data demonstrated that while the expansion of the universe was slowing down as expected over most of cosmic history, it began speeding up a few billion years ago.

Scientists have since determined that whatever is causing this acceleration currently makes up about 68% of the total matter and energy in the universe, but so far we don’t know much more about it. Uncovering the nature and role of dark energy will be one of WFIRST’s primary goals. Scientists will use three surveys to examine the dark energy puzzle from different angles, including a survey of one key type of supernova, building on the observations that led to dark energy’s discovery. The mission’s two large area surveys will measure the shapes of hundreds of millions of galaxies and find the distances to tens of millions. This will turn WFIRST's wide-field images into 3D maps that measure the expansion of the universe and the growth of galaxies within it.

WFIRST will help us understand how dark energy has affected the expansion of the universe in the past, which will shed light on how it may influence the future of the cosmos.

While Hubble views the cosmos in infrared, visible and ultraviolet light, WFIRST will be tuned to see a slightly wider range of infrared light than Hubble can observe. Detecting more of the spectrum of light allows Hubble to create a more comprehensive picture of many processes at work in individual objects in the cosmos. WFIRST is designed to expand on Hubble's infrared observations specifically, because conducting enormous surveys of the infrared universe will let us see vast numbers of cosmic objects and subtler processes in regions of space that would otherwise be difficult or impossible to view.

WFIRST will help unravel mysteries surrounding dark energy and the evolution of galaxies by peering across enormous stretches of the universe — even farther than Hubble is capable of seeing. These studies require precise infrared observations because light shifts into longer wavelengths, from ultraviolet and visible into infrared, as it travels across vast astronomical distances due to the expansion of space.

WFIRST's infrared capabilities will also provide a new view into objects that are closer to home. The heart of our Milky Way galaxy is densely populated with rich targets, but shrouded in dust that obscures visible light. As an infrared telescope, WFIRST will essentially use heat-vision goggles to peer right through the dust, giving us a new view into the inner workings of the galaxy.

These observations will allow astronomers to study stellar evolution — the births, lives and deaths of stars. WFIRST will also expand our inventory of exoplanets — planets outside our solar system — by revealing thousands of worlds that astronomers expect will be very different from most of the 4,100 now known. Most of the currently known exoplanets are either very close to their host stars, or large planets orbiting farther away. Hubble has observed some of these planets directly using coronagraphs, which block the glare from stars. WFIRST will build upon that technology to make an active coronagraph that is much better at suppressing starlight — a demonstration of technology that, when further advanced, will enable future space telescopes to image Earth-size exoplanets.

Scientists will also use WFIRST's cosmic surveys to obtain enormous samples of some of the most extreme objects in the universe, including quasars — active galaxies with super-bright centers. Pinpointing their locations will allow Hubble and other telescopes to follow up for detailed observations. These investigations will enable astronomers to piece together the history of galaxy growth and the evolution of the universe.

To make these studies possible, WFIRST will operate much farther away from Earth than Hubble does. While Hubble orbits about 340 miles above us, WFIRST will be located about 930,000 miles (1.5 million km) away from Earth in the direction opposite the Sun. At this special place in space, called the second Sun-Earth Lagrange point, or L2, gravitational forces from the Sun and Earth balance to keep spacecraft in relatively stable orbits.

Near L2, WFIRST will orbit the Sun in sync with Earth, using a sunshield to block sunlight and keep the spacecraft cool. Since infrared light is heat radiation, if WFIRST is warmed by radiation from Earth, the Sun or even its own instruments, it will overwhelm the infrared sensors. From this vantage point, WFIRST can view large swaths of sky smoothly over long periods of time.

To collect as much light as possible, telescopes need large primary mirrors. Since both WFIRST and Hubble have a primary mirror that is 2.4 meters (7.9 feet) across, they gather the same amount of light. While the same size, WFIRST's mirror is only one-fourth the weight of Hubble's thanks to advancements in technology.

With Hubble’s similar light collection, resolution and an overlap in infrared capabilities, it can help set expectations for WFIRST. For example, Hubble produced a panoramic image of our neighboring Andromeda galaxy as part of the Panchromatic Hubble Andromeda Treasury (PHAT) program. Scientists compiled the PHAT image from 7,398 exposures taken over the course of three years. WFIRST could replicate Hubble’s PHAT image more than 1,000 times faster. This type of observation will reveal how stars change with time and influence the galaxy in which they reside.

Like Hubble, WFIRST will also offer a General Observer program to support the astronomical community, allowing scientists to take advantage of the mission’s unique capabilities by proposing new, competitively selected observations. As with Hubble, the pursuit of investigations not even contemplated before launch will likely become the primary legacy of the WFIRST mission. The entire trove of WFIRST data will be publicly available within days of being taken — a first for a NASA astrophysics flagship mission. WFIRST will have a robust archival research program to allow scientists to take full advantage of these vast datasets.

WFIRST benefits from an additional 30 years of major technological advances, however Hubble will continue to transform our understanding of the universe. In the coming years, WFIRST’s enormous infrared surveys will reveal interesting targets for follow up by other missions. Hubble can view the targets in additional wavelengths of light and will provide the only high-resolution view of the ultraviolet universe. The James Webb Space Telescope can make detailed observations that go even further into the infrared with its high-resolution, zoomed in view. Combining the WFIRST’s findings with Hubble’s and Webb’s could revolutionize our understanding in a multitude of cosmic pursuits.

“WFIRST’s surveys don’t require that we know exactly where and when to look to make exciting discoveries — we won’t be limited to looking under the cosmic lamppost,” said Goddard’s Julie McEnery, the WFIRST deputy project scientist. “The mission will turn on the floodlights so we can explore the universe in a whole new way.”

WFIRST is managed at Goddard, with participation by NASA’s Jet Propulsion Laboratory and Caltech/IPAC in Pasadena, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from research institutions across the United States.

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanet Apparently Disappears in Latest Hubble Observations

6 min read

NASA Science Editorial Team

Now you see it, now you don't.

What astronomers thought was a planet beyond our solar system has now seemingly vanished from sight. Though this happens in science fiction, such as Superman's home planet Krypton exploding, astronomers are looking for a plausible explanation.

One interpretation is that, rather than being a full-sized planetary object, which was first photographed in 2004, it could instead be a vast, expanding cloud of dust produced in a collision between two large bodies orbiting the bright nearby star Fomalhaut. Potential follow-up observations might confirm this extraordinary conclusion.

"These collisions are exceedingly rare and so this is a big deal that we actually get to see one," said András Gáspár of the University of Arizona, Tucson. "We believe that we were at the right place at the right time to have witnessed such an unlikely event with NASA's Hubble Space Telescope."

"The Fomalhaut system is the ultimate test lab for all of our ideas about how exoplanets and star systems evolve," added George Rieke of the University of Arizona's Steward Observatory. "We do have evidence of such collisions in other systems, but none of this magnitude has been observed in our solar system. This is a blueprint of how planets destroy each other."

The object, called Fomalhaut b, was first announced in 2008, based on data taken in 2004 and 2006. It was clearly visible in several years of Hubble observations that revealed it was a moving dot. Until then, evidence for exoplanets had mostly been inferred through indirect detection methods, such as subtle back-and-forth stellar wobbles and shadows from planets passing in front of their stars.

Unlike other directly imaged exoplanets, however, nagging puzzles arose with Fomalhaut b early on. The object was unusually bright in visible light, but did not have any detectable infrared heat signature. Astronomers conjectured that the added brightness came from a huge shell or ring of dust encircling the planet that may possibly have been collision-related. The orbit of Fomalhaut b also appeared unusual, possibly very eccentric.

"Our study, which analyzed all available archival Hubble data on Fomalhaut revealed several characteristics that together paint a picture that the planet-sized object may never have existed in the first place," said Gáspár.

The team emphasizes that the final nail in the coffin came when their data analysis of Hubble images taken in 2014 showed the object had vanished, to their disbelief. Adding to the mystery, earlier images showed the object to continuously fade over time, they say. "Clearly, Fomalhaut b was doing things a bona fide planet should not be doing," said Gáspár.

The interpretation is that Fomalhaut b is slowly expanding from the smashup that blasted a dissipating dust cloud into space. Taking into account all available data, Gáspár and Rieke think the collision occurred not too long prior to the first observations taken in 2004. By now the debris cloud, consisting of dust particles around 1 micron (1/50th the diameter of a human hair), is below Hubble's detection limit. The dust cloud is estimated to have expanded by now to a size larger than the orbit of Earth around our Sun.

Equally confounding is that the team reports that the object is more likely on an escape path, rather than on an elliptical orbit, as expected for planets. This is based on the researchers adding later observations to the trajectory plots from earlier data. "A recently created massive dust cloud, experiencing considerable radiative forces from the central star Fomalhaut, would be placed on such a trajectory," said Gáspár. "Our model is naturally able to explain all independent observable parameters of the system: its expansion rate, its fading and its trajectory."

Because Fomalhaut b is presently inside a vast ring of icy debris encircling the star, colliding bodies would likely be a mixture of ice and dust, like the comets that exist in the Kuiper belt on the outer fringe of our solar system. Gáspár and Rieke estimate that each of these comet-like bodies measured about 125 miles (200 kilometers) across (roughly half the size of the asteroid Vesta).

According to the authors, their model explains all the observed characteristics of Fomalhaut b. Sophisticated dust dynamical modeling done on a cluster of computers at the University of Arizona shows that such a model is able to fit quantitatively all the observations. According to the author's calculations, the Fomalhaut system, located about 25 light-years from Earth, may experience one of these events only every 200,000 years.

Gáspár and Rieke — along with other members of an extended team — will also be observing the Fomalhaut system with NASA's upcoming James Webb Space Telescope in its first year of science operations. The team will be directly imaging the inner warm regions of the system, spatially resolving for the first time the elusive asteroid-belt component of an extrasolar planetary system. The team will also search for bona fide planets orbiting Fomalhaut that might be gravitationally sculpting the outer disk. They will also analyze the chemical composition of the disk.

Their paper, "New HST [Hubble] data and modeling reveal a massive planetesimal collision around Fomalhaut" is being published on April 20, 2020, in the Proceedings of the National Academy of Sciences.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore410-338-4514villard@stsci.edu

András GáspárUniversity of Arizona, Tucson, Arizonaagaspar@as.arizona.edu

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanet Apparently Disappears in Latest Hubble Observations

6 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Now you see it, now you don't.

What astronomers thought was a planet beyond our solar system has now seemingly vanished from sight. Though this happens in science fiction, such as Superman's home planet Krypton exploding, astronomers are looking for a plausible explanation.

One interpretation is that, rather than being a full-sized planetary object, which was first photographed in 2004, it could instead be a vast, expanding cloud of dust produced in a collision between two large bodies orbiting the bright nearby star Fomalhaut. Potential follow-up observations might confirm this extraordinary conclusion.

"These collisions are exceedingly rare and so this is a big deal that we actually get to see one," said András Gáspár of the University of Arizona, Tucson. "We believe that we were at the right place at the right time to have witnessed such an unlikely event with NASA's Hubble Space Telescope."

"The Fomalhaut system is the ultimate test lab for all of our ideas about how exoplanets and star systems evolve," added George Rieke of the University of Arizona's Steward Observatory. "We do have evidence of such collisions in other systems, but none of this magnitude has been observed in our solar system. This is a blueprint of how planets destroy each other."

The object, called Fomalhaut b, was first announced in 2008, based on data taken in 2004 and 2006. It was clearly visible in several years of Hubble observations that revealed it was a moving dot. Until then, evidence for exoplanets had mostly been inferred through indirect detection methods, such as subtle back-and-forth stellar wobbles and shadows from planets passing in front of their stars.

Unlike other directly imaged exoplanets, however, nagging puzzles arose with Fomalhaut b early on. The object was unusually bright in visible light, but did not have any detectable infrared heat signaturewhen observed by NASA's Spitzer Space Telescope. Astronomers conjectured that the added brightness came from a huge shell or ring of dust encircling the planet that may possibly have been collision-related. The orbit of Fomalhaut b also appeared unusual, possibly very eccentric.

"Our study, which analyzed all available archival Hubble data on Fomalhaut revealed several characteristics that together paint a picture that the planet-sized object may never have existed in the first place," said Gáspár.

The team emphasizes that the final nail in the coffin came when their data analysis of Hubble images taken in 2014 showed the object had vanished, to their disbelief. Adding to the mystery, earlier images showed the object to continuously fade over time, they say. "Clearly, Fomalhaut b was doing things a bona fide planet should not be doing," said Gáspár.

The interpretation is that Fomalhaut b is slowly expanding from the smashup that blasted a dissipating dust cloud into space. Taking into account all available data, Gáspár and Rieke think the collision occurred not too long prior to the first observations taken in 2004. By now the debris cloud, consisting of dust particles around 1 micron (1/50th the diameter of a human hair), is below Hubble's detection limit. The dust cloud is estimated to have expanded by now to a size larger than the orbit of Earth around our Sun.

Equally confounding is that the team reports that the object is more likely on an escape path, rather than on an elliptical orbit, as expected for planets. This is based on the researchers adding later observations to the trajectory plots from earlier data. "A recently created massive dust cloud, experiencing considerable radiative forces from the central star Fomalhaut, would be placed on such a trajectory," said Gáspár. "Our model is naturally able to explain all independent observable parameters of the system: its expansion rate, its fading and its trajectory."

Because Fomalhaut b is presently inside a vast ring of icy debris encircling the star, colliding bodies would likely be a mixture of ice and dust, like the comets that exist in the Kuiper belt on the outer fringe of our solar system. Gáspár and Rieke estimate that each of these comet-like bodies measured about 125 miles (200 kilometers) across (roughly half the size of the asteroid Vesta).

According to the authors, their model explains all the observed characteristics of Fomalhaut b. Sophisticated dust dynamical modeling done on a cluster of computers at the University of Arizona shows that such a model is able to fit quantitatively all the observations. According to the author's calculations, the Fomalhaut system, located about 25 light-years from Earth, may experience one of these events only every 200,000 years.

Gáspár and Rieke — along with other members of an extended team — will also be observing the Fomalhaut system with NASA's upcoming James Webb Space Telescope in its first year of science operations. The team will be directly imaging the inner warm regions of the system, spatially resolving for the first time the elusive asteroid-belt component of an extrasolar planetary system. The team will also search for bona fide planets orbiting Fomalhaut that might be gravitationally sculpting the outer disk. They will also analyze the chemical composition of the disk.

Their paper, "New HST [Hubble] data and modeling reveal a massive planetesimal collision around Fomalhaut" is being published on April 20, 2020, in the Proceedings of the National Academy of Sciences.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore410-338-4514villard@stsci.edu

András GáspárUniversity of Arizona, Tucson, Arizonaagaspar@as.arizona.edu

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

Earth-Size, Habitable Zone Planet Found Hidden in Early NASA Kepler Data

6 min read

NASA Science Editorial Team

A team of transatlantic scientists, using reanalyzed data from NASA's Kepler space telescope, has discovered an Earth-size exoplanet orbiting in its star's habitable zone, the area around a star where a rocky planet could support liquid water.

Scientists discovered this planet, called Kepler-1649c, when looking through old observations from Kepler, which the agency retired in 2018. While previous searches with a computer algorithm misidentified it, researchers reviewing Kepler data took a second look at the signature and recognized it as a planet. Out of all the exoplanets found by Kepler, this distant world – located 300 light-years from Earth – is most similar to Earth in size and estimated temperature.

This newly revealed world is only 1.06 times larger than our own planet. Also, the amount of starlight it receives from its host star is 75% of the amount of light Earth receives from our Sun – meaning the exoplanet's temperature may be similar to our planet's, as well. But unlike Earth, it orbits a red dwarf. Though none have been observed in this system, this type of star is known for stellar flare-ups that may make a planet's environment challenging for any potential life.

"This intriguing, distant world gives us even greater hope that a second Earth lies among the stars, waiting to be found," said Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate in Washington. "The data gathered by missions like Kepler and our Transiting Exoplanet Survey Satellite (TESS) will continue to yield amazing discoveries as the science community refines its abilities to look for promising planets year after year."

There is still much that is unknown about Kepler-1649c, including its atmosphere, which could affect the planet's temperature. Current calculations of the planet's size have significant margins of error, as do all values in astronomy when studying objects so far away. But based on what is known, Kepler-1649c is especially intriguing for scientists looking for worlds with potentially habitable conditions.

There are other exoplanets estimated to be closer to Earth in size, such as TRAPPIST-1f and, by some calculations, Teegarden c. Others may be closer to Earth in temperature, such as TRAPPIST-1d and TOI 700d. But there is no other exoplanet that is considered to be closer to Earth in both of these values that also lies in the habitable zone of its system.

"Out of all the mislabeled planets we've recovered, this one's particularly exciting – not just because it's in the habitable zone and Earth-size, but because of how it might interact with this neighboring planet," said Andrew Vanderburg, a researcher at the University of Texas at Austin and first author on the paper released today in The Astrophysical Journal Letters. "If we hadn't looked over the algorithm's work by hand, we would have missed it."

Kepler-1649c orbits its small red dwarf star so closely that a year on Kepler-1649c is equivalent to only 19.5 Earth days. The system has another rocky planet of about the same size, but it orbits the star at about half the distance of Kepler-1649c, similar to how Venus orbits our Sun at about half the distance that Earth does. Red dwarf stars are among the most common in the galaxy, meaning planets like this one could be more common that we previously thought.

Previously, scientists on the Kepler mission developed an algorithm called Robovetter to help sort through the massive amounts of data produced by the Kepler spacecraft, managed by NASA's

Ames Research Center in California's Silicon Valley. Kepler searched for planets using the transit method, staring at stars, looking for dips in brightness as planets passed in front of their host stars.

Most of the time, those dips come from phenomena other than planets – ranging from natural changes in a star's brightness to other cosmic objects passing by – making it look like a planet is there when it's not. Robovetter's job was to distinguish the 12% of dips that were real planets from the rest. Those signatures Robovetter determined to be from other sources were labeled "false positives," the term for a test result mistakenly classified as positive.

With an enormous number of tricky signals, astronomers knew the algorithm would make mistakes and would need to be double-checked – a perfect job for the Kepler False Positive Working Group. That team reviews Robovetter's work, going through each false positive to ensure they are truly errors and not exoplanets, ensuring fewer potential discoveries are overlooked. As it turns out, Robovetter had mislabeled Kepler-1649c.

Even as scientists work to further automate analysis processes to get the most science as possible out of any given dataset, this discovery shows the value of double-checking automated work. Even six years after Kepler stopped collecting data from the original Kepler field – a patch of sky it stared at from 2009 to 2013, before going on to study many more regions – this rigorous analysis uncovered one of the most unique Earth-analogs discovered yet.

Kepler-1649c not only is one of the best matches to Earth in terms of size and energy received from its star, but it provides an entirely new look at its home system. For every nine times the outer planet in the system orbits the host star, the inner planet orbits almost exactly four times. The fact that their orbits match up in such a stable ratio indicates the system itself is extremely stable, and likely to survive for a long time.

Nearly perfect period ratios are often caused by a phenomenon called orbital resonance, but a nine-to-four ratio is relatively unique among planetary systems. Usually resonances take the form of ratios such as two-to-one or three-to-two. Though unconfirmed, the rarity of this ratio could hint to the presence of a middle planet with which both the inner and outer planets revolve in synchronicity, creating a pair of three-to-two resonances.

The team looked for evidence of such a mystery third planet, with no results. However, that could be because the planet is too small to see or at an orbital tilt that makes it impossible to find using Kepler's transit method.

Either way, this system provides yet another example of an Earth-size planet in the habitable zone of a red dwarf star. These small and dim stars require planets to orbit extremely close to be within that zone – not too warm and not too cold – for life as we know it to potentially exist. Though this single example is only one among many, there is increasing evidence that such planets are common around red dwarfs.

"The more data we get, the more signs we see pointing to the notion that potentially habitable and Earth-size exoplanets are common around these kinds of stars," said Vanderburg. "With red dwarfs almost everywhere around our galaxy, and these small, potentially habitable and rocky planets around them, the chance one of them isn't too different than our Earth looks a bit brighter."

For more information about Kepler and its discoveries, go to: https://www.nasa.gov/kepler

Felicia Chou

Headquarters, Washington

202-358-0257

Alison Hawkes

Ames Research Center, Silicon Valley, Calif.

650-604-4789

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Tale of Two Telescopes: WFIRST and Hubble

9 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Editor's note, Sept. 23, 2020: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

NASA’s Wide Field Infrared Survey Telescope (WFIRST), planned for launch in the mid-2020s, will create enormous cosmic panoramas. Using them, astronomers will explore everything from our solar system to the edge of the observable universe, including planets throughout our galaxy and the nature of dark energy.

Though it’s often compared to the Hubble Space Telescope, which turns 30 years old this week, WFIRST will study the cosmos in a unique and complementary way.

“WFIRST will enable incredible scientific progress on a broad range of topics, from stellar populations and distant planets to dark energy and the structure of galaxies,” said Ken Carpenter, the WFIRST ground system project scientist and Hubble operations project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Hubble contributed tremendously to our understanding in these areas, but WFIRST will propel us forward by studying far more objects in the sky.”

Thirty years after its launch, Hubble continues to provide us with stunning, detailed images of the universe. When WFIRST opens its eyes to the cosmos, it will generate much larger images while matching Hubble’s crisp infrared resolution.

Hubble adds to our picture of the universe in ways WFIRST can’t by using ultraviolet vision that captures the high-resolution details, and by providing more specialized features for in-depth study of the light emitted by individual objects. WFIRST provides a more general capability in covering wide areas at visible and infrared wavelengths.

Each WFIRST image will capture a patch of the sky bigger than the apparent size of a full Moon. Hubble’s widest exposures, taken with its Advanced Camera for Surveys, are nearly 100 times smaller. Over the first five years of observations, WFIRST will image over 50 times as much sky as Hubble has covered so far in 30 years.

Since the quality will be the same, WFIRST will function like a fleet of 100 Hubbles operating in sync. Its large field of view will enable WFIRST to conduct sweeping cosmic surveys that would take hundreds of years using Hubble. Scientists will use these surveys to study some of the most compelling mysteries in the universe, including dark energy — a strange force that is accelerating the expansion of the universe.

Hubble played a major role in discovering dark energy. In 1998, astronomers measured how fast the universe is expanding by using ground-based telescopes to study relatively nearby exploding stars, called supernovae. They made the surprising discovery that the expansion of the universe is speeding up. Astronomers using Hubble confirmed this result by measuring supernovae over a longer period of time. The data demonstrated that while the expansion of the universe was slowing down as expected over most of cosmic history, it began speeding up a few billion years ago.

Scientists have since determined that whatever is causing this acceleration currently makes up about 68% of the total matter and energy in the universe, but so far we don’t know much more about it. Uncovering the nature and role of dark energy will be one of WFIRST’s primary goals. Scientists will use three surveys to examine the dark energy puzzle from different angles, including a survey of one key type of supernova, building on the observations that led to dark energy’s discovery. The mission’s two large area surveys will measure the shapes of hundreds of millions of galaxies and find the distances to tens of millions. This will turn WFIRST’s wide-field images into 3D maps that measure the expansion of the universe and the growth of galaxies within it.

WFIRST will help us understand how dark energy has affected the expansion of the universe in the past, which will shed light on how it may influence the future of the cosmos.

While Hubble views the cosmos in infrared, visible and ultraviolet light, WFIRST will be tuned to see a slightly wider range of infrared light than Hubble can observe. Detecting more of the spectrum of light allows Hubble to create a more comprehensive picture of many processes at work in individual objects in the cosmos. WFIRST is designed to expand on Hubble’s infrared observations specifically, because conducting enormous surveys of the infrared universe will let us see vast numbers of cosmic objects and subtler processes in regions of space that would otherwise be difficult or impossible to view.

WFIRST will help unravel mysteries surrounding dark energy and the evolution of galaxies by peering across enormous stretches of the universe — even farther than Hubble is capable of seeing. These studies require precise infrared observations because light shifts into longer wavelengths, from ultraviolet and visible into infrared, as it travels across vast astronomical distances due to the expansion of space.

WFIRST’s infrared capabilities will also provide a new view into objects that are closer to home. The heart of our Milky Way galaxy is densely populated with rich targets, but shrouded in dust that obscures visible light. As an infrared telescope, WFIRST will essentially use heat-vision goggles to peer right through the dust, giving us a new view into the inner workings of the galaxy.

These observations will allow astronomers to study stellar evolution — the births, lives and deaths of stars. WFIRST will also expand our inventory of exoplanets — planets outside our solar system — by revealing thousands of worlds that astronomers expect will be very different from most of the 4,100 now known. Most of the currently known exoplanets are either very close to their host stars, or large planets orbiting farther away. Hubble has observed some of these planets directly using coronagraphs, which block the glare from stars. WFIRST will build upon that technology to make an active coronagraph that is much better at suppressing starlight — a demonstration of technology that, when further advanced, will enable future space telescopes to image Earth-size exoplanets.

Scientists will also use WFIRST’s cosmic surveys to obtain enormous samples of some of the most extreme objects in the universe, including quasars — active galaxies with super-bright centers. Pinpointing their locations will allow Hubble and other telescopes to follow up for detailed observations. These investigations will enable astronomers to piece together the history of galaxy growth and the evolution of the universe.

To make these studies possible, WFIRST will operate much farther away from Earth than Hubble does. While Hubble orbits about 340 miles above us, WFIRST will be located about 930,000 miles (1.5 million km) away from Earth in the direction opposite the Sun. At this special place in space, called the second Sun-Earth Lagrange point, or L2, gravitational forces from the Sun and Earth balance to keep spacecraft in relatively stable orbits.

Near L2, WFIRST will orbit the Sun in sync with Earth, using a sunshield to block sunlight and keep the spacecraft cool. Since infrared light is heat radiation, if WFIRST is warmed by radiation from Earth, the Sun or even its own instruments, it will overwhelm the infrared sensors. From this vantage point, WFIRST can view large swaths of sky smoothly over long periods of time.

To collect as much light as possible, telescopes need large primary mirrors. Since both WFIRST and Hubble have a primary mirror that is 2.4 meters (7.9 feet) across, they gather the same amount of light. While the same size, WFIRST’s mirror is only one-fourth the weight of Hubble’s thanks to advancements in technology.

With Hubble’s similar light collection, resolution and an overlap in infrared capabilities, it can help set expectations for WFIRST. For example, Hubble produced a panoramic image of our neighboring Andromeda galaxy as part of the Panchromatic Hubble Andromeda Treasury (PHAT) program. Scientists compiled the PHAT image from 7,398 exposures taken over the course of three years. WFIRST could replicate Hubble’s PHAT image more than 1,000 times faster. This type of observation will reveal how stars change with time and influence the galaxy in which they reside.

Like Hubble, WFIRST will also offer a General Observer program to support the astronomical community, allowing scientists to take advantage of the mission’s unique capabilities by proposing new, competitively selected observations. As with Hubble, the pursuit of investigations not even contemplated before launch will likely become the primary legacy of the WFIRST mission. The entire trove of WFIRST data will be publicly available within days of being taken — a first for a NASA astrophysics flagship mission. WFIRST will have a robust archival research program to allow scientists to take full advantage of these vast datasets.

WFIRST benefits from an additional 30 years of major technological advances, however Hubble will continue to transform our understanding of the universe. In the coming years, WFIRST’s enormous infrared surveys will reveal interesting targets for follow up by other missions. Hubble can view the targets in additional wavelengths of light and will provide the only high-resolution view of the ultraviolet universe. The James Webb Space Telescope can make detailed observations that go even further into the infrared with its high-resolution, zoomed in view. Combining the WFIRST’s findings with Hubble’s and Webb’s could revolutionize our understanding in a multitude of cosmic pursuits.

“WFIRST’s surveys don’t require that we know exactly where and when to look to make exciting discoveries — we won’t be limited to looking under the cosmic lamppost,” said Goddard’s Julie McEnery, the WFIRST deputy project scientist. “The mission will turn on the floodlights so we can explore the universe in a whole new way.”

WFIRST is managed at Goddard, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Pasadena, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from research institutions across the United States.

Banner: This famous Hubble Ultra Deep Field image captured the cosmos in three different types of light: infrared, visible and ultraviolet. While WFIRST will be tuned to see infrared light exclusively, its much wider field of view will enable larger surveys that would take hundreds or even thousands of years for Hubble to complete. Credit: NASA, ESA, H. Teplitz, M. Rafelski (IPAC/Caltech), A. Koekemoer (STScI), R. Windhorst (Arizona State University) and Z. Levay (STScI)

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

The Weirdest Solar System We’ve Found So Far? You May Be In It

5 min read

NASA Science Editorial Team

Before we found the first exoplanets — planets orbiting other stars — it seemed reasonable to suppose that other planetary systems looked like ours: small, rocky planets close to a Sun-like star, a big Jupiter and a few other gas giants farther out.

But after a quarter century of discovery revealing thousands of exoplanets in our galaxy, things look very different. In a word, we are “weird” — at least among the planetary systems found so far.

Just how weird is still a matter of debate. And weirdness is relative. We’ve detected “hot Jupiters” in scorching, star-hugging orbits around their stars, where a “year” — one trip around the star — takes only a few days. We’ve found a string of small, rocky worlds, all in Earth’s size-range, in lock-step orbits around a tiny red-dwarf star called TRAPPIST-1. We’ve seen systems with one or more planets that are larger than Earth and smaller than Neptune. The properties of these worlds are a mystery because they’re unlike anything in our solar system — and yet, they’re among the most common types of exoplanets discovered so far.

In all this variety, we’ve seen nothing yet that quite resembles our own setup: a Sun-like star with a retinue of rocky planets close in and more distant gas giants (including a domineering Jupiter).

We’re also notable for what we don’t have. Those planets larger than Earth and smaller than Neptune, for one. Systems like TRAPPIST-1 also have multiple planets in nearby orbits that are similar to each other in size and mass. For us, it’s a bit of a hodge-podge.

“Mercury and Mars are less massive than Venus and Earth,” says Yasuhiro Hasegawa, a NASA Jet Propulsion Laboratory researcher who studies the formation of planets and disks around stars. Why do we start with a small planet, Mercury, then have a relatively big Venus and Earth, then a smallish Mars?

And speaking of Mercury, why is our innermost planet so far from the Sun? You could fit the entire TRAPPIST-1 system of seven planets well within Mercury’s orbit. Many other systems detected so far also have planets in orbits far closer to their stars.

“Why is there no planet within Mercury’s orbit?” Hasegawa asks.

Nothing closer to the Sun than Mercury, a small Mars just beyond a bigger Venus and Earth, a really big Jupiter in a distant orbit. “That kind of configuration currently seems very rare,” Hasegawa says.

Some of our strangeness, of course, is likely an artifact of our limited technology. Detecting systems like ours, with planets in years-long orbits around middle-weight, yellow stars, is far more difficult with present methods than finding planets in short orbits around small red dwarfs. Such planets are easier to detect by the “transit” method, when a telescope measures a tiny dip in starlight as a planet crosses the face of its star; planets in longer orbits require far more observation time to find them.

Yet despite these limitations, large “survey” efforts have revealed a few broader truths. Jupiters, for instance, seem to be in short supply. And that could turn out to be important.

Some simulations of solar system formation suggest that Jupiter had an outsized influence on the development of the inner planets, for better and for worse. Early in our history, its gravity might have flung ice-bearing comets in our direction, helping fill future oceans. Later, the same tendency of Jupiter to throw its weight around might have helped hurl destructive monsters our way — for instance, the miles-wide rocky chunk that did in the dinosaurs.

How planetary arrangements affect the chance of life arising in other systems also is unknown. We might be tempted to assume that a long list of conditions that mirror our own system is necessary for life. But we don’t have any evidence, really, to support such assertions.

“It’s a rabbit hole if you start requiring Jupiter, say, for Earth to be habitable,” said Jessie Christiansen, a research scientist at NASA’s Exoplanet Science Institute. “Then you have to start saying, ‘Does Earth need a Moon? The Moon is doing a lot to Earth. Does it play an important role?’ Very rapidly, you end up saying the only way it could happen is this incredible set of circumstances all lined up at the same time.”

A few conditions do seem either hard to avoid or potential deal-breakers. For example, liquid water certainly seems essential for life as we know it. And actively flaring stars could doom otherwise temperate planets that orbit too close.

Scientists also produce thought-provoking computer models of possible life-bearing worlds in very different contexts from our own. These could help point the way to life signs we otherwise might have missed.

In the meantime, we can revel in our own oddness: a somewhat strange solar system parked in the suburbs of the Milky Way galaxy. Yes, we are the weird ones.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

With NASA’s Europa Clipper just weeks away from launch, five short videos give a behind-the-scenes peek at some of the engineers dedicated to making the mission a success. What does it take to build a massive spacecraft that will seek to determine if a mysterious moon has the right ingredients for life? Find out in […]

A decade ago, on Sept. 21, 2014, NASA’s MAVEN (Mars Atmospheric and Volatile EvolutioN) spacecraft entered orbit around Mars, beginning its ongoing exploration of the Red Planet’s upper atmosphere. The mission has produced a wealth of data about how Mars’ atmosphere

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Download our Exoplanet Coloring Pages and #ColorWithNASA

4 min read

NASA Science Editorial Team

NASA studies exoplanets – the planets beyond our solar system – with telescopes on the ground and in space, but our best idea of what they might look like comes from artists' illustrations based on real science, like our Exoplanet Travel Bureau posters.

These posters are now available as coloring pages for you to add your own creative vision to exoplanet art. Grab crayons, markers, paint or colored pencils and shade in the hues of rocky terrain, lava oceans, planetary systems and more.

We want to see your creations! Post photos of your colored pages on social media and be sure to tag us on Twitter with @NASAExoplanets and use the hashtag #ColorWithNASA so we see your creations on Instagram and Facebook, too.

There are many ways to #ColorWithNASA. We have to admit, we're quite fond of the TESS coloring book inspired by NASA's exoplanet hunting space telescope.

There are coloring pages and more in an activity book based on the James Webb Space Telescope – the most powerful and complex space science telescope ever!

So far, we've found more than 4,000 exoplanets. Of those, 1,300+ are gas giants. So, we love this coloring book from NASA's Juno mission to Jupiter, our solar system's largest gas giant. How do you picture the swirling storms on Jupiter?

You can check out coloring pages focusing on the other planets in our solar system from NASA's Space Place.

All of NASA's science missions are driven by powerful questions to help us better understand our planet, our solar system, and beyond. Color your universe! What vibrant colors will you bring to scenes of exploration?

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

As students head back to school, teachers have a new tool that brings NASA satellite data down to their earthly classrooms. For over 50 years of observing Earth, NASA's satellites have collected petabytes of global science data (that's millions and millions of gigabytes) – with even more terabytes coming in by the day. Since 2004, the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: New Planet — a Heavyweight, but Habitable?

3 min read

Alicia Cermak

The planet: GJ 1061d

The discovery: This planet joins a mysterious group — possibly habitable worlds in tight orbits around small, red-dwarf stars in our galaxy. GJ 1061d is part of a system of at least three planets a mere 12 light-years from Earth. Its surface temperature might be just right for liquid water.

Key facts: The planet is a bruiser, about 1.7 times the "weight," or mass, of Earth, and is probably a rocky world — imagine a scaled-up version of our planet. The energy it receives from its star is between what Earth and Mars receive from our Sun. In other words, the planet falls within its star's "habitable zone." If it is rocky and has a suitable atmosphere, GJ 1061d could have water on its surface.

Details: For now, that's a very big "if." On the plus side: The planet is the outermost of the three discovered in this system. That still places it in an extremely tight orbit — a "year" on this world, once around the star, takes only 12 to 13 days. But because its red-dwarf star is so small and cool, the closer orbit still means a potentially temperate planet. Another plus: the star seems to be older, and less active than young red dwarfs, so the planet could be less prone to sterilizing stellar flares. On the minus side: We don't know some of the basic properties of GJ 1061d, such as how big around it is, its true composition or whether it has any atmosphere at all. All this will require future investigation.

Fun facts: The discovery of this new planetary system, whose other two planets also outweigh Earth, is part of an unusual scientific campaign called the "Red Dots" collaboration. Carl Sagan famously called our planet a "pale blue dot;" the red dots are the red dwarf stars within 16 light-years of Earth. The Red Dots approach — zeroing in on one star at a time — has yielded other exciting discoveries, including that of a potentially rocky planet orbiting our nearest stellar neighbor, Proxima Centauri. Some 15 exoplanet systems are known within 16 light-years, most of them around red dwarfs, also called M-type stars. Together, these systems possess 33 planets; more than half include more than one planet. And the new system resembles other, more distant systems, including the seven roughly Earth-sized planets orbiting a red dwarf, TRAPPIST-1, some 40 light-years away.

The discoverers: An international team led by Stefan Dreizler of the University of Gottingen, in Germany, discovered the new system using an instrument called the HARPS spectrograph on the 3.6-meter European Southern Observatory telescope at La Silla, Chile. The instrument measures "wobbles" in the motion of a star, caused by the gravitational tugs of orbiting planets — a method of exoplanet detection known as "radial velocity." The three new planets were among nine entered into NASA's Exoplanet Archive on March 5, 2020.

Read the paper

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Warped Space-time to Help WFIRST Find Exoplanets

9 min read

Editor’s note, Sept. 23, 2020: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

NASA’s Wide Field Infrared Survey Telescope (WFIRST) will search for planets outside our solar system toward the center of our Milky Way galaxy, where most stars are. Studying the properties of exoplanet worlds will help us understand what planetary systems throughout the galaxy are like and how planets form and evolve.

Combining WFIRST’s findings with results from NASA’s Kepler and Transiting Exoplanet Survey Satellite (TESS) missions will complete the first planet census that is sensitive to a wide range of planet masses and orbits, bringing us a step closer to discovering habitable Earth-like worlds beyond our own.

To date, astronomers have found most planets when they pass in front of their host star in events called transits, which temporarily dim the star’s light. WFIRST data can spot transits too, but the mission will primarily watch for the opposite effect — little surges of radiance produced by a light-bending phenomenon called microlensing. These events are much less common than transits because they rely on the chance alignment of two widely separated and unrelated stars drifting through space.

“Microlensing signals from small planets are rare and brief, but they’re stronger than the signals from other methods,” said David Bennett, who leads the gravitational microlensing group at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “Since it’s a one-in-a-million event, the key to WFIRST finding low-mass planets is to search hundreds of millions of stars.”

In addition, microlensing is better at finding planets in and beyond the habitable zone — the orbital distances where planets might have liquid water on their surfaces.

This effect occurs when light passes near a massive object. Anything with mass warps the fabric of space-time, sort of like the dent a bowling ball makes when set on a trampoline. Light travels in a straight line, but if space-time is bent — which happens near something massive, like a star — light follows the curve.

Any time two stars align closely from our vantage point, light from the more distant star curves as it travels through the warped space-time of the nearer star. This phenomenon, one of the predictions of Einstein’s general theory of relativity, was famously confirmed by British physicist Sir Arthur Eddington during a total solar eclipse in 1919. If the alignment is especially close, the nearer star acts like a natural cosmic lens, focusing and intensifying light from the background star.

Planets orbiting the foreground star may also modify the lensed light, acting as their own tiny lenses. The distortion they create allows astronomers to measure the planet’s mass and distance from its host star. This is how WFIRST will use microlensing to discover new worlds.

“Trying to interpret planet populations today is like trying to interpret a picture with half of it covered,” said Matthew Penny, an assistant professor of physics and astronomy at Louisiana State University in Baton Rouge who led a study to predict WFIRST’s microlensing survey capabilities. “To fully understand how planetary systems form we need to find planets of all masses at all distances. No one technique can do this, but WFIRST’s microlensing survey, combined with the results from Kepler and TESS, will reveal far more of the picture.”

More than 4,000 confirmed exoplanets have been discovered so far, but only 86 were found via microlensing. The techniques commonly used to find other worlds are biased toward planets that tend to be very different from those in our solar system. The transit method, for example, is best at finding sub-Neptune-like planets that have orbits much smaller than Mercury's. For a solar system like our own, transit studies could miss every planet.

WFIRST's microlensing survey will help us find analogs to every planet in our solar system except Mercury, whose small orbit and low mass combine to put it beyond the mission's reach. WFIRST will find planets that are the mass of Earth and even smaller — perhaps even large moons, like Jupiter's moon Ganymede.

WFIRST will find planets in other poorly studied categories, too. Microlensing is best suited to finding worlds from the habitable zone of their star and farther out. This includes ice giants, like Uranus and Neptune in our solar system, and even rogue planets — worlds freely roaming the galaxy unbound to any stars.

While ice giants are a minority in our solar system, a 2016 study indicated that they may be the most common kind of planet throughout the galaxy. WFIRST will put that theory to the test and help us get a better understanding of which planetary characteristics are most prevalent.

WFIRST will explore regions of the galaxy that haven't yet been systematically scoured for exoplanets due to the different goals of previous missions. Kepler, for example, searched a modest-sized region of about 100 square degrees with 100,000 stars at typical distances of around a thousand light years. TESS scans the entire sky and tracks 200,000 stars, however their typical distances are around 100 light-years. WFIRST will search roughly 3 square degrees, but will follow 200 million stars at distances of around 10,000 light years.

Since WFIRST is an infrared telescope, it will see right through the clouds of dust that block other telescopes from studying planets in the crowded central region of our galaxy. Most ground-based microlensing observations to date have been in visible light, making the center of the galaxy largely uncharted exoplanet territory. A microlensing survey conducted since 2015 using the United Kingdom Infrared Telescope (UKIRT) in Hawaii is smoothing the way for WFIRST's exoplanet census by mapping out the region.

The UKIRT survey is providing the first measurements of the rate of microlensing events toward the galaxy's core, where stars are most densely concentrated. The results will help astronomers select the final observing strategy for WFIRST's microlensing effort.

The UKIRT team's most recent goal is detecting microlensing events using machine learning, which will be vital for WFIRST. The mission will produce such a vast amount of data that combing through it solely by eye will be impractical. Streamlining the search will require automated processes.

Additional UKIRT results point to an observing strategy that will reveal the most microlensing events possible while avoiding the thickest dust clouds that can block even infrared light.

"Our current survey with UKIRT is laying the groundwork so that WFIRST can implement the first space-based dedicated microlensing survey," said Savannah Jacklin, an astronomer at Vanderbilt University in Nashville, Tennessee who has led several UKIRT studies. "Previous exoplanet missions expanded our knowledge of planetary systems, and WFIRST will move us a giant step closer to truly understanding how planets — particularly those within the habitable zones of their host stars — form and evolve."

The same microlensing survey that will reveal thousands of planets will also detect hundreds of other bizarre and interesting cosmic objects. Scientists will be able to study free-floating bodies with masses ranging from that of Mars to 100 times the Sun's.

The low end of the mass range includes planets that were ejected from their host stars and now roam the galaxy as rogue planets. Next are brown dwarfs, which are too massive to be characterized as planets but not quite massive enough to ignite as stars. Brown dwarfs don't shine visibly like stars, but WFIRST will be able to study them in infrared light through the heat left over from their formation.

Objects at the higher end include stellar corpses — neutron stars and black holes — left behind when massive stars exhaust their fuel. Studying them and measuring their masses will help scientists understand more about stars' death throes while providing a census of stellar-mass black holes.

"WFIRST's microlensing survey will not only advance our understanding of planetary systems," said Penny, "it will also enable a whole host of other studies of the variability of 200 million stars, the structure and formation of the inner Milky Way, and the population of black holes and other dark, compact objects that are hard or impossible to study in any other way."

The FY2020 Consolidated Appropriations Act funds the WFIRST program through September 2020. The FY2021 budget request proposes to terminate funding for the WFIRST mission and focus on the completion of the James Webb Space Telescope, now planned for launch in March 2021. The Administration is not ready to proceed with another multi-billion-dollar telescope until Webb has been successfully launched and deployed.

WFIRST is managed at Goddard, with participation by NASA's Jet Propulsion Laboratory and Caltech/IPAC in Pasadena, the Space Telescope Science Institute in Baltimore, and a science team comprising scientists from research institutions across the United States.

Download high-resolution graphics from NASA Goddard's Scientific Visualization Studio.

By Ashley BalzerNASA's Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Approves Development of Universe-Studying, Planet-Finding Mission

2 min read

Editor’s note, Sept. 29, 2023: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

NASA’s Wide Field Infrared Survey Telescope (WFIRST) project has passed a critical programmatic and technical milestone, giving the mission the official green light to begin hardware development and testing.

The WFIRST space telescope will have a viewing area 100 times larger than that of NASA’s Hubble Space Telescope, which will enable it to detect faint infrared signals from across the cosmos while also generating enormous panoramas of the universe, revealing secrets of dark energy, discovering planets outside our solar system (exoplanets), and addressing a host of other astrophysics and planetary science topics.

WFIRST’s design already is at an advanced stage, using components with mature technologies. These include heritage hardware –primarily Hubble-quality telescope assets transferred to NASA from another federal agency — and lessons learned from NASA’s James Webb Space Telescope – the agency’s flagship infrared observatory, targeted for launch next year.

With the passage of this latest key milestone, the team will begin finalizing the WFIRST mission design by building engineering test units and models to ensure the design will hold up under the extreme conditions during launch and while in space.

WFIRST has an expected development cost of $3.2 billion. Including the cost of five years of operations and science, and a ride-along technology demonstration instrument capable of imaging planets around other stars, brings the maximum cost of WFIRST to $3.934 billion.

The FY2020 Consolidated Appropriations Act funds the WFIRST program through September 2020. The FY2021 budget request proposes to terminate funding for the WFIRST mission and focus on the completion of the James Webb Space Telescope, now planned for launch in March 2021. The Administration is not ready to proceed with another multi-billion-dollar telescope until Webb has been successfully launched and deployed.

WFIRST is managed at Goddard, with participation by the Jet Propulsion Laboratory (JPL) in Pasadena, California, the Space Telescope Science Institute in Baltimore, the Infrared Processing and Analysis Center, also in Pasadena, and a science team comprised of members from U.S. research institutions across the country.

For more information about NASA’s WFIRST mission, visit: https://www.nasa.gov/wfirst

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Citizen Scientists Supercharged Data from NASA's TESS Mission and Helped A Planet Come to Light

2 min read

NASA Science Editorial Team

You may have heard about the recent discovery of a new planet orbiting a pair of "eclipsing binary" stars led by summer intern Wolf Cukier and his mentor, Veselin Kostov, using data from NASA's TESS mission. Eclipsing binaries are pairs of stars whose orbits are lined up in a handy way so the stars pass in front of one another now and then with one star blocking the light from the other. If there's a planet orbiting the eclipsing binary, it's likely to orbit in the same plane as the stars, and block out the light from one or more of the stars as it passes by. That's what Cukier and Kostov were thinking when they embarked on their planet search.

So where did Cukier and Kostov go to find a list of eclipsing binaries to search? They went to the Planet Hunters TESS citizen science project.

There, in the "TALK" pages at planethunters.org, citizen scientists had assembled a handy list of eclipsing binaries with transit data. "The Planet Hunters TESS catalog was much easier for us to search because it the TESS data was right there with it," said Kostov. "We just searched for the eclipsing binary hashtag." It's another great example of how citizen scientists have been adding value to NASA data. Hurray for citizen scientists Peter Ansorge, Joel Bergeron, Marc Huten, Giuseppe Pappa, Frank Barnet, Timo van der Straeten and BassLightyear who helped build this useful list of eclipsing binaries—and helped humankind discover a new world!

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: This Four-planet System is Leaking

2 min read

Alicia Cermak

Planets: DMPP-1 d, e, c and b

The discovery: Three "hot super-Earths" and a "warm Neptune" orbit a relatively nearby, bright star not unlike our own Sun, a new study suggests. One or more of these planets is so thoroughly cooked that its atmosphere appears to be leaking into space – in fact, that's how astronomers found these planets using a brand-new detection method.

Key facts: DMPP-1 belongs to the class of stars labeled "F": a bit larger and hotter than our Sun, which is a "G"-type star. DMPP-1 is also more yellow-white than our yellow star. The name itself stands for the "Dispersed Matter Planet Project," and it's the first star with planets detected by searching for the gas that they're venting into space.

Details: A team of scientists led by Carole Haswell and Daniel Staab of the U.K.'s Open University tried out their new search method using a 3.6-meter telescope in Chile. Relying on an instrument called a spectrograph, they zeroed in on a star about 200 light-years away. The spectrograph can reveal what types of gases are present in a planetary system, and in this case, found evidence of a possible "circumstellar gas shroud" – a diffuse cloud of gas orbiting the star, likely bleeding into space from one or more of the inner, "super Earth" planets. The team used radial velocity measurements, which track the wobbles of a star caused by the gravity of orbiting planets, to estimate the size and number of planets in this system.

Fun facts: The planet, or planets, that are leaking gas could shed light on the "Neptune desert" – an orbital region so close to a star that Neptune-type planets migrating inward from the outer reaches of the system would have their atmospheres stripped away, leaving behind nothing but a rocky core. It's possible the gas-hemorrhaging planet, or planets, are in the late stages of this process.

The discoverers: The overall Dispersed Matter Planet Project Survey, led by Haswell, used the High Accuracy Radial Velocity Planet Searcher (HARPS) spectrograph on the European Southern Observatory's 3.6-meter telescope in La Silla, Chile. This international science team studied stars now known as DMPP-1, 2 and 3. The paper on DMPP-1, led by Staab, was published in "Nature Astronomy" in December 2019, and the discoveries were entered into the NASA Exoplanet Archive in January 2020.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Spitzer Space Telescope Ends Mission of Astronomical Discovery

6 min read

NASA Science Editorial Team

After more than 16 years studying the universe in infrared light, revealing new wonders in our solar system, our galaxy and beyond, NASA's Spitzer Space Telescope's mission has come to an end.

Mission engineers confirmed at about 2:30 p.m. PST (5:30 p.m. EST) Thursday the spacecraft was placed in safe mode, ceasing all science operations. After the decommissioning was confirmed, Spitzer Project Manager Joseph Hunt declared the mission had officially ended.

Launched in 2003, Spitzer was one of NASA's four Great Observatories, along with the Hubble Space Telescope, the Chandra X-ray Observatory and the Compton Gamma Ray Observatory. The Great Observatories program demonstrated the power of using different wavelengths of light to create a fuller picture of the universe.

"Spitzer has taught us about entirely new aspects of the cosmos and taken us many steps further in understanding how the universe works, addressing questions about our origins, and whether or not are we alone," said Thomas Zurbuchen, associate administrator of NASA's Science Mission Directorate in Washington. "This Great Observatory has also identified some important and new questions and tantalizing objects for further study, mapping a path for future investigations to follow. Its immense impact on science certainly will last well beyond the end of its mission."

Among its many scientific contributions, Spitzer studied comets and asteroids in our own solar system and found a previously unidentified ring around Saturn. It studied star and planet formation, the evolution of galaxies from the ancient universe to today, and the composition of interstellar dust. It also proved to be a powerful tool for detecting exoplanets and characterizing their atmospheres. Spitzer's best-known work may be detecting the seven Earth-size planets in the TRAPPIST-1 system — the largest number of terrestrial planets ever found orbiting a single star — and determining their masses and densities.

In 2016, following a review of operating astrophysics missions, NASA made a decision to close out the Spitzer mission in 2018 in anticipation of the launch of the James Webb Space Telescope, which also will observe the universe in infrared light. When Webb's launch was postponed, Spitzer was granted an extension to continue operations until this year. This gave Spitzer additional time to continue producing transformative science, including insights that will pave the way for Webb, which is scheduled to launch in 2021.

"Everyone who has worked on this mission should be extremely proud today," Hunt said. "There are literally hundreds of people who contributed directly to Spitzer's success, and thousands who used its scientific capabilities to explore the universe. We leave behind a powerful scientific and technological legacy."

Though it was not NASA's first space-based infrared telescope, Spitzer was the most sensitive infrared telescope in history when it launched, and it delivered a deeper and more far-reaching view of the infrared cosmos than its predecessors. Above Earth's atmosphere, Spitzer could detect some wavelengths that cannot be observed from the ground. The spacecraft's Earth-trailing orbit placed it far away from our planet's infrared emissions, which also gave Spitzer better sensitivity than was possible for larger telescopes on Earth.

Spitzer's prime mission came to an end in 2009, when the telescope exhausted its supply of the liquid helium coolant necessary for operating two of its three instruments — the Infrared Spectrograph and Multiband Imaging Photometer for Spitzer (MIPS). The mission was deemed a success, having achieved all of its primary science objectives and more. But Spitzer's story wasn't over. Engineers and scientists were able to keep the mission going using only two out of four wavelength channels on the third instrument, the Infrared Array Camera. Despite increasing engineering and operations challenges, Spitzer continued to produce transformational science for another 10 1/2 years — far longer than mission planners anticipated.

During its extended mission, Spitzer continued to make significant scientific discoveries. In 2014, it detected evidence of asteroid collisions in a newly formed planetary system, providing evidence that such smash-ups might be common in early solar systems and crucial to the formation of some planets. In 2016, Spitzer worked with Hubble to image the most distant galaxy ever detected. From 2016 onward, Spitzer studied the TRAPPIST-1 system for more than 1,000 hours. All of Spitzer's data are free and available to the public in the Spitzer data archive. Mission scientists say they expect researchers to continue making discoveries with Spitzer long after the spacecraft's decommissioning.

"I think that Spitzer is an example of the very best that people can achieve," said Spitzer Project Scientist Michael Werner. "I feel very fortunate to have worked on this mission, and to have seen the ingenuity, doggedness and brilliance that people on the team showed. When you tap into those things and empower people to use them, then truly incredible things will happen."

NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, conducts mission operations and manages the Spitzer Space Telescope mission for the agency's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Spacecraft operations are based at Lockheed Martin Space in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

Lockheed Martin in Sunnyvale, California, built the Spitzer spacecraft, and during development served as lead for systems and engineering, and integration and testing. Ball Aerospace and Technologies Corporation in Boulder, Colorado provided the optics, cryogenics and thermal shells and shields for Spitzer.

Ball developed the Infrared Spectrograph (IRS) instrument, with science leadership based at Cornell University, and the Multiband Imaging Photometer for Spitzer (MIPS) instrument, with science leadership based at the University of Arizona in Tucson. NASA's Goddard Space Flight Center in Greenbelt, Maryland, developed the Infrared Array Camera (IRAC) instrument, with science leadership based at the Harvard Smithsonian Astrophysics Observatory in Cambridge, Massachusetts.

View some of the amazing images showcasing some of Spitzer's greatest discoveries at:

https://www.jpl.nasa.gov/news/news.php?feature=7221

Grey Hautaluoma / Elizabeth LandauNASA Headquarters, Washington202-358-0668; 818-359-3241grey.hautaluoma-1@nasa.gov / elandau@jpl.nasa.gov

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

How Earth Climate Models Help Scientists Picture Life on Unimaginable Worlds

12 min read

In a generic brick building on the northwestern edge of NASA's Goddard Space Flight Center campus in Greenbelt, Maryland, thousands of computers packed in racks the size of vending machines hum in a deafening chorus of data crunching. Day and night, they spit out 7 quadrillion calculations per second. These machines collectively are known as NASA's Discover supercomputer and they are tasked with running sophisticated climate models to predict Earth's future climate.

But now, they're also sussing out something much farther away: whether any of the more than 4,000 curiously weird planets beyond our solar system discovered in the past two decades could support life.

Scientists are finding that the answer not only is yes, but that it's yes under a range of surprising conditions compared to Earth. This revelation has prompted many of them to grapple with a question vital to NASA's search for life beyond Earth. Is it possible that our notions of what makes a planet suitable for life are too limiting?

The next generation of powerful telescopes and space observatories will surely give us more clues. These instruments will allow scientists for the first time to analyze the atmospheres of the most tantalizing planets out there: rocky ones, like Earth, that could have an essential ingredient for life — liquid water — flowing on their surfaces.

For the time being, it's difficult to probe far-off atmospheres. Sending a spacecraft to the closest planet outside our solar system, or exoplanet, would take 75,000 years with today's technology. Even with powerful telescopes nearby exoplanets are virtually impossible to study in detail. The trouble is that they're too small and too drowned out by the light of their stars for scientists to make out the faint light signatures they reflect — signatures that could reveal the chemistry of life at the surface.

In other words, detecting the ingredients of the atmospheres around these phantom planets, as many scientists like to point out, is like standing in Washington, D.C., and trying to glimpse a firefly next to a searchlight in Los Angeles. This reality makes climate models critical to exploration, said chief exoplanetary scientist Karl Stapelfeldt, who's based at NASA's Jet Propulsion Laboratory in Pasadena, California.

"The models make specific, testable predictions of what we should see," he said. "These are very important for designing our future telescopes and observing strategies."

In scanning the cosmos with large ground-based and space telescopes, astronomers have discovered an eclectic assortment of worlds that seem drawn from the imagination.

"For a long time, scientists were really focused on finding Sun- and Earth-like systems. That's all we knew," said Elisa Quintana, a NASA Goddard astrophysicist who led the 2014 discovery of Earth-sized planet Kepler-186f. "But we found out that there's this whole crazy diversity in planets. We found planets as small as the Moon. We found giant planets. And we found some that orbit tiny stars, giant stars and multiple stars."

Indeed, most of the planets detected by NASA's Kepler space telescope and the new Transiting Exoplanet Survey Satellite, as well as ground-based observations, don't exist in our solar system. They fall between the size of a terrestrial Earth and a gaseous Uranus, which is four times bigger than this planet.

Download above image here

Planets closest in size to Earth, and most likely in theory to have habitable conditions, so far have been found only around “red dwarf” stars, which make up a vast majority of stars in the galaxy. But that’s likely because red dwarfs are smaller and dimmer than the Sun, so the signal from planets orbiting them is easier for telescopes to detect.

Because red dwarfs are small, planets have to lap uncomfortably close — closer than Mercury is to the Sun — to stay gravitationally attached to them. And because red dwarfs are cool, compared to all other stars, planets have to be closer to them to draw enough heat to allow liquid water to pool on their surfaces.

Download above image here

Among the most alluring recent discoveries in red dwarf systems are planets like Proxima Centauri b, or simply Proxima b. It’s the closest exoplanet. There are also seven rocky planets in the nearby system TRAPPIST-1. Whether or not these planets could sustain life is still a matter of debate. Scientists point out that red dwarfs can spew up to 500 times more harmful ultraviolet and X-ray radiation at their planets than the Sun ejects into the solar system. On the face of it, this environment would strip atmospheres, evaporate oceans and fry DNA on any planet close to a red dwarf.

Yet, maybe not. Earth climate models are showing that rocky exoplanets around red dwarfs could be habitable despite the radiation.

Anthony Del Genio is a recently retired planetary climate scientist from NASA’s Goddard Institute for Space Studies in New York City. During his career he simulated the climates of Earth and of other planets, including Proxima b.

Del Genio’s team recently simulated possible climates on Proxima b to test how many would leave it warm and wet enough to host life. This type of modeling work helps NASA scientists identify a handful of promising planets worthy of more rigorous study with NASA’s forthcoming James Webb Space Telescope.

“While our work can’t tell observers if any planet is habitable or not, we can tell them whether a planet is smack in the midrange of good candidates to search further,” Del Genio said.

Proxima b orbits Proxima Centauri in a three-star system located just 4.2 light years from the Sun. Besides that, scientists don’t know much about it. They believe it’s rocky, based on its estimated mass, which is slightly larger than Earth’s. Scientists can infer mass by watching how much Proxima b tugs on its star as it orbits it.

The problem with Proxima b is that it’s 20 times closer to its star than Earth is to the Sun. Therefore, it takes the planet only 11.2 days to make one orbit (Earth takes 365 days to orbit the Sun once). Physics tells scientists that this cozy arrangement could leave Proxima b gravitationally locked to its star, like the Moon is gravitationally locked to Earth. If true, one side of Proxima b faces the star’s intense radiation while the other one freezes in the darkness of space in a planetary recipe that doesn’t bode well for life on either side.

But Del Genio’s simulations show that Proxima b, or any planet with similar characteristics, could be habitable despite the forces conspiring against it. “And the clouds and oceans play a fundamental role in that,” Del Genio said.

Del Genio’s team upgraded an Earth climate model first developed in the 1970s to create a planetary simulator called ROCKE-3D. Whether Proxima b has an atmosphere is an open and critical question that will hopefully be settled by future telescopes. But Del Genio's team assumed that it does.

With each simulation Del Genio's team varied the types and amounts of greenhouse gases in Proxima b's air. They also changed the depth, size, and salinity of its oceans and adjusted the ratio of land to water to see how these tweaks would influence the planet's climate.

Models such as ROCKE-3D begin with only grains of basic information about an exoplanet: its size, mass, and distance from its star. Scientists can infer these things by watching the light from a star dip as a planet crosses in front of it, or by measuring the gravitational tugging on a star as a planet circles it.

These scant physical details inform equations that comprise up to a million lines of computer code needed to build the most sophisticated climate models. The code instructs a computer like NASA's Discover supercomputer to use established rules of nature to simulate global climate systems. Among many other factors, climate models consider how clouds and oceans circulate and interact and how radiation from a sun interacts with a planet's atmosphere and surface.

When Del Genio's team ran ROCKE-3D on Discover they saw that Proxima b's hypothetical clouds acted like a massive sun umbrella by deflecting radiation. This could lower the temperature on Proxima b's sun-facing side from too hot to warm.

Other scientists have found that Proxima b could form clouds so massive they would blot out the entire sky if one were looking up from the surface.

"If a planet is gravitationally locked and rotating slowly on its axis a circle of clouds forms in front of the star, always pointing towards it. This is due to a force known as the Coriolis effect, which causes convection at the location where the star is heating the atmosphere," said Ravi Kopparapu, a NASA Goddard planetary scientist who also models the potential climates of exoplanets. "Our modeling shows that Proxima b could look like this."

In addition to making Proxima b's day side more temperate than expected, a combination of atmosphere and ocean circulation would move warm air and water around the planet, thereby transporting heat to the cold side. "So you not only keep the atmosphere on the night side from freezing out, you create parts on the night side that actually maintain liquid water on the surface, even though those parts see no light," Del Genio said.

Atmospheres are envelopes of molecules around planets. Besides helping maintain and circulate heat, atmospheres distribute gases that nourish life or are produced by it.

These gases are the so-called "biosignatures" scientists will look for in the atmospheres of exoplanets. But what exactly they should be looking for is still undecided.

Earth's is the only evidence scientists have of the chemistry of a life-sustaining atmosphere. Yet, they have to be cautious when using Earth's chemistry as a model for the rest of the galaxy. Simulations from Goddard planetary scientist Giada Arney, for instance, show that even something as simple as oxygen — the quintessential sign of plant life and photosynthesis on modern Earth — could present a trap.

Download above image here

Arney's work highlights something interesting. Had alien civilizations pointed their telescopes toward Earth billions of years ago hoping to find a blue planet swimming in oxygen, they would have been disappointed; maybe they would have turned their telescopes toward another world. But instead of oxygen, methane could have been the best biosignature to look for 3.8 to 2.5 billion years ago. This molecule was produced in abundance back then, likely by the microorganisms quietly flourishing in the oceans.

“What is interesting about this phase of Earth’s history is that it was so alien compared to modern Earth,” Arney said. “There was no oxygen yet, so it wasn’t even a pale blue dot. It was a pale orange dot,” she said, referencing the orange haze produced by the methane smog that may have shrouded early Earth.

Findings like this one, Arney said, “have broadened our thinking about what’s possible among exoplanets,” helping expand the list of biosignatures planetary scientists will look for in distant atmospheres.

While the lessons from planetary climate models are theoretical — meaning scientists haven’t had an opportunity to test them in the real world — they offer a blueprint for future observations.

One major goal of simulating climates is to identify the most promising planets to turn to with the Webb telescope and other missions so that scientists can use limited and expensive telescope time most efficiently. Additionally, these simulations are helping scientists create a catalog of potential chemical signatures that they will one day detect. Having such a database to draw from will help them quickly determine the type of planet they’re looking at and decide whether to keep probing or turn their telescopes elsewhere.

Discovering life on distant planets is a gamble, Del Genio noted: “So if we want to observe most wisely, we have to take recommendations from climate models, because that’s just increasing the odds.”

The researchers and science profiled in this story are part of the Sellers Exoplanet Environments Collaboration, or SEEC, at NASA’s Goddard Space Flight Center. The multidisciplinary collaborative brings together experts from planetary and Earth sciences, with those from astrophysics and heliophysics, to build the most comprehensive and sophisticated computer models of exoplanets in order to better prepare for current and future exoplanet observations. To learn more, visit: https://seec.gsfc.nasa.gov/index.html.

By Lonnie ShekhtmanNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Kepler Witnesses Vampire Star System Undergoing Super-Outburst

4 min read

NASA’s Kepler spacecraft was designed to find exoplanets by looking for stars that dim as a planet crosses the star’s face. Fortuitously, the same design makes it ideal for spotting other astronomical transients – objects that brighten or dim over time. A new search of Kepler archival data has uncovered an unusual super-outburst from a previously unknown dwarf nova. The system brightened by a factor of 1,600 over less than a day before slowly fading away.

The star system in question consists of a white dwarf star with a brown dwarf companion about one-tenth as massive as the white dwarf. A white dwarf is the leftover core of an aging Sun-like star and contains about a Sun’s worth of material in a globe the size of Earth. A brown dwarf is an object with a mass between 10 and 80 Jupiters that is too small to undergo nuclear fusion.

The brown dwarf circles the white dwarf star every 83 minutes at a distance of only 250,000 miles (400,000 km) – about the distance from Earth to the Moon. They are so close that the white dwarf’s strong gravity strips material from the brown dwarf, sucking its essence away like a vampire. The stripped material forms a disk as it spirals toward the white dwarf (known as an accretion disk).

It was sheer chance that Kepler was looking in the right direction when this system underwent a super-outburst, brightening by more than 1,000 times. In fact, Kepler was the only instrument that could have witnessed it, since the system was too close to the Sun from Earth’s point of view at the time. Kepler’s rapid cadence of observations, taking data every 30 minutes, was crucial for catching every detail of the outburst.

The event remained hidden in Kepler’s archive until identified by a team led by Ryan Ridden-Harper of the Space Telescope Science Institute (STScI), Baltimore, Maryland, and the Australian National University, Canberra, Australia. “In a sense, we discovered this system accidentally. We weren’t specifically looking for a super-outburst. We were looking for any sort of transient,” said Ridden-Harper.

Kepler captured the entire event, observing a slow rise in brightness followed by a rapid intensification. While the sudden brightening is predicted by theories, the cause of the slow start remains a mystery. Standard theories of accretion disk physics don’t predict this phenomenon, which has subsequently been observed in two other dwarf nova super-outbursts.

“These dwarf nova systems have been studied for decades, so spotting something new is pretty tricky,” said Ridden-Harper. “We see accretion disks all over – from newly forming stars to supermassive black holes – so it’s important to understand them.”

Theories suggest that a super-outburst is triggered when the accretion disk reaches a tipping point. As it accumulates material, it grows in size until the outer edge experiences gravitational resonance with the orbiting brown dwarf. This might trigger a thermal instability, causing the disk to get superheated. Indeed, observations show that the disk’s temperature rises from about 5,000–10,000° F (2,700–5,300° C) in its normal state to a high of 17,000–21,000° F (9,700–11,700° C) at the peak of the super-outburst.

This type of dwarf nova system is relatively rare, with only about 100 known. An individual system may go for years or decades between outbursts, making it a challenge to catch one in the act.

“The detection of this object raises hopes for detecting even more rare events hidden in Kepler data,” said co-author Armin Rest of STScI.

The team plans to continue mining Kepler data, as well as data from another exoplanet hunter, the Transiting Exoplanet Survey Satellite (TESS) mission, in search of other transients.

“The continuous observations by Kepler/K2, and now TESS, of these dynamic stellar systems allows us to study the earliest hours of the outburst, a time domain that is nearly impossible to reach from ground-based observatories,” said Peter Garnavich of the University of Notre Dame in Indiana.

This work was published in the Oct. 21, 2019 issue of the Monthly Notices of the Royal Astronomical Society.

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Christine PulliamSpace Telescope Science Institute, Baltimore410-338-4366cpulliam@stsci.edu

Ryan Ridden-HarperSpace Telescope Science Institute, Baltimore, and Australian National University, Canberra, Australiarridden@stsci.edu

For Hottest Planet, a Major Meltdown, Study Shows

4 min read

Alicia Cermak

Massive gas giants called "hot Jupiters" — planets that orbit too close to their stars to sustain life — are some of the strangest worlds found beyond our solar system. New observations show that the hottest of them all is stranger still, prone to planetwide meltdowns so severe they tear apart the molecules that make up its atmosphere.

Called KELT-9b, the planet is an ultra-hot Jupiter, one of several varieties of exoplanets — planets around other stars — found in our galaxy. It weighs in at nearly three times the mass of our own Jupiter and orbits a star some 670 light-years away. With a surface temperature of 7,800 degrees Fahrenheit (4,300 degrees Celsius) — hotter than some stars — this planet is the hottest found so far.

Now, a team of astronomers using NASA's Spitzer space telescope has found evidence that the heat is too much even for molecules to remain intact. Molecules of hydrogen gas are likely ripped apart on the dayside of KELT-9b, unable to re-form until their disjointed atoms flow around to the planet's nightside.

Though still extremely hot, the nightside's slight cooling is enough to allow hydrogen gas molecules to reform — that is, until they flow back to the dayside, where they're torn apart all over again.

"This kind of planet is so extreme in temperature, it is a bit separate from a lot of other exoplanets," said Megan Mansfield, a graduate student at the University of Chicago and lead author of a new paper revealing these findings. "There are some other hot Jupiters and ultra-hot Jupiters that are not quite as hot but still warm enough that this effect should be taking place."

The findings, published in Astrophysical Journal Letters, showcase the rising sophistication of the technology and analysis needed to probe these very distant worlds. Science is just beginning to peer into the atmospheres of exoplanets, examining the molecular meltdowns of the hottest and brightest.

KELT-9b will stay firmly categorized among the uninhabitable worlds. Astronomers became aware of its extremely hostile environment in 2017, when it was first detected using the Kilodegree Extremely Little Telescope (KELT) system — a combined effort involving observations from two robotic telescopes, one in southern Arizona and one in South Africa.

In the Astrophysical Journal Letters study, the science team used the Spitzer space telescope to parse temperature profiles from this infernal giant. Spitzer, which makes observations in infrared light, can measure subtle variations in heat. Repeated over many hours, these observations allow Spitzer to capture changes in the atmosphere as the planet presents itself in phases while orbiting the star. Different halves of the planet roll into view as it orbits around its star.

That allowed the team to catch a glimpse of the difference between KELT-9b's dayside and its "night." In this case, the planet orbits its star so tightly that a "year" — once around the star — takes only 1 1/2 days. That means the planet is tidally locked, presenting one face to its star for all time (as our Moon presents only one face to Earth). On the far side of KELT-9b, nighttime lasts forever.

But gases and heat flow from one side to the other. A big question for researchers trying to understand exoplanet atmospheres is how radiation and flow balance each other out.

Computer models are major tools in such investigations, showing how these atmospheres are likely to behave in different temperatures. The best fit for the data from KELT-9b was a model that included hydrogen molecules being torn apart and reassembled, a process known as dissociation and recombination.

"If you don't account for hydrogen dissociation, you get really fast winds of [37 miles or] 60 kilometers per second," Mansfield said. "That's probably not likely."

KELT-9b turns out not to have huge temperature differences between its day- and nightsides, suggesting heat flow from one to the other. And the "hot spot" on the dayside, which is supposed to be directly under this planet's star, was shifted away from its expected position. Scientists don't know why — yet another mystery to be solved on this strange, hot planet.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

For Hottest Planet, a Major Meltdown, Study Shows

4 min read

Massive gas giants called “hot Jupiters” — planets that orbit too close to their stars to sustain life — are some of the strangest worlds found beyond our solar system. New observations show that the hottest of them all is stranger still, prone to planetwide meltdowns so severe they tear apart the molecules that make up its atmosphere.

Called KELT-9b, the planet is an ultra-hot Jupiter, one of several varieties of exoplanets — planets around other stars — found in our galaxy. It weighs in at nearly three times the mass of our own Jupiter and orbits a star some 670 light-years away. With a surface temperature of 7,800 degrees Fahrenheit (4,300 degrees Celsius) — hotter than some stars — this planet is the hottest found so far.

Now, a team of astronomers using NASA’s Spitzer space telescope has found evidence that the heat is too much even for molecules to remain intact. Molecules of hydrogen gas are likely ripped apart on the dayside of KELT-9b, unable to re-form until their disjointed atoms flow around to the planet’s nightside.

Though still extremely hot, the nightside’s slight cooling is enough to allow hydrogen gas molecules to reform — that is, until they flow back to the dayside, where they’re torn apart all over again.

“This kind of planet is so extreme in temperature, it is a bit separate from a lot of other exoplanets,” said Megan Mansfield, a graduate student at the University of Chicago and lead author of a new paper revealing these findings. “There are some other hot Jupiters and ultra-hot Jupiters that are not quite as hot but still warm enough that this effect should be taking place.”

The findings, published in Astrophysical Journal Letters, showcase the rising sophistication of the technology and analysis needed to probe these very distant worlds. Science is just beginning to peer into the atmospheres of exoplanets, examining the molecular meltdowns of the hottest and brightest.

KELT-9b will stay firmly categorized among the uninhabitable worlds. Astronomers became aware of its extremely hostile environment in 2017, when it was first detected using the Kilodegree Extremely Little Telescope (KELT) system — a combined effort involving observations from two robotic telescopes, one in southern Arizona and one in South Africa.

In the Astrophysical Journal Letters study, the science team used the Spitzer space telescope to parse temperature profiles from this infernal giant. Spitzer, which makes observations in infrared light, can measure subtle variations in heat. Repeated over many hours, these observations allow Spitzer to capture changes in the atmosphere as the planet presents itself in phases while orbiting the star. Different halves of the planet roll into view as it orbits around its star.

That allowed the team to catch a glimpse of the difference between KELT-9b’s dayside and its “night.” In this case, the planet orbits its star so tightly that a “year” — once around the star — takes only 1 1/2 days. That means the planet is tidally locked, presenting one face to its star for all time (as our Moon presents only one face to Earth). On the far side of KELT-9b, nighttime lasts forever.

But gases and heat flow from one side to the other. A big question for researchers trying to understand exoplanet atmospheres is how radiation and flow balance each other out.

Computer models are major tools in such investigations, showing how these atmospheres are likely to behave in different temperatures. The best fit for the data from KELT-9b was a model that included hydrogen molecules being torn apart and reassembled, a process known as dissociation and recombination.

“If you don’t account for hydrogen dissociation, you get really fast winds of [37 miles or] 60 kilometers per second,” Mansfield said. “That’s probably not likely.”

KELT-9b turns out not to have huge temperature differences between its day- and nightsides, suggesting heat flow from one to the other. And the “hot spot” on the dayside, which is supposed to be directly under this planet’s star, was shifted away from its expected position. Scientists don’t know why — yet another mystery to be solved on this strange, hot planet.

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Written by Pat Brennan

2020-015

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NESSI Emerges as New Tool for Exoplanet Atmospheres

6 min read

NASA Science Editorial Team

The darkness surrounding the Hale Telescope breaks with a sliver of blue sky as the dome begins to open, screeching with metallic, sci-fi-like sounds atop San Diego County's Palomar Mountain. The historic observatory smells of the oil pumped in to support the bearings that make this giant telescope float ever so slightly as it moves to track the stars.

Since February 2018, scientists have been testing an instrument at the Hale Telescope called the New Mexico Exoplanet Spectroscopic Survey Instrument, or NESSI. A collaboration between NASA's Jet Propulsion Laboratory in Pasadena, California, and the New Mexico Institute of Mining and Technology, NESSI was built to examine the atmospheres of planets that orbit stars beyond our Sun, or exoplanets, providing new insights into what these worlds are like.

So far, NESSI has checked out two "hot Jupiters," massive gas giants orbiting close to their stars and too scorching to sustain life. One, called HD 189773b, has such extreme temperatures and winds that it may rain glass sideways there. The other, WASP-33b, has a "sunscreen" layer of atmosphere, with molecules that absorb ultraviolet and visible light.

Tag along with the NESSI team for a night of observations

Recently, NESSI observed these planets crossing their host stars, proving the instrument would be able to help confirm possible planets previously observed by other telescopes. Now it is ready for more detailed studies of distant cousins of our solar system. And while the instrument is designed to look at planets much larger than Earth, NESSI's methods could be used to search for Earth-size planets someday as well once future technologies become available.

"NESSI is a powerful tool to help us meet the family," said Mark Swain, an astrophysicist and the JPL lead for NESSI. "Twenty-five years ago, to our best knowledge, we thought we were alone. Now we know that — at least in terms of planets — we're not, and that this family is extensive and very diverse."

Why NESSI?

NESSI views the galaxy in infrared light, which is invisible to the human eye. It stares at individual stars to observe the dimming of light as a planet passes in front of its host star — an event called a transit. From the transit, astronomers can learn how big the planet is relative to its host star. When the planet passes directly behind the star and re-emerges, it's called an eclipse. NESSI can look for signatures of molecules from the planet's atmosphere detectable in starlight before and after the eclipse.

Inside NESSI, devices that focus infrared light spread it into a rainbow, or spectrum, filtering it for particular wavelengths that relate to the atmospheric chemistry of distant planets.

"We can pick out the parts of the spectrum where the molecules are, because that's really what we're looking for in the infrared in these exoplanets — molecular signatures of things like carbon dioxide and water and methane to tell us that there's something interesting going on in that particular planet," said Michelle Creech-Eakman, principal investigator for NESSI at New Mexico Tech.

NESSI is equipped to follow up on discoveries from other observatories such as NASA's Transiting Exoplanet Survey Satellite (TESS). TESS scans the entire sky in visible light for planets around bright, nearby stars, but the planet candidates it discovers must be confirmed through other methods. That is to make sure these signals TESS detects actually come from planet transits, not other sources.

NESSI can also help bridge the science between TESS and NASA's James Webb Space Telescope, scheduled to launch in 2021. The largest, most complex space observatory ever to fly, Webb will study individual planets to learn about their atmospheres and whether they contain molecules associated with habitability. But since Webb's time will be precious, scientists want to point it only at the most interesting and accessible targets. For example, if NESSI sees no molecular signatures around a planet, that implies clouds are blocking its atmosphere, making it unlikely to be a good target for Webb.

"This helps us see if a planet is clear or cloudy or hazy," said Rob Zellem, an astrophysicist and the JPL commissioning lead on NESSI. "And if it's clear, we'll see the molecules. And if then we see the molecules, they'll say, 'Hey, it's a great target to look at with James Webb or Hubble or anything else.'"

A Window to the Galaxy

NESSI began as a concept in 2008 when Swain visited Creech-Eakman's astrobiology class at New Mexico Tech. Over coffee, Swain told his colleague about exoplanet observations he had done with a ground-based telescope that didn't turn out well. Creech-Eakman realized a different instrument combined with the right telescope could accomplish Swain's goals. On a napkin, the two sketched an idea for what would become NESSI.

They designed the instrument for the Magdalena Ridge Observatory in Magdalena, New Mexico. But once the researchers began using it in April 2014, the instrument didn't work as expected.

Swain suggested moving NESSI to Palomar's 200-inch Hale Telescope, which is much larger and more powerful — and also more accessible for the team. Owned and operated by Caltech, which manages JPL for NASA, Palomar has designated observing nights for researchers from JPL.

Relocating NESSI — a 5-foot-tall (1.5-meter-tall) blue, cylindrical device with wires coming out of it — wasn't just a matter of placing it on a truck and driving southwest. The electrical and optical systems needed to be reworked for its new host and then tested again. NESSI also needed a way to communicate with a different telescope, so University of Arizona doctoral student Kyle Pearson developed software to operate the instrument at Palomar. By early 2018, NESSI was ready to climb the mountain.

A crane lifted NESSI more than 100 feet (30 meters) to the top of the Hale Telescope on Feb. 1, 2018. Technicians installed the instrument in a "cage" at the Hale's prime focus, which enables all of the light from the 530-ton telescope to be funneled into NESSI's detectors.

The team celebrated NESSI's glimpse of its first star on Feb. 2, 2018, but between limited telescope time and fickle weather, more than a year of testing and troubleshooting would pass (never mind the time the decades-old lift got stuck as Zellem and Swain ascended to the telescope cage).

"We track down the problems and we fix them. That's the name of the game," Creech-Eakman said.

As the team continued making adjustments in 2019, Swain tapped a local high school student to design a baffle — a cylindrical device to help direct more light to NESSI's sensors. This piece was then 3D-printed in JPL's machine shop.

When NESSI finally detected transiting planets on Sept. 11, 2019, the team didn't pause to pop open champagne. Researchers are now working out the measurements of HD 189773b's atmosphere. The team has also compiled a list of exoplanets they want to go after next.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

How NASA’s Webb Telescope Will Continue Spitzer’s Legacy

9 min read

As one window to the universe closes, another will open with an even better view. Some of the same planets, stars and galaxies we first saw through the first window will appear in even sharper detail in the one that will soon open.

NASA’s Spitzer Space Telescope concludes its mission on Jan. 30, 2020, after more than 16 extraordinary years of exploration. The telescope has made many discoveries beyond the imaginations of its designers, such as planets outside our solar system, called exoplanets, and galaxies that formed close to the beginning of the universe. Many of Spitzer’s breakthroughs will be studied more precisely with the forthcoming James Webb Space Telescope, which is expected to launch in 2021.

“We have a lot of new questions to ask about the universe because of Spitzer,” said Michael Werner, Spitzer project scientist based at NASA’s Jet Propulsion Laboratory in Pasadena, California. “It’s very gratifying to know there’s such a powerful set of capabilities coming along to follow up on what we’ve been able to start with Spitzer.”

Both Webb and Spitzer are specialized for infrared light, which is invisible to human eyes. But with its giant gold-coated beryllium mirror and nine new technologies, Webb is about 1,000 times more powerful. The forthcoming telescope will be able to push Spitzer’s science findings to new frontiers, from identifying chemicals in exoplanet atmospheres to locating some of the first galaxies to form after the Big Bang.

Beyond its discoveries, Spitzer is also a pathfinder for Webb in terms of how to operate a telescope of this kind. In order to measure infrared light with high sensitivity, a telescope must be very cold. Spitzer has shown engineers how an infrared observatory behaves in the vastness of space and what temperatures mission planners should expect to grapple with for Webb.

“Having a huge telescope in space is hard. But having a huge telescope that’s cold is much harder,” said Amber Straughn, deputy project scientist for James Webb Space Telescope Science Communications. “Spitzer helped us learn how to better operate a very cold telescope in space.”

With more than 8,700 scientific papers published based on Spitzer’s discoveries, the telescope has been a tremendous asset to astronomers across a variety of disciplines. Many of these tantalizing results are ripe for revisiting with a more powerful telescope, and Webb is poised to begin looking into them early in its mission. Here is a sampling of Spitzer’s accomplishments that Webb will build upon.

One of Spitzer’s most stunning discoveries was that there are not just three, but seven rocky Earth-size planets orbiting a small, faint star called TRAPPIST-1. TRAPPIST-1 is one of the best-studied planetary systems apart from our own, but there is a lot more to learn about it.

The fourth planet from the star, TRAPPIST-1e is especially interesting because it has a density and surface gravity very similar to Earth’s and receives enough stellar radiation to have temperatures friendly enough for liquid water. Webb will observe this planet to get a better sense of whether the planet has an atmosphere and, if so, what its chemistry is.

The presence of molecules such as carbon dioxide, dominant on Mars and Venus, would have implications for whether a planet could have liquid water and other habitable conditions. Webb will be able to detect atmospheric water, too. Additionally, Webb will search for heat coming from

TRAPPIST-1b, the planet closest to its star.

“The diversity of atmospheres around terrestrial worlds is probably beyond our wildest imaginations,” said Nikole Lewis, assistant professor of astronomy at Cornell University in Ithaca, New York. “Getting any information about air on these planets is going to be very useful.”

WASP-18b is another intriguing planet that Spitzer examined and that Webb will investigate further in observations early in the mission. This gas giant, with 10 times the mass of Jupiter, is located extremely close to its star, completing an orbit once every 23 hours. Because of its high temperature — a whopping 4,800 degrees Fahrenheit (2,650 degrees Celsius) — and large size, it is known as a “hot Jupiter.” Using data from Spitzer and Hubble, astronomers figured out in 2017 that this planet has a lot of carbon monoxide in its upper atmosphere and little water vapor. This planet is particularly interesting because it’s so close to its star that it’s in danger of being torn apart completely, and it may not survive another million years. Astronomers are interested in using Webb to look at the processes happening in this planet’s atmosphere, which will provide insights into hot Jupiters in general.

Spitzer has also delivered unprecedented weather reports for exoplanets. In 2007, it made the first-ever map of the surface of an exoplanet, the hot Jupiter HD 189733b, showing its temperature variations and cloud tops. More recently, in 2016, Spitzer highlighted the climate patterns of 55 Cancri e, a possibly lava-covered world more than twice the size of Earth. But maps from Spitzer have given scientists a lot to think about as they look to further investigations with Webb.

Spitzer has also made strides in identifying and characterizing brown dwarfs. A brown dwarf is larger than a planet but less massive than a star, and while stars generate their own energy by fusing hydrogen, brown dwarfs do not. Spitzer has been able to look at the clouds in brown dwarf atmospheres and observe how they move and change shape with time. Webb will also examine brown dwarf cloud properties and delve deeper into the physics of these mysterious objects.

Infrared light has also been revolutionary for looking at disks of gas and dust orbiting stars, and both Spitzer and Webb are sensitive to the infrared glow of this material. Disks that Spitzer has studied contain the raw materials for making planets and may represent the state of our solar system before Earth and its neighbors formed. Spitzer has seen particles around young stars beginning to transform into the seeds of small planetary bodies, and that some disks have materials similar to those seen in comets in our solar system. Webb can look at the same disks and find out even more about the planetary formation process.

As light travels from distant objects to Earth, its wavelength becomes longer because the universe is expanding and those objects are moving farther from us. Just like the sound of a siren seems to lower in pitch as an ambulance drives away, light from distant galaxies also lowers in frequency, a phenomenon called “redshift.” That means stars that give off visible light in the early universe will appear in the infrared by the time their light reaches Earth. This makes infrared light an especially powerful tool for exploring the universe’s ancient past.

Pinpointing hundreds of billions of galaxies is currently impossible, but Spitzer has made large galaxy catalogs that represent different slices of the universe, containing some of the most distant galaxies we know. The large survey areas of Spitzer and Hubble Space Telescope have allowed astronomers to efficiently look for objects that could be studied in further detail with Webb.

For example, Spitzer, together with Hubble, took an image of a galaxy called GN-z11, which holds the record for most distant galaxy measured yet. It is a relic from when the universe was only 400 million years old, just 3% of its current age and less than 10% of its size today.

“Spitzer surveyed thousands of galaxies, mapped the Milky Way and performed other groundbreaking feats by looking at large areas of the sky,” said Sean Carey, manager of the Spitzer Science Center at Caltech/IPAC in Pasadena, California. “Webb won’t have this capability, but it will revisit some of the most interesting targets in the Spitzer surveys to reveal them in amazing clarity.”

What’s more, Webb’s higher sensitivity will allow the telescope to look for galaxies dating back even earlier in the universe. And questions still abound about these distant galaxies: Are there a lot of stars forming in them or relatively few? Are they rich in gas or poor? Are there black holes at their centers, and how do those black holes interact with stars? And, scientists have pondered a chicken-and-egg problem for decades about which came first: the black hole or the surrounding galaxy?

“We’ll be able to see some of the earliest galaxies to form in the universe that we’ve never seen before,” said Straughn.

Closer to home, Spitzer also studied many examples of a mysterious kind of galaxy called a luminous infrared galaxy, or LIRG. Such galaxies are generating tens to hundreds of times more energy per second than a typical galaxy, and most of that energy takes the form of far-infrared light. Scientists have used Spitzer to study LIRGs and learn about star formation and the growth of black holes during periods of rapid evolution when galaxies collide and merge. Such collisions were even more common 6 billion to 10 billion years ago and influenced the evolution of the universe as we know it.

“Webb will take inspiration from Spitzer and examine a variety of nearby and distant LIRGs to learn more about the role of galactic mergers, bursts of star formation and the growth of supermassive black holes in galactic evolution over cosmic time,” said Lee Armus of Caltech, who will lead a LIRG observing program for Webb.

For more than 16 years, Spitzer mapped out many of the most pressing questions in infrared astronomy. Now it’s up to Webb to revisit them with sharper vision, through the grandest window yet to the cosmos.

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Elizabeth LandauNASA Headquarters, Washington818-359-3241elandau@jpl.nasa.gov

2020-011

10 Things Spitzer Taught Us About Exoplanets

8 min read

NASA Science Editorial Team

Initially scheduled for a 2.5-year primary mission, NASA’s Spitzer spacecraft has gone above and beyond since its launch in 2003. The space telescope was designed to explore our universe with infrared vision and has been used to discover amazing worlds, and to tell us more about them.

On Jan. 30, 2020, Spitzer’s mission will end. The spacecraft will be switched off, remaining in orbit around the Sun, trailing far (and safely) behind Earth. The engineers and scientists behind Spitzer did not have exoplanet science in mind when they designed the observatory back in the 1990s, but thanks to its extraordinary stability, and a series of engineering reworks after launch, Spitzer’s observational powers were utilized far beyond its original limits and expectations. Here are 10 examples of Spitzer's exoplanet discoveries.

Exoplanet science was in its infancy when Spitzer launched, so original mission planners didn’t anticipate that exoplanet science would become a major focus. But the telescope’s accurate star-targeting system and infrared vision are invaluable tools in this field.

In May 2009, scientists using data from Spitzer produced the first-ever "weather map" of an exoplanet. This exoplanet weather map charted temperature variations over the surface of a giant gas planet, HD 189733b. The study also revealed that roaring winds likely whip through the planet's atmosphere.

Seven Earth-size planets orbit the star known as TRAPPIST-1. The largest batch of Earth-size planets ever discovered in a single system, this amazing planetary system inspired scientists and non-scientists alike. Three of the planets sit in the "habitable zone" around the star, where temperatures might be right to support liquid water on a planet's surface. The discovery represents a major step in the search for life beyond Earth.

Scientists observed the TRAPPIST-1 system for over 500 hours with Spitzer to identify five of the new planets orbiting the star (two were already known). The telescope's infrared vision was ideal for studying the small, dim and red TRAPPIST-1 star, which is much cooler than our Sun. Spitzer's observations helped us understand the size and mass of these planets.

In 2010, Spitzer helped scientists detect one of the most remote planets ever discovered, about 13,372 light-years away from Earth. Most previously known exoplanets lie within 1,000 light-years of Earth.

Spitzer accomplished this task with the help of a ground-based telescope and a technique called microlensing (an effect first predicted by Albert Einstein 100 years ago). This approach relies on gravitational lensing, in which light is bent and magnified by gravity. When a star passes in front of a more distant star, as seen from Earth, the foreground star's gravity can bend and magnify the light from the background star. If a planet orbits the foreground star, the planet's gravity contributes to the brightness and leaves a distinctive imprint on the magnified light.

The discovery of OGLE-2014-BLG-0124Lb provides one more clue for scientists who want to know if the population of planets is similar throughout different regions of the galaxy.

Scientists also used Spitzer and microlensing to tell us more about far-off exoplanets. In 2017, scientists used Spitzer and the Korea Microlensing Telescope Network (KMTNet), operated by the Korea Astronomy and Space Science Institute, to track a microlensing event and discover a new planet with the mass of Earth, orbiting its star at the same distance that we orbit our Sun.

OGLE-2016-BLG-1195Lb is likely far too cold to be habitable for life as we know it, however, because its star is so much fainter than our Sun. But the discovery adds to scientists' understanding of the types of planetary systems that exist beyond our own.

OGLE-2016-BLG-1195Lb is 12,752 light-years away and orbits a star so small, scientists aren't sure if it's a star at all. It could be a brown dwarf, a star-like object whose core is not hot enough to generate energy through nuclear fusion. This particular star is only 7.8 percent the mass of our Sun, right on the border between being a star and not.

Astronomers using data from the Spitzer and Kepler space telescopes created the first cloud map of a planet beyond our solar system, a sizzling, Jupiter-like world known as Kepler-7b.

The planet is marked by high clouds in the west and clear skies in the east. Previous studies from Spitzer showed exoplanet temperature maps, but this was the first look at cloud structures on a distant world. Kepler was used to discover the planet and create a rough map that showed a bright spot on its western hemisphere.

Spitzer's ability to detect infrared light meant it was able to measure Kepler-7b's temperature, estimating it to be between 1,500 and 1,800 degrees Fahrenheit (1,100 and 1,300 Kelvin). This is relatively cool for a planet that orbits so close to its star. Scientists determined that light from the planet's star is bouncing off cloud tops its west side. The findings were an early step toward using similar techniques to study the atmospheres of exoplanets more like Earth in composition and size.

Eighty hours of observations from Spitzer led to the first temperature map of a super-Earth – a rocky planet nearly two times as big as ours. The map revealed extreme temperature swings from one side of the planet 55 Cancri e to the other, and hinted at an ocean of lava across the surface.

In this case, 55 Cancri e was found to have dramatically different temperatures on each of its sides (the planet is tidally locked, so one side, the day side, always faces the star). The day side of the planet is nearly 4,400 degrees Fahrenheit (2,700 Kelvin), and the “cooler,” night side is 2,060 degrees Fahrenheit (1,400 Kelvin).

In 2007, Spitzer for the first time captured enough light from two exoplanets to identify molecules in their atmospheres. It was a landmark achievement.

Astronomers used Spitzer's spectrograph to obtain infrared spectra for two hot Jupiters using the "secondary eclipse" technique. In this method, the spectrograph first collects the combined infrared light from the planet plus its star, then, as the planet is eclipsed by the star, the infrared light of just the star. Subtracting the latter from the former reveals the planet's own rainbow of infrared colors.

Spitzer revealed that HD 209458b and HD 189733b are drier and cloudier than predicted. Theorists thought hot Jupiters would have lots of water in their atmospheres, but surprisingly none was found. A mystery!

One of the planets, HD 209458b, showed hints of tiny sand grains, called silicates, in its atmosphere. This could mean the planet's skies are filled with high, dusty clouds unlike anything seen around planets in our own solar system.

Because Spitzer looks at targets in infrared, it was able to help confirm and refine discoveries from other spacecraft. Take Kepler-10c for instance. That planet was first identified by Kepler, and later validated using a combination of Spitzer and a computer simulation technique called "Blender." Both of these methods proved powerful to validate Kepler planets that are too small and far away for ground-based telescopes to confirm.

Spitzer is also a great partner with the Hubble Space Telescope. In 2015, an international team of astronomers undertook the largest ever study of hot Jupiters, exploring and comparing 10 planets, including HD 209458b and HD 189733b, with Spitzer and Hubble in a bid to understand their atmospheres. The team was able to discover why some of these worlds seem to have less water than expected. The team’s models revealed that, while apparently cloud-free exoplanets showed strong signs of water, the atmospheres of those hot Jupiters with faint water signals also contained clouds and haze — both of which are known to hide water from view. Mystery solved!

Spitzer used its infrared vision to observe the dust of six dead "white dwarf" stars littered with the remains of shredded asteroids. Asteroids are leftover scraps of planetary material. They form early in a star's history when planets are forming out of collisions between rocky bodies. When a star like our Sun dies, its core shrinks to a skeleton of its former self called a white dwarf, and its asteroids get jostled about. If one of these asteroids gets too close to the white dwarf, the white dwarf's gravity will chew the asteroid up, leaving a cloud of dust.

Spitzer found that the dust contains a glassy silicate mineral called olivine, commonly found on Earth. The results suggest that the same materials that make up Earth and our solar system's other rocky bodies could be common in the universe. If the materials are common, then rocky planets could be, too.

Spitzer later saw an eruption of dust around a young star, possibly the result of a smashup between large asteroids. Scientists had been regularly tracking the star, NGC 2547-ID8, when it surged with a huge amount of fresh dust between August 2012 and January 2013. Spitzer saw the warm glow of the dust in infrared, and its observations give us a glimpse into the violent process to tell us more about the formation of rocky planets like Earth.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NESSI Emerges as New Tool for Exoplanet Atmospheres

7 min read

The darkness surrounding the Hale Telescope breaks with a sliver of blue sky as the dome begins to open, screeching with metallic, sci-fi-like sounds atop San Diego County's Palomar Mountain. The historic observatory smells of the oil pumped in to support the bearings that make this giant telescope float ever so slightly as it moves to track the stars.

Since February 2018, scientists have been testing an instrument at the Hale Telescope called the New Mexico Exoplanet Spectroscopic Survey Instrument, or NESSI. A collaboration between NASA's Jet Propulsion Laboratory in Pasadena, California, and the New Mexico Institute of Mining and Technology, NESSI was built to examine the atmospheres of planets that orbit stars beyond our Sun, or exoplanets, providing new insights into what these worlds are like.

So far, NESSI has checked out two "hot Jupiters," massive gas giants orbiting close to their stars and too scorching to sustain life. One, called HD 189773b, has such extreme temperatures and winds that it may rain glass sideways there. The other, WASP-33b, has a "sunscreen" layer of atmosphere, with molecules that absorb ultraviolet and visible light.

Recently, NESSI observed these planets crossing their host stars, proving the instrument would be able to help confirm possible planets previously observed by other telescopes. Now it is ready for more detailed studies of distant cousins of our solar system. And while the instrument is designed to look at planets much larger than Earth, NESSI's methods could be used to search for Earth-size planets someday as well once future technologies become available.

"NESSI is a powerful tool to help us meet the family," said Mark Swain, an astrophysicist and the JPL lead for NESSI. "Twenty-five years ago, to our best knowledge, we thought we were alone. Now we know that — at least in terms of planets — we're not, and that this family is extensive and very diverse."

NESSI views the galaxy in infrared light, which is invisible to the human eye. It stares at individual stars to observe the dimming of light as a planet passes in front of its host star — an event called a transit. From the transit, astronomers can learn how big the planet is relative to its host star. When the planet passes directly behind the star and re-emerges, it's called an eclipse. NESSI can look for signatures of molecules from the planet's atmosphere detectable in starlight before and after the eclipse.

Inside NESSI, devices that focus infrared light spread it into a rainbow, or spectrum, filtering it for particular wavelengths that relate to the atmospheric chemistry of distant planets.

"We can pick out the parts of the spectrum where the molecules are, because that's really what we're looking for in the infrared in these exoplanets — molecular signatures of things like carbon dioxide and water and methane to tell us that there's something interesting going on in that particular planet," said Michelle Creech-Eakman, principal investigator for NESSI at New Mexico Tech.

NESSI is equipped to follow up on discoveries from other observatories such as NASA's Transiting Exoplanet Survey Satellite (TESS). TESS scans the entire sky in visible light for planets around bright, nearby stars, but the planet candidates it discovers must be confirmed through other methods. That is to make sure these signals TESS detects actually come from planet transits, not other sources.

NESSI can also help bridge the science between TESS and NASA’s James Webb Space Telescope, scheduled to launch in 2021. The largest, most complex space observatory ever to fly, Webb will study individual planets to learn about their atmospheres and whether they contain molecules associated with habitability. But since Webb’s time will be precious, scientists want to point it only at the most interesting and accessible targets. For example, if NESSI sees no molecular signatures around a planet, that implies clouds are blocking its atmosphere, making it unlikely to be a good target for Webb.

“This helps us see if a planet is clear or cloudy or hazy,” said Rob Zellem, an astrophysicist and the JPL commissioning lead on NESSI. “And if it’s clear, we’ll see the molecules. And if then we see the molecules, they’ll say, ‘Hey, it’s a great target to look at with James Webb or Hubble or anything else.’”

NESSI began as a concept in 2008 when Swain visited Creech-Eakman’s astrobiology class at New Mexico Tech. Over coffee, Swain told his colleague about exoplanet observations he had done with a ground-based telescope that didn’t turn out well. Creech-Eakman realized a different instrument combined with the right telescope could accomplish Swain’s goals. On a napkin, the two sketched an idea for what would become NESSI.

They designed the instrument for the Magdalena Ridge Observatory in Magdalena, New Mexico. But once the researchers began using it in April 2014, the instrument didn’t work as expected.

Swain suggested moving NESSI to Palomar’s 200-inch Hale Telescope, which is much larger and more powerful — and also more accessible for the team. Owned and operated by Caltech, which manages JPL for NASA, Palomar has designated observing nights for researchers from JPL.

Relocating NESSI — a 5-foot-tall (1.5-meter-tall) blue, cylindrical device with wires coming out of it — wasn’t just a matter of placing it on a truck and driving southwest. The electrical and optical systems needed to be reworked for its new host and then tested again. NESSI also needed a way to communicate with a different telescope, so University of Arizona doctoral student Kyle Pearson developed software to operate the instrument at Palomar. By early 2018, NESSI was ready to climb the mountain.

A crane lifted NESSI more than 100 feet (30 meters) to the top of the Hale Telescope on Feb. 1, 2018. Technicians installed the instrument in a “cage” at the Hale’s prime focus, which enables all of the light from the 530-ton telescope to be funneled into NESSI’s detectors.

The team celebrated NESSI’s glimpse of its first star on Feb. 2, 2018, but between limited telescope time and fickle weather, more than a year of testing and troubleshooting would pass (never mind the time the decades-old lift got stuck as Zellem and Swain ascended to the telescope cage).

“We track down the problems and we fix them. That’s the name of the game,” Creech-Eakman said.

As the team continued making adjustments in 2019, Swain tapped a local high school student to design a baffle — a cylindrical device to help direct more light to NESSI’s sensors. This piece was then 3D-printed in JPL’s machine shop.

When NESSI finally detected transiting planets on Sept. 11, 2019, the team didn’t pause to pop open champagne. Researchers are now working out the measurements of HD 189773b’s atmosphere. The team has also compiled a list of exoplanets they want to go after next.

“It’s really rewarding, finally, to see all of our hard work is paying off and that we’re getting NESSI to work,” Zellem said. “It’s been a long journey, and it’s really gratifying to see this happen, especially in real time.”

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Written by Elizabeth Landau

2020-010

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A New Tool for ‘Weighing’ Unseen Planets

4 min read

A new instrument funded by NASA and the National Science Foundation called NEID (pronounced “NOO-id”; sounds like “fluid”) will help scientists measure the masses of planets outside our solar system — exoplanets — by observing the gravitational pull they exert on their parent stars. That information can help reveal a planet’s composition, one critical aspect in determining its potential habitability.

NEID recently made its first observations on the WIYN 3.5-meter (11.5-foot) telescope at Kitt Peak National Observatory when it studied 51 Pegasi, which in 1995 was the first Sun-like star found to host an exoplanet.

Located in southern Arizona, the observatory sits on land of the Tohono O’odham Nation, and NEID’s pronunciation evokes a word that roughly translates as “to see” in the Tohono O’odham language. The instrument finds and studies planets using what is called the radial velocity method, where scientists measure how the star wobbles slightly due to an orbiting planet’s gravitational pull. The more massive the planet, the stronger its tug and the faster the star moves. (A smaller star is also more susceptible to a planet’s gravitational pull than a larger one.)

Armed with measurements of a planet’s diameter and mass, scientists can determine its density as well, which can typically reveal whether the planet is rocky (like Earth, Venus and Mars) or mostly gaseous (like Jupiter and Saturn). This is a first step toward finding potentially habitable worlds similar to Earth. When applied to many planets, the method provides a more comprehensive view of what types are most common in the galaxy and how other planetary systems form.

Planets in our own solar system cause our Sun to wobble: Jupiter, with its immense gravity, causes our home star to move back and forth at roughly 43 feet per second (13 meters per second), whereas Earth causes a more sedate movement of only 0.3 feet per second (0.1 meters per second). The speed is proportional to an orbiting planet’s mass as well as to the mass of the star and the distance between those two objects.

Until now, instruments have typically been able to measure speeds as low as about 3 feet per second (1 meter per second), but NEID belongs to a new generation of instruments capable of achieving about three-times-finer precision. It has the potential to detect and study rocky planets around stars smaller than the Sun. In addition, the scientists and engineers working with the instrument want to use it to demonstrate “extreme precision radial velocity” that could perhaps one day detect planets as small as Earth orbiting around Sun-like stars in the habitable zone, where liquid water could potentially exist on a planet’s surface.

NEID will also confirm the presence and measure masses of planets discovered by NASA’s recently launched TESS (or Transiting Exoplanet Survey Satellite) space telescope, which detects planets via a different method from NEID: TESS hunts for tiny dips in the light coming from nearby stars, an indication that a planet is crossing the star’s face, or disk. This approach can reveal how big around the planet is (information necessary for calculating the planet’s density) and, based on the wobble, the length of its “year,” or one trip around its star. NEID can also investigate planet candidates found by other telescopes.

Members of the NEID team will discuss the first light results at the 235th meeting of the American Astronomical Society in Honolulu.

The NASA-NSF Exoplanet Observational Research (NN-EXPLORE) partnership funds NEID, short for NN-EXPLORE Exoplanet Investigations with Doppler spectroscopy. NN-EXPLORE is managed at NASA by the Exoplanet Exploration Program (ExEP), based at the Jet Propulsion Laboratory in

Pasadena, California. The NEID team is led by the Pennsylvania State University with major partners at the University of Pennsylvania, the University of Arizona, NASA's Goddard Space Flight Center and the NASA Exoplanet Science Institute at Caltech.

The NEID spectrograph was built at the Pennsylvania State University. NSF's National Optical-Infrared Astronomy Research Laboratory (NOIR Lab) was responsible for modifications to the WIYN 3.5-meter telescope to accommodate NEID. The telescope port adapter design was led by the NOIR Lab and was constructed at the University of Wisconsin. Additional NEID participants include Carleton College, the National Institute for Standards and Technology, the University of California Irvine, the University of Colorado and Macquarie University.

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

2020-004

Discovery Alert! High School Student Finds a World With Two Suns

6 min read

NASA Science Editorial Team

In 2019, when Wolf Cukier finished his junior year at Scarsdale High School in New York, he joined NASA's Goddard Space Flight Center in Greenbelt, Maryland, as a summer intern. His job was to examine variations in star brightness captured by NASA's Transiting Exoplanet Survey Satellite (TESS) and uploaded to the Planet Hunters TESS citizen science project.

"I was looking through the data for everything the volunteers had flagged as an eclipsing binary, a system where two stars circle around each other and from our view eclipse each other every orbit," Cukier said. "About three days into my internship, I saw a signal from a system called TOI 1338. At first I thought it was a stellar eclipse, but the timing was wrong. It turned out to be a planet."

TOI 1338 b, as it is now called, is TESS' first circumbinary planet, a world orbiting two stars. The discovery was featured in a panel discussion on Monday, Jan. 6, at the 235th American Astronomical Society meeting in Honolulu. A paper, which Cukier co-authored along with scientists from Goddard, San Diego State University, the University of Chicago and other institutions, has been submitted to a scientific journal.

The TOI 1338 system lies 1,300 light-years away in the constellation Pictor. The two stars orbit each other every 15 days. One is about 10% more massive than our Sun, while the other is cooler, dimmer and only one-third the Sun's mass.

TOI 1338 b is the only known planet in the system. It's around 6.9 times larger than Earth, or between the sizes of Neptune and Saturn. The planet orbits in almost exactly the same plane as the stars, so it experiences regular stellar eclipses.

TESS has four cameras, which each take a full-frame image of a patch of the sky every 30 minutes for 27 days. Scientists use the observations to generate graphs of how the brightness of stars change over time. When a planet crosses in front of its star from our perspective, an event called a transit, its passage causes a distinct dip in the star's brightness.

But planets orbiting two stars are more difficult to detect than those orbiting one. TOI 1338 b's transits are irregular, between every 93 and 95 days, and vary in depth and duration thanks to the orbital motion of its stars. TESS only sees the transits crossing the larger star; the transits of the smaller star are too faint to detect.

"These are the types of signals that algorithms really struggle with," said lead author Veselin Kostov, a research scientist at the SETI Institute and Goddard. "The human eye is extremely good at finding patterns in data, especially non-periodic patterns like those we see in transits from these systems."

This explains why Cukier had to visually examine each potential transit. For example, he initially thought TOI 1338 b's transit was a result of the smaller star in the system passing in front of the larger one — both cause similar dips in brightness. But the timing was wrong for an eclipse.

After identifying TOI 1338 b, the research team used a software package called eleanor, named after Eleanor Arroway, the central character in Carl Sagan's novel "Contact," to confirm the transits were real and not a result of instrumental artifacts.

“Throughout all of its images, TESS is monitoring millions of stars,” said co-author Adina Feinstein, a graduate student at the University of Chicago. “That’s why our team created eleanor. It’s an accessible way to download, analyze and visualize transit data. We designed it with planets in mind, but other members of the community use it to study stars, asteroids and even galaxies.”

TOI 1338 had already been studied from the ground by radial velocity surveys, which measure motion along our line of sight. Kostov’s team used this archival data to analyze the system and confirm the planet. Its orbit is stable for at least the next 10 million years. The orbit’s angle to us, however, changes enough that the planet transit will cease after November 2023 and resume eight years later.

NASA’s Kepler and K2 missions previously discovered 12 circumbinary planets in 10 systems, all similar to TOI 1338 b. Observations of binary systems are biased toward finding larger planets, Kostov said. Transits of smaller bodies don’t have as big an effect on the stars’ brightness. TESS is expected to observe hundreds of thousands of eclipsing binaries during its initial two-year mission, so many more of these circumbinary planets should be waiting for discovery.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Saying Goodbye to One of NASA’s Great Observatories

3 min read

NASA Science Editorial Team

◆ Live-streamed show will feature mission members and NASA leadership will air Jan. 22, 2020 at 10 a.m. PT | 1 p.m. ET.

◆ Members of the public can ask questions on social media with #AskNASA

NASA will host a live program at 10 a.m. PST (1 p.m. EST) Wednesday, Jan. 22, to celebrate the far-reaching legacy of the agency's Spitzer Space Telescope – a mission that, after 16 years of amazing discoveries, soon will come to an end.

The event will air live on NASA Television, Facebook Live, Ustream, YouTube, Twitter and the agency's website.

Experts on the program will include NASA Director of Astrophysics Paul Hertz and, from the agency's Jet Propulsion Laboratory (JPL), Spitzer Project Scientist Mike Werner, astrophysicist Farisa Morales, current Mission Manager Joseph Hunt, and former Mission Manager Suzanne Dodd.

The public can ask questions on Twitter using the hashtag #askNASA or in the comment section of the NASA Facebook and YouTube pages.

One of NASA's four Great Observatories, Spitzer launched on Aug. 25, 2003, and has studied the cosmos in infrared light. Its breathtaking images have revealed the beauty of the infrared universe.

Spitzer made some of the first studies of exoplanet atmospheres (atmospheres of planets around stars other than our Sun). It confirmed two and discovered five ofthe seven Earth-size exoplanets around the star TRAPPIST-1 - the largest batch of terrestrial planets ever found around a single star. On Thursday, Jan. 30, engineers will decommission the Spitzer spacecraft and bring this amazing mission to a close.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena, California. Space operations are based at Lockheed Martin Space in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

For more information about Spitzer, visit:

https://www.nasa.gov/spitzer

http:www.spitzer.caltech.edu/

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Mission Uncovers Its 1st World With Two Stars

6 min read

In 2019, when Wolf Cukier finished his junior year at Scarsdale High School in New York, he joined NASA’s Goddard Space Flight Center in Greenbelt, Maryland, as a summer intern. His job was to examine variations in star brightness captured by NASA’s Transiting Exoplanet Survey Satellite (TESS) and uploaded to the Planet Hunters TESS citizen science project.

“I was looking through the data for everything the volunteers had flagged as an eclipsing binary, a system where two stars circle around each other and from our view eclipse each other every orbit,” Cukier said. “About three days into my internship, I saw a signal from a system called TOI 1338. At first I thought it was a stellar eclipse, but the timing was wrong. It turned out to be a planet.”

TOI 1338 b, as it is now called, is TESS’s first circumbinary planet, a world orbiting two stars. The discovery was featured in a panel discussion on Monday, Jan. 6, at the 235th American Astronomical Society meeting in Honolulu. A paper, which Cukier co-authored along with scientists from Goddard, San Diego State University, the University of Chicago and other institutions, has been submitted to a scientific journal.

The TOI 1338 system lies 1,300 light-years away in the constellation Pictor. The two stars orbit each other every 15 days. One is about 10% more massive than our Sun, while the other is cooler, dimmer and only one-third the Sun’s mass.

TOI 1338 b is the only known planet in the system. It’s around 6.9 times larger than Earth, or between the sizes of Neptune and Saturn. The planet orbits in almost exactly the same plane as the stars, so it experiences regular stellar eclipses.

TESS has four cameras, which each take a full-frame image of a patch of the sky every 30 minutes for 27 days. Scientists use the observations to generate graphs of how the brightness of stars change over time. When a planet crosses in front of its star from our perspective, an event called a transit, its passage causes a distinct dip in the star’s brightness.

But planets orbiting two stars are more difficult to detect than those orbiting one. TOI 1338 b’s transits are irregular, between every 93 and 95 days, and vary in depth and duration thanks to the orbital motion of its stars. TESS only sees the transits crossing the larger star; the transits of the smaller star are too faint to detect.

“These are the types of signals that algorithms really struggle with,” said lead author Veselin Kostov, a research scientist at the SETI Institute and Goddard. “The human eye is extremely good at finding patterns in data, especially non-periodic patterns like those we see in transits from these systems.”

This explains why Cukier had to visually examine each potential transit. For example, he initially thought TOI 1338 b’s transit was a result of the smaller star in the system passing in front of the larger one — both cause similar dips in brightness. But the timing was wrong for an eclipse.

After identifying TOI 1338 b, the research team used a software package called eleanor, named after Eleanor Arroway, the central character in Carl Sagan’s novel “Contact,” to confirm the transits were real and not a result of instrumental artifacts.

“Throughout all of its images, TESS is monitoring millions of stars,” said co-author Adina Feinstein, a graduate student at the University of Chicago. “That’s why our team created eleanor. It’s an accessible way to download, analyze and visualize transit data. We designed it with planets in mind, but other members of the community use it to study stars, asteroids and even galaxies.”

TOI 1338 had already been studied from the ground by radial velocity surveys, which measure motion along our line of sight. Kostov’s team used this archival data to analyze the system and confirm the planet. Its orbit is stable for at least the next 10 million years. The orbit’s angle to us, however, changes enough that the planet transit will cease after November 2023 and resume eight years later.

NASA’s Kepler and K2 missions previously discovered 12 circumbinary planets in 10 systems, all similar to TOI 1338 b. Observations of binary systems are biased toward finding larger planets, Kostov said. Transits of smaller bodies don’t have as big an effect on the stars’ brightness. TESS is expected to observe hundreds of thousands of eclipsing binaries during its initial two-year mission, so many more of these circumbinary planets should be waiting for discovery.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

Media contact:

Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.(301) 286-1940

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Planet Hunter Finds its 1st Earth-size Habitable-zone World

7 min read

NASA’s Transiting Exoplanet Survey Satellite (TESS) has discovered its first Earth-size planet in its star’s habitable zone, the range of distances where conditions may be just right to allow the presence of liquid water on the surface. Scientists confirmed the find, called TOI 700 d, using NASA’s Spitzer Space Telescope and have modeled the planet’s potential environments to help inform future observations.

TOI 700 d is one of only a few Earth-size planets discovered in a star’s habitable zone so far. Others include several planets in the TRAPPIST-1 system and other worlds discovered by NASA’s Kepler Space Telescope.

“TESS was designed and launched specifically to find Earth-sized planets orbiting nearby stars,” said Paul Hertz, astrophysics division director at NASA Headquarters in Washington. “Planets around nearby stars are easiest to follow-up with larger telescopes in space and on Earth. Discovering TOI 700 d is a key science finding for TESS. Confirming the planet’s size and habitable zone status with Spitzer is another win for Spitzer as it approaches the end of science operations this January.”

TESS monitors large swaths of the sky, called sectors, for 27 days at a time. This long stare allows the satellite to track changes in stellar brightness caused by an orbiting planet crossing in front of its star from our perspective, an event called a transit.

TOI 700 is a small, cool M dwarf star located just over 100 light-years away in the southern constellation Dorado. It’s roughly 40% of the Sun’s mass and size and about half its surface temperature. The star appears in 11 of the 13 sectors TESS observed during the mission’s first year, and scientists caught multiple transits by its three planets.

The star was originally misclassified in the TESS database as being more similar to our Sun, which meant the planets appeared larger and hotter than they really are. Several researchers, including Alton Spencer, a high school student working with members of the TESS team, identified the error.

“When we corrected the star’s parameters, the sizes of its planets dropped, and we realized the outermost one was about the size of Earth and in the habitable zone,” said Emily Gilbert, a graduate student at the University of Chicago. “Additionally, in 11 months of data we saw no flares from the star, which improves the chances TOI 700 d is habitable and makes it easier to model its atmospheric and surface conditions.”

Gilbert and other researchers presented the findings at the 235th meeting of the American Astronomical Society in Honolulu, and three papers — one of which Gilbert led — have been submitted to scientific journals.

The innermost planet, called TOI 700 b, is almost exactly Earth-size, is probably rocky and completes an orbit every 10 days. The middle planet, TOI 700 c, is 2.6 times larger than Earth — between the sizes of Earth and Neptune — orbits every 16 days and is likely a gas-dominated world. TOI 700 d, the outermost known planet in the system and the only one in the habitable zone, measures 20% larger than Earth, orbits every 37 days and receives from its star 86% of the energy that the Sun provides to Earth. All of the planets are thought to be tidally locked to their star, which means they rotate once per orbit so that one side is constantly bathed in daylight.

A team of scientists led by Joseph Rodriguez, an astronomer at the Center for Astrophysics | Harvard & Smithsonian in Cambridge, Massachusetts, requested follow-up observations with Spitzer to confirm TOI 700 d.

“Given the impact of this discovery — that it is TESS’s first habitable-zone Earth-size planet — we really wanted our understanding of this system to be as concrete as possible,” Rodriguez said. “Spitzer saw TOI 700 d transit exactly when we expected it to. It’s a great addition to the legacy of a mission that helped confirm two of the TRAPPIST-1 planets and identify five more.”

The Spitzer data increased scientists’ confidence that TOI 700 d is a real planet and sharpened their measurements of its orbital period by 56% and its size by 38%. It also ruled out other possible astrophysical causes of the transit signal, such as the presence of a smaller, dimmer companion star in the system.

Rodriguez and his colleagues also used follow-up observations from a 1-meter ground-based telescope in the global Las Cumbres Observatory network to improve scientists’ confidence in the orbital period and size of TOI 700 c by 30% and 36%, respectively.

Because TOI 700 is bright, nearby, and shows no sign of stellar flares, the system is a prime candidate for precise mass measurements by current ground-based observatories. These measurements could confirm scientists’ estimates that the inner and outer planets are rocky and the middle planet is made of gas.

Future missions may be able to identify whether the planets have atmospheres and, if so, even determine their compositions.

While the exact conditions on TOI 700 d are unknown, scientists can use current information, like the planet’s size and the type of star it orbits, to generate computer models and make predictions. Researchers at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, modeled 20 potential environments of TOI 700 d to gauge if any version would result in surface temperatures and pressures suitable for habitability.

Their 3D climate models examined a variety of surface types and atmospheric compositions typically associated with what scientists regard to be potentially habitable worlds. Because TOI 700 d is tidally locked to its star, the planet’s cloud formations and wind patterns may be strikingly different from Earth’s.

One simulation included an ocean-covered TOI 700 d with a dense, carbon-dioxide-dominated atmosphere similar to what scientists suspect surrounded Mars when it was young. The model atmosphere contains a deep layer of clouds on the star-facing side. Another model depicts TOI 700 d as a cloudless, all-land version of modern Earth, where winds flow away from the night side of the planet and converge on the point directly facing the star.

When starlight passes through a planet’s atmosphere, it interacts with molecules like carbon dioxide and nitrogen to produce distinct signals, called spectral lines. The modeling team, led by Gabrielle Engelmann-Suissa, a Universities Space Research Association visiting research assistant at Goddard, produced simulated spectra for the 20 modeled versions of TOI 700 d.

“Someday, when we have real spectra from TOI 700 d, we can backtrack, match them to the closest simulated spectrum, and then match that to a model,” Engelmann-Suissa said. “It’s exciting because no matter what we find out about the planet, it’s going to look completely different from what we have here on Earth.”

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts;

MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

The Jet Propulsion Laboratory in Pasadena, California, manages the Spitzer Space Telescope mission for NASA’s Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Space operations are based at Lockheed Martin Space in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

The modeling work was funded through the Sellers Exoplanet Environments Collaboration at Goddard, a multidisciplinary collaboration that brings together experts to build comprehensive and sophisticated computer models to better analyze current and future exoplanet observations.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

Simulated Image Demonstrates the Power of NASA’s Wide Field Infrared Survey Telescope

8 min read

NASA Science Editorial Team

Imagine a fleet of 100 Hubble Space Telescopes, deployed in a strategic space-invader-shaped array a million miles from Earth, scanning the universe at warp speed.

With NASA's Wide Field Infrared Survey Telescope, scheduled for launch in the mid-2020s, this vision will (effectively) become reality.

WFIRST will capture the equivalent of 100 high-resolution Hubble images in a single shot, imaging large areas of the sky 1,000 times faster than Hubble. In several months, WFIRST could survey as much of the sky in near-infrared light — in just as much detail — as Hubble has over its entire three decades.

Elisa Quintana, WFIRST Deputy Project Scientist for Communications at NASA's Goddard Space Flight Center in Greenbelt, Maryland, is confident that WFIRST will have the power to transform astrophysics. "To answer fundamental questions like: How common are planets like those in our solar system? How do galaxies form, evolve, and interact? Exactly how — and why — has the universe's expansion rate changed over time? We need a tool that can give us both a broad and detailed view of the sky. WFIRST will be that tool."

Although WFIRST has not yet opened its wide, keen eyes on the universe, astronomers are already running simulations to demonstrate what it will be able to see and plan their observations.

This simulated image of a portion of our neighboring galaxy, Andromeda (M31), provides a preview of the vast expanse and fine detail that can be covered with just a single pointing of WFIRST. Using information gleaned from hundreds of Hubble observations, the simulated image covers a swath roughly 34,000 light-years across, showcasing the red and infrared light of more than 50 million individual stars detectable with WFIRST.

While it may appear to be a somewhat haphazard arrangement of 18 separate images, the simulation actually represents a single shot. Eighteen square detectors, 4096 by 4096 pixels each, make up WFIRST’s Wide Field Instrument (WFI) and give the telescope its unique window into space.

With each pointing, WFIRST will cover an area roughly 1■ times that of the full Moon. By comparison, each individual infrared Hubble image covers an area less than 1% of the full Moon.

WFIRST is designed to collect the big data needed to tackle essential questions across a wide range of topics, including dark energy, exoplanets, and general astrophysics spanning from our solar system to the most distant galaxies in the observable universe. Over its 5-year planned lifetime, WFIRST is expected to amass more than 20 petabytes of information on thousands of planets, billions of stars, millions of galaxies, and the fundamental forces that govern the cosmos.

For astronomers like Ben Williams of the University of Washington in Seattle, who generated the simulated data set for this image, WFIRST will provide a valuable opportunity to understand large nearby objects like Andromeda, which are otherwise extremely time-consuming to image because they take up such a large portion of the sky.

"We have spent the last couple of decades getting images at high resolution in small parts of nearby galaxies. With Hubble you get these really tantalizing glimpses of very complex nearby systems. With WFIRST, all of a sudden you can cover the whole thing without spending lots of time," Williams said.

The ability to image such a large area will provide astronomers with important context needed to understand how stars form and how galaxies change over time. Williams explained that with a wide field, "you get the individual stars, you get the structures they live in, and the structures that surround them in their environment."

Julianne Dalcanton of the University of Washington, who led the Panchromatic Hubble Andromeda Treasury (PHAT) program that the simulated data are based on, also believes that WFIRST's combination of ultra-telephoto and super-wide-angle capabilities will be ground-breaking. "The PHAT survey of Andromeda was a tremendous investment of time, requiring careful justification and forethought. This new simulation shows how easy an equivalent observation could be for WFIRST." WFIRST could survey Andromeda nearly 1,500 times faster than Hubble, building a panorama of the main disk of the galaxy in just a few hours.

WFIRST's extraordinary survey speed is a result of its wide field of view, its agility, and its orbit. Williams explained that by covering more area in one field and being able to switch fields more quickly, "you're avoiding all those overheads that are associated with repointing the telescope so many times." In addition, WFIRST's orbit one million miles out will provide a view that is generally unobstructed by Earth. While Hubble is often able to collect data during only half of its low-Earth orbit 350 miles up, WFIRST will be able to observe more-or-less continuously.

Because it can collect so much detailed data so quickly, WFIRST is ideally suited for large surveys. A significant portion of the mission will be dedicated to monitoring hundreds of thousands of distant galaxies for supernova explosions, which can be used to study dark energy and the expansion of the universe. Another major program will involve mapping the shapes and distribution of galaxies in order to better understand how the universe — including galaxies, dark matter, and dark energy — has evolved over the past 13+ billion years.WFIRST will also play an important role in the census of exoplanets. By monitoring the brightness of billions of stars in the Milky Way, astronomers expect to catch thousands of microlensing events — slight increases in brightness that occur when a planet passes between the telescope and a distant star. WFIRST's ability to detect planets that are relatively small or far from their own stars — as well as rogue planets, which don't orbit any star at all — will help fill major gaps in our knowledge of planets beyond our solar system. Although microlensing will not give us the ability to see exoplanets directly, WFIRST will also carry a coronagraph, a technology demonstration instrument designed to block enough of the blinding starlight to make direct imaging and characterization of orbiting planets possible.

These large surveys are also expected to reveal the unexpected: strange, transient phenomena that have never before been observed. "If you cover a lot of the sky, you're going to find those rare things," explained Williams.

Further broadening its potential impact, all of the data collected by WFIRST will be non-proprietary and immediately available to the public. Dalcanton underscored the importance of this aspect of the mission: "Thousands of minds from across the globe are going to be able to think about that data and come up with new ways to use it. It's hard to anticipate what the WFIRST data will unlock, but I do know that the more people we have looking at it, the greater the pace of discovery."

WFIRST's combination of talents will be a valuable complement to those of other observatories, including Hubble and the James Webb Space Telescope. "With one hundred times the field of view of Hubble, and the ability to rapidly survey the sky, WFIRST will be an extremely powerful discovery tool," explained Karoline Gilbert, WFIRST Mission Scientist at the Space Telescope Science Institute in Baltimore, Maryland. "Webb, which is 100 times more sensitive and can see deeper into the infrared, will be able to observe the rare astronomical objects discovered by WFIRST in exquisite detail. Meanwhile, Hubble will continue to provide a unique view into the optical and ultraviolet light emitted by the objects that WFIRST discovers, and Webb follows up on."

The simulated image is being presented at the 235th meeting of the American Astronomical Society in Honolulu, Hawaii.

WFIRST is managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by the Jet Propulsion Laboratory (JPL) in Pasadena, California; the Space Telescope Science Institute (STScI) in Baltimore, Maryland; the Infrared Processing and Analysis Center (IPAC), also in Pasadena; and a science team comprising members from U.S. research institutions across the country, as well as international and industrial partners. WFIRST's Science Operations Center (SOC) will reside at the STScI, which also runs science operations for Hubble and will be SOC and Mission Operations Center for the James Webb Space Telescope. All of the data collected by the WFIRST mission will be held in the Barbara A. Mikulski Archive for Space Telescopes (MAST) at STScI.

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Margaret W. Carruthers / Christine PulliamSpace Telescope Science Institute, Baltimore, Md.667-218-6427 / 410-338-4366mcarruthers@stsci.edu / cpulliam@stsci.edu

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

‘Cotton Candy’ Planet Mysteries Unravel in New Hubble Observations

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

"Super-Puffs" may sound like a new breakfast cereal. But it's actually the nickname for a unique and rare class of young exoplanets that have the density of cotton candy. Nothing like them exists in our solar system.

New data from NASA's Hubble Space Telescope have provided the first clues to the chemistry of two of these super-puffy planets, which are located in the Kepler 51 system. This exoplanet system, which actually boasts three super-puffs orbiting a young Sun-like star, was discovered by NASA's Kepler space telescope in 2012. However, it wasn't until 2014 when the low densities of these planets were determined, to the surprise of many.

The recent Hubble observations allowed a team of astronomers to refine the mass and size estimates for these worlds — independently confirming their "puffy" nature. Though no more than several times the mass of Earth, their hydrogen/helium atmospheres are so bloated they are nearly the size of Jupiter. In other words, these planets might look as big and bulky as Jupiter, but are roughly a hundred times lighter in terms of mass.

How and why their atmospheres balloon outwards remains unknown, but this feature makes super-puffs prime targets for atmospheric investigation. Using Hubble, the team went looking for evidence of components, notably water, in the atmospheres of the planets, called Kepler-51 b and 51 d. Hubble observed the planets when they passed in front of their star, aiming to observe the infrared color of their sunsets. Astronomers deduced the amount of light absorbed by the atmosphere in infrared light. This type of observation allows scientists to look for the telltale signs of the planets' chemical constituents, such as water.

To the amazement of the Hubble team, they found the spectra of both planets not to have any telltale chemical signatures. They attribute this result to clouds of particles high in their atmospheres. "This was completely unexpected," said Jessica Libby-Roberts of the University of Colorado, Boulder. "We had planned on observing large water absorption features, but they just weren't there. We were clouded out!" However, unlike Earth's water-clouds, the clouds on these planets may be composed of salt crystals or photochemical hazes, like those found on Saturn's largest moon, Titan.

These clouds provide the team with insight into how Kepler-51 b and 51 d stack up against other low-mass, gas-rich planets outside of our solar system. When comparing the flat spectra of the super-puffs against the spectra of other planets, the team was able to support the hypothesis that cloud/haze formation is linked to the temperature of a planet — the cooler a planet is, the cloudier it becomes.

The team also explored the possibility that these planets weren't actually super-puffs at all. The gravitational pull among the planets creates slight changes to their orbital periods, and from these timing effects planetary masses can be derived. By combining the variations in the timing of when a planet passes in front of its star (an event called a transit) with those transits observed by the Kepler space telescope, the team better constrained the planetary masses and dynamics of the system. Their results agreed with previous measured ones for Kepler-51 b. However, they found that Kepler-51 d was slightly less massive (or the planet was even more puffy) than previously thought.

In the end, the team concluded that the low densities of these planets are in part a consequence of the young age of the system, a mere 500 million years old, compared to our 4.6-billion-year-old Sun. Models suggest these planets formed outside of the star's "snow line," the region of possible orbits where icy materials can survive. The planets then migrated inward, like a string of railroad cars.

Now, with the planets much closer to the star, their low-density atmospheres should evaporate into space over the next few billion years. Using planetary evolution models, the team was able to show that Kepler-51 b, the planet closest to the star, will one day (in a billion years) look like a smaller and hotter version of Neptune, a type of planet that is fairly common throughout the Milky Way. However, it appears that Kepler-51 d, which is farther from the star, will continue to be a low-density oddball planet, though it will both shrink and lose some small amount of atmosphere. "This system offers a unique laboratory for testing theories of early planet evolution," said Zach Berta-Thompson of the University of Colorado, Boulder.

The good news is that all is not lost for determining the atmospheric composition of these two planets. NASA's upcoming James Webb Space Telescope, with its sensitivity to longer infrared wavelengths of light, may be able to peer through the cloud layers. Future observations with this telescope could provide insight as to what these cotton candy planets are actually made of. Until then, these planets remain a sweet mystery.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore410-338-4514villard@stsci.edu

Daniel StrainUniversity of Colorado, Boulderdaniel.strain@colorado.edu

Jessica Libby-Roberts / Zach Berta-ThompsonUniversity of Colorado, Boulderjessica.e.roberts@colorado.edu / zachory.bertathompson@colorado.edu

NASA’s Webb Telescope to Search for Young Brown Dwarfs and Rogue Planets

4 min read

How small are the smallest celestial objects that form like stars, but don’t produce their own light? How common are they compared to full-fledged stars? How about “rogue planets,” which formed around stars before being tossed into interstellar space? When NASA’s James Webb Space Telescope launches in 2021, it will shed light on these questions.

Answering them will set a boundary between objects that form like stars, which are born out of gravitationally collapsing clouds of gas and dust, and those that form like planets, which are created when gas and dust clump together in a disk around a young star. It will also distinguish among competing ideas about the origins of brown dwarfs, objects with masses between 1% and 8% of the Sun that cannot sustain hydrogen fusion at their cores.

In a study led by Aleks Scholz of the University of St Andrews in the United Kingdom, researchers will use Webb to discover the smallest, faintest residents of a nearby stellar nursery called NGC 1333. Located about 1,000 light-years away in the constellation Perseus, the stellar cluster NGC 1333 is fairly close in astronomical terms. It is also very compact and contains many young stars. These three factors make it an ideal place to study star formation in action, particularly for those interested in very faint, free-floating objects.

“The least massive brown dwarfs identified so far are only five to 10 times heftier than the planet Jupiter,” explained Scholz. “We don’t yet know whether even lower mass objects form in stellar nurseries. With Webb, we expect to identify cluster members as puny as Jupiter for the first time ever. Their numbers relative to heftier brown dwarfs and stars will shed light on their origins and also give us important clues about the star formation process more broadly.”

A Fuzzy Boundary

Very low-mass objects are cool, meaning they emit most of their light in infrared wavelengths. Observing infrared light from ground-based telescopes is challenging because of interference from Earth’s atmosphere. Due to its sheer size and ability to see infrared light with unprecedented sensitivity, Webb is ideally suited for finding and characterizing young free-floating objects with masses below five Jupiters.

The distinction between brown dwarfs and giant planets is blurry.

“There are some objects with masses below the 10-Jupiter mark freely floating through the cluster. As they don’t orbit any particular star, we may call them brown dwarfs, or planetary-mass objects, since we don’t know better,” said team member Koraljka Muzic of the University of Lisbon in Portugal. “On the other hand, some massive giant planets may have fusion reactions. And some brown dwarfs may form in a disk.”

There is also the issue of “rogue planets”—objects that form like planets and then later get ejected from their solar systems. These free-floating bodies are doomed to wander between the stars forever.

Dozens at Once

The team will use Webb’s Near Infrared Imager and Slitless Spectrograph (NIRISS) to study these various low-mass objects. A spectrograph breaks the light from a single source into its component colors the way a prism splits white light into a rainbow. That light carries fingerprints produced when material emits or interacts with light. Spectrographs allow researchers to analyze those fingerprints and discover properties like temperature and composition.

NIRISS will give the team simultaneous information for dozens of objects. “That is key. For an unambiguous confirmation of a brown dwarf or rogue planet we need to see the absorption signatures of molecules — water and methane primarily — in the spectra,” explained team member Ray Jayawardhana of Cornell University. “Spectroscopy is time consuming, and being able to observe many objects simultaneously helps enormously. The alternative is to take images first, measure colors, select candidates, and then go and take spectra, which will take much more time and relies on more assumptions.”

This work is being conducted as part of a Webb Guaranteed Time Observations (GTO) program. This program is designed to reward scientists who helped develop the key hardware and software components or technical and interdisciplinary knowledge for the observatory. Jayawardhana has been involved in the design and development of NIRISS, as well as its key science programs, as a core member of the instrument team since 2004.

The James Webb Space Telescope will be the world’s premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

For more information about Webb, visit www.nasa.gov/webb.

By Ann JenkinsSpace Telescope Science InstituteBaltimore, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Simulated Image Demonstrates the Power of NASA’s Wide Field Infrared Survey Telescope

8 min read

Editor’s note, Mar. 30, 2022: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

Imagine a fleet of 100 Hubble Space Telescopes, deployed in a strategic space-invader-shaped array a million miles from Earth, scanning the universe at warp speed.

With NASA’s Wide Field Infrared Survey Telescope, scheduled for launch in the mid-2020s, this vision will (effectively) become reality.

WFIRST will capture the equivalent of 100 high-resolution Hubble images in a single shot, imaging large areas of the sky 1,000 times faster than Hubble. In several months, WFIRST could survey as much of the sky in near-infrared light — in just as much detail — as Hubble has over its entire three decades.

Elisa Quintana, WFIRST Deputy Project Scientist for Communications at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, is confident that WFIRST will have the power to transform astrophysics. “To answer fundamental questions like: How common are planets like those in our solar system? How do galaxies form, evolve, and interact? Exactly how — and why — has the universe’s expansion rate changed over time? We need a tool that can give us both a broad and detailed view of the sky. WFIRST will be that tool.”

Although WFIRST has not yet opened its wide, keen eyes on the universe, astronomers are already running simulations to demonstrate what it will be able to see and plan their observations.

This simulated image of a portion of our neighboring galaxy, Andromeda (M31), provides a preview of the vast expanse and fine detail that can be covered with just a single pointing of WFIRST. Using information gleaned from hundreds of Hubble observations, the simulated image covers a swath roughly 34,000 light-years across, showcasing the red and infrared light of more than 50 million individual stars detectable with WFIRST.

While it may appear to be a somewhat haphazard arrangement of 18 separate images, the simulation actually represents a single shot. Eighteen square detectors, 4096 by 4096 pixels each, make up WFIRST’s Wide Field Instrument (WFI) and give the telescope its unique window into space.

With each pointing, WFIRST will cover an area roughly 1■ times that of the full Moon. By comparison, each individual infrared Hubble image covers an area less than 1% of the full Moon.

The Advantages of Speed

WFIRST is designed to collect the big data needed to tackle essential questions across a wide range of topics, including dark energy, exoplanets, and general astrophysics spanning from our solar system to the most distant galaxies in the observable universe. Over its 5-year planned lifetime, WFIRST is expected to amass more than 20 petabytes of information on thousands of planets, billions of stars, millions of galaxies, and the fundamental forces that govern the cosmos.

For astronomers like Ben Williams of the University of Washington in Seattle, who generated the simulated data set for this image, WFIRST will provide a valuable opportunity to understand large nearby objects like Andromeda, which are otherwise extremely time-consuming to image because they take up such a large portion of the sky.

“We have spent the last couple of decades getting images at high resolution in small parts of nearby galaxies. With Hubble you get these really tantalizing glimpses of very complex nearby systems. With WFIRST, all of a sudden you can cover the whole thing without spending lots of time,” Williams said.

The ability to image such a large area will provide astronomers with important context needed to understand how stars form and how galaxies change over time. Williams explained that with a wide field, “you get the individual stars, you get the structures they live in, and the structures that surround them in their environment.”

Julianne Dalcanton of the University of Washington, who led the Panchromatic Hubble Andromeda Treasury (PHAT) program that the simulated data are based on, also believes that WFIRST’s combination of ultra-telephoto and super-wide-angle capabilities will be ground-breaking. “The PHAT survey of Andromeda was a tremendous investment of time, requiring careful justification and forethought. This new simulation shows how easy an equivalent observation could be for WFIRST.” WFIRST could survey Andromeda nearly 1,500 times faster than Hubble, building a panorama of the main disk of the galaxy in just a few hours.

WFIRST’s extraordinary survey speed is a result of its wide field of view, its agility, and its orbit. Williams explained that by covering more area in one field and being able to switch fields more quickly, “you’re avoiding all those overheads that are associated with repointing the telescope so many times.” In addition, WFIRST’s orbit one million miles out will provide a view that is generally unobstructed by Earth. While Hubble is often able to collect data during only half of its low-Earth orbit 350 miles up, WFIRST will be able to observe more-or-less continuously.

Major Survey Programs

Because it can collect so much detailed data so quickly, WFIRST is ideally suited for large surveys. A significant portion of the mission will be dedicated to monitoring hundreds of thousands of distant galaxies for supernova explosions, which can be used to study dark energy and the expansion of the universe. Another major program will involve mapping the shapes and distribution of galaxies in order to better understand how the universe — including galaxies, dark matter, and dark energy — has evolved over the past 13+ billion years.

WFIRST will also play an important role in the census of exoplanets. By monitoring the brightness of billions of stars in the Milky Way, astronomers expect to catch thousands of microlensing events — slight increases in brightness that occur when a planet passes between the telescope and a distant star. WFIRST’s ability to detect planets that are relatively small or far from their own stars — as well as rogue planets, which don’t orbit any star at all — will help fill major gaps in our knowledge of planets beyond our solar system. Although microlensing will not give us the ability to see exoplanets directly, WFIRST will also carry a coronagraph, a technology demonstration instrument designed to block enough of the blinding starlight to make direct imaging and characterization of orbiting planets possible.

These large surveys are also expected to reveal the unexpected: strange, transient phenomena that have never before been observed. “If you cover a lot of the sky, you’re going to find those rare things,” explained Williams.

Open-Access Data

Further broadening its potential impact, all of the data collected by WFIRST will be non-proprietary and immediately available to the public. Dalcanton underscored the importance of this aspect of the mission: “Thousands of minds from across the globe are going to be able to think about that data and come up with new ways to use it. It’s hard to anticipate what the WFIRST data will unlock, but I do know that the more people we have looking at it, the greater the pace of discovery.”

Complementing other Observatories

WFIRST's combination of talents will be a valuable complement to those of other observatories, including Hubble and the James Webb Space Telescope. "With one hundred times the field of view of Hubble, and the ability to rapidly survey the sky, WFIRST will be an extremely powerful discovery tool," explained Karoline Gilbert, WFIRST Mission Scientist at the Space Telescope Science Institute in Baltimore, Maryland. "Webb, which is 100 times more sensitive and can see deeper into the infrared, will be able to observe the rare astronomical objects discovered by WFIRST in exquisite detail. Meanwhile, Hubble will continue to provide a unique view into the optical and ultraviolet light emitted by the objects that WFIRST discovers, and Webb follows up on."

The simulated image is being presented at the 235th meeting of the American Astronomical Society in Honolulu, Hawaii.

WFIRST is managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland, with participation by the Jet Propulsion Laboratory (JPL) in Pasadena, California; the Space Telescope Science Institute (STScI) in Baltimore, Maryland; the Infrared Processing and Analysis Center (IPAC), also in Pasadena; and a science team comprising members from U.S. research institutions across the country, as well as international and industrial partners. WFIRST's Science Operations Center (SOC) will reside at the STScI, which also runs science operations for Hubble and will be SOC and Mission Operations Center for the James Webb Space Telescope. All of the data collected by the WFIRST mission will be held in the Barbara A. Mikulski Archive for Space Telescopes (MAST) at STScI.

By Margaret Carruthers

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Margaret W. Carruthers / Christine PulliamSpace Telescope Science Institute, Baltimore, Md.667-218-6427 / 410-338-4366mcarruthers@stsci.edu / cpulliam@stsci.edu

Discovery Alert: Hellish Planet, Meet Your New Rival

2 min read

Alicia Cermak

Planet: HD 213885b

The discovery: This planet orbits a "G"-type star, quite similar to our Sun, about 156 light-years away. It is nearly nine times as heavy as Earth, and 1.7 times as big around, placing it in the size-class known as "super Earth."

Date: Placed in NASA's Exoplanet Archive on Dec. 5, 2019

Key facts: This planet hugs its star so tightly that a "year" – one trip around the star – takes little more than a day. That means the star looms extremely large in its sky; the surface temperature on HD 213885b is about 3,400 degrees Fahrenheit (1,854 Celsius).

Details: The planet is one of two known to orbit the same star. The other, HD 213885c, is around the same "weight," or mass, as our own planet Neptune, with a roughly five-day orbit.

Fun facts: The discoverers of planet HD 213885b noticed an odd similarity to 55 Cancri e, a far better known, extremely hot super Earth that orbits another G-type star about 42 light-years from Earth. The two planets have similar masses and diameters, and receive about the same amount of radiation from their respective stars. They even have comparable temperature estimates, although 55 Cancri e is thought to be slightly cooler at around 3,064 degrees Fahrenheit (1,684 Celsius).

The discoverers: The two new planets were announced in November 2019 by an international scientific team led by Nestor Espinoza of NASA's Space Telescope Science Institute in Baltimore, Maryland. The planets were detected using the recently launched TESS (Transiting Exoplanet Survey Satellite).

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers Propose a Novel Method of Finding Atmospheres on Rocky Worlds

6 min read

When NASA's James Webb Space Telescope launches in 2021, one of its most anticipated contributions to astronomy will be the study of exoplanets—planets orbiting distant stars. Among the most pressing questions in exoplanet science is: Can a small, rocky exoplanet orbiting close to a red dwarf star hold onto an atmosphere?

In a series of four papers in the Astrophysical Journal, a team of astronomers proposes a new method of using Webb to determine whether a rocky exoplanet has an atmosphere. The technique, which involves measuring the planet's temperature as it passes behind its star and then comes back into view, is significantly faster than more traditional methods of atmospheric detection like transmission spectroscopy.

"We find that Webb could easily infer the presence or absence of an atmosphere around a dozen known rocky exoplanets with less than 10 hours of observing time per planet," said Jacob Bean of the University of Chicago, a co-author on three of the papers.

Astronomers are particularly interested in exoplanets orbiting red dwarf stars for a number of reasons. These stars, which are smaller and cooler than the Sun, are the most common type of star in our galaxy. Also, because a red dwarf is small, a planet passing in front of it will appear to block a larger fraction of the star's light than if the star were larger, like our Sun. This makes the planet orbiting a red dwarf easier to detect through this "transit" technique.

Red dwarfs also produce a lot less heat than our Sun, so to enjoy habitable temperatures, a planet would need to orbit quite close to a red dwarf star. In fact, to be in the habitable zone — the area around the star where liquid water could exist on a planet's surface — the planet has to orbit much closer to the star than Mercury is to the Sun. As a result, it will transit the star more frequently, making repeated observations easier.

But a planet orbiting so close to a red dwarf is subjected to harsh conditions. Young red dwarfs are very active, blasting out huge flares and plasma eruptions. The star also emits a strong wind of charged particles. All of these effects could potentially scour away a planet's atmosphere, leaving behind a bare rock.

"Atmospheric loss is the number one existential threat to the habitability of planets," said Bean.

Another key characteristic of exoplanets orbiting close to red dwarfs is central to the new technique: They are expected to be tidally locked, meaning they have a permanent dayside and nightside. As a result, we see different phases of the planet at different points in its orbit. When it crosses the face of the star, we see only the planet's nightside. But when it is about to cross behind the star (an event known as a secondary eclipse), or is just emerging from behind the star, we can observe the dayside.

If a rocky exoplanet lacks an atmosphere, its dayside would be very hot, just as we see with the Moon or Mercury. However if a rocky exoplanet has an atmosphere, the presence of that atmosphere is expected to lower the dayside temperature that Webb would measure. It could do this in two ways. A thick atmosphere could transport heat from the dayside to the nightside through winds. A thinner atmosphere could still host clouds, which reflect a portion of the incoming starlight thereby lowering the temperature of the planet's dayside.

“Whenever you add an atmosphere, you’re going to lower the temperature of the dayside. So if we see something cooler than bare rock, we would infer it’s likely a sign of an atmosphere,” explained Daniel Koll of the Massachusetts Institute of Technology (MIT), the lead author on two of the papers.

Webb is ideally suited for making these measurements because it has a much larger mirror than other telescopes such as NASA’s Hubble or Spitzer space telescopes, which allows it to collect more light, and it can target the appropriate infrared wavelengths.

The team’s calculations show that Webb should be able to detect the heat signature of a planet’s atmosphere in one to two secondary eclipses – just a few hours of observing time. In contrast, detecting an atmosphere through spectroscopic observations would typically require eight or more transits for these same planets.

Transmission spectroscopy, which studies starlight filtered through the planet’s atmosphere, also suffers from interference due to clouds or hazes, which can mask the molecular signatures of the atmosphere. In that case the spectral plot, rather than showing pronounced absorption lines due to molecules, would be essentially flat.

“In transmission spectroscopy, if you get a flat line, it doesn’t tell you anything. The flat line could mean the universe is full of dead planets that don’t have an atmosphere, or that the universe is full of planets that have a whole range of diverse, interesting atmospheres, but they all look the same to us because they’re cloudy,” said Eliza Kempton of the University of Maryland, a co-author on three of the papers.

“Exoplanet atmospheres without clouds and hazes are like unicorns – we just haven’t seen them yet, and they may not exist at all,” she added.

The team emphasized that a cooler than expected dayside temperature would be an important clue, but it would not absolutely confirm an atmosphere exists. Any remaining doubts about the presence of an atmosphere can be ruled out with follow-up studies using other methods like transmission spectroscopy.

The new technique’s true strength will be in determining what fraction of rocky exoplanets likely have an atmosphere. Approximately a dozen exoplanets that are good candidates for this method were detected during the past year. More are likely to be found by the time Webb is operational.

“The Transiting Exoplanet Survey Satellite, or TESS, is finding piles of these planets,” stated Kempton.

The secondary eclipse method has one key limitation: it works best on planets that are too hot to be located in the habitable zone. However, determining whether or not these hot planets host atmospheres holds important implications for habitable-zone planets.

“If hot planets can hold onto an atmosphere, cooler ones should be able to at least as well,” said Koll.

The James Webb Space Telescope will be the world’s premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international project led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

By Christine Pulliam / Laura BetzSpace Telescope Science Institute, Baltimore, Md./NASA Goddardcpulliam@stsci.edu / Laura.e.betz@nasa.gov

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Public Helps Name More Than 100 Exoplanets

4 min read

NASA Science Editorial Team

More than 100 exoplanets and host stars got new names from the International Astronomical Union in December 2019, including a gas giant now named for a river in Alaska that has long supported indigenous and native populations.

Members of the public, more than 780,000 people in all, proposed and selected the names as part of the IAU’s NameExoWorlds project, only the second time that the public helped pick proper names for exoplanets, a process governed by the IAU. To celebrate the IAU’s 100th anniversary, every country was given the chance to name one planetary system, comprising an exoplanet and its host star. Each nation's designated star for naming is visible from that country, and is sufficiently bright to be observed through a small telescope.

In recognition of the UN 2019 International Year of Indigenous Languages, speakers of indigenous languages were encouraged to propose names from those languages, and a few dozen of the selected names are of indigenous etymology. In Argentina, the winning proposal was submitted by a teacher and community leader in the indigenous Moqoit community. The new names for the planet HD 48265 b (Naqaya) and star HD 48265 (Nosaxa) mean brother-family-relative (referring to all human beings as brothers) and spring (literally, new year), respectively, in the Moqoit language.

The International Astronomical Union, a worldwide group of astronomers, gives proper names to celestial objects, like planets and their surface features. In recent years, the IAU, has started the process of adopting proper names for exoplanets.

The planet named by those in the United States is Mulchatna, its host star will be called Nushagak. Nushagak is a river near Dillingham, Alaska, known for its wild salmon that sustain local indigenous communities. The Mulchatna name comes from a tributary of the Nushagak River. The star and planet, known as HD 17156, are in the Cassiopeia constellation, 255 light-years away. The gas giant planet was discovered in 2007. It’s 3.5 times as massive as Jupiter and orbits its star in only 21 days.

Other examples of the new IAU names for exoplanets and their stars include:

"Astronomical observations over the past generation have now discovered over 4,000 planets orbiting other stars — called exoplanets. The number of discoveries continues to double about every 2½ years, revealing remarkable new planet populations and putting our own Earth and solar system in perspective. Statistically, most of the stars in the sky are likely to be orbited by their own planets — they are everywhere,” said Eric Mamajek, deputy program scientist of NASA's Exoplanet Exploration Program and co-chair of the NameExoWorlds Steering Committee. “While astronomers catalog their new discoveries using telephone-number-like designations, there has been growing interest amongst astronomers and the public alike in also assigning proper names, as is done for solar system bodies.”

Typically, exoplanet names can look long and complicated at first, especially in comparison to names like Venus and Mars. But they have a logic behind them that is important to scientists cataloging thousands of planets.

Astronomers differentiate between the alphanumeric "designations" and alphabetical "proper names." All stars and exoplanets have designations, but very few have proper names. In recent years, the IAU, the international authority for the naming of celestial objects, has started the process of adopting proper names for exoplanets. The first batch of named exoplanets came from a contest open to the public, and included about 15 stars and 20 exoplanets. From the contest, the first giant exoplanet discovered in 1995 (51 Peg b) was named "Dimidium" and its host star (51 Peg) "Helvetios."

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Takes a Cue From Silicon Valley to Hatch Artificial Intelligence Technologies

8 min read

Could the same computer algorithms that teach autonomous cars to drive safely help identify nearby asteroids or discover life in the universe? NASA scientists are trying to figure that out by partnering with pioneers in artificial intelligence (AI) — companies such as Intel, IBM and Google — to apply advanced computer algorithms to problems in space science.

Machine learning is a type of AI. It describes the most widely used algorithms and other tools that allow computers to learn from data in order to make predictions and categorize objects much faster and more accurately than a human being can. Consequently, machine learning is widely used to help technology companies recognize faces in photos or predict what movies people would enjoy. But some scientists see applications far beyond Earth.

Giada Arney, an astrobiologist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, hopes machine learning can help her and her colleagues find a needle of life in a haystack of data that will be collected by future telescopes and observatories such as NASA's James Webb Space Telescope.

"These technologies are very important, especially for big data sets and especially in the exoplanet field," Arney says. "Because the data we're going to get from future observations is going to be sparse and noisy. It's going to be really hard to understand. So using these kinds of tools has so much potential to help us."

To help scientists like Arney build cutting-edge research tools, NASA's Frontier Development Lab, or FDL, brings together technology and space innovators for eight weeks every summer to brainstorm and develop computer code. The four-year-old program is a partnership between the SETI Institute and NASA's Ames Research Center, both based in Silicon Valley where startup-hatching incubators that bring talented people together to accelerate the development of breakthrough technologies are abundant.

In NASA's version, FDL pairs science and computer engineering early-career doctoral students with experts from the space agency, academia, and some of the world's biggest technology companies. Partner companies contribute various combinations of hardware, algorithms, super-compute resources, funding, facilities and subject-matter experts. All of the AI techniques developed at FDL will be publicly available, with some already helping identify asteroids, find planets, and predict extreme solar radiation events.

"FDL feels like some really good musicians with different instruments getting together for a jam session in the garage, finding something really cool, and saying, 'Hey we've got a band here,'" says Shawn Domagal-Goldman, a NASA Goddard astrobiologist who, together with Arney, mentored an FDL team in 2018. Their team developed a machine learning technique for scientists who aim to study the atmospheres of exoplanets, or planets beyond our solar system.

These Goddard scientists hope to one day use advanced machine learning techniques to quickly interpret data revealing the chemistry of exoplanets based on the wavelengths of light emitted or absorbed by molecules in their atmospheres. Since thousands of exoplanets have been discovered so far, making quick decisions about which ones have the most promising chemistry associated with habitability could help winnow down the candidates to only a few that deserve further, and costly, investigation.

To this end, the FDL team Arney and Domagal-Goldman helped advise, with technical support from Google Cloud, deployed a technique known as a “neural network.” This technology can solve super complicated problems in a process analogous to the workings of the brain. In a neural network, billions of “neurons,” which are nerve cells in the brain that help us form memories and make decisions, connect with billions of others to process and transmit information. University of Oxford computer science graduate student, Adam Cobb, along with Michael D. Himes, a physics graduate student from the University of Central Florida, led a study to test the capability of a “Bayesian” neural network against a widely used machine learning technique known as a “random forest.” Another researcher team not associated with FDL had already used this latter method to analyze the atmosphere of WASP-12b, an exoplanet discovered in 2008, based on mountains of data collected by NASA’s Hubble Space Telescope. Could the Bayesian neural network do better, the team wondered?

“We found out right away that the neural network had better accuracy than random forest in identifying the abundance of various molecules in WASP-12b’s atmosphere,” Cobb says.

But besides better accuracy, the Bayesian technique offered something equally as critical: it could tell the scientists how certain it was about its prediction. “In places where the data weren’t good enough to give a really accurate result, this model was better at knowing that it wasn’t sure of the answer, which is really important if we are to trust these predictions,” Domagal-Goldman says.

While the technique developed by this team is still in development, other FDL technologies have already been adopted in the real world. By 2017, FDL participants developed a machine learning program that could quickly create 3D models of nearby asteroids, accurately estimating their shapes, sizes, and spin rates. This information is critical to NASA’s efforts to detect and deflect threatening asteroids from Earth.

Traditionally, astronomers use simple computer software to develop 3D models. The software analyzes many radar measurements of a moving asteroid and then helps scientists infer its physical properties based on changes in the radar signal.

“An adept astronomer with standard compute resources, could shape a single asteroid in one to three months,” says Bill Diamond, SETI’s president and chief executive officer. “So the question for the research team was: Can we speed it up?”

Download image here

The answer was yes. The team, which included students from France, South Africa and the United States, plus mentors from academia and from technology company Nvidia, developed an algorithm that could render an asteroid in as little as four days. Today, the technique is used by astronomers at the Arecibo Observatory in Puerto Rico to do nearly real-time shape modeling of asteroids.

The asteroid modeling, along with exoplanetary atmosphere analysis, are a couple of FDL examples that show the promise in applying sophisticated algorithms to the volumes of data collected by NASA’s more than 100 missions.

As NASA heliophysicist Madhulika (Lika) Guhathakurta notes, the space agency gathers about 2 gigabytes of data (and growing) every 15 seconds from its fleet of spacecraft. “But we analyze only a fraction of that data, because we have limited people, time and resources. That is why we need to utilize these tools more,” she says.

A lead on missions focused on understanding and predicting the Sun’s effects on Earth, technology and astronauts in space, Guhathakurta has been with FDL for the last three years and has been a key architect in shaping this program. She supported a team in 2018 that resolved a problem with a malfunctioning sensor on NASA’s Solar Dynamics Observatory (SDO), a spacecraft that studies the Sun’s influence on Earth and near-Earth space.

Back in 2014, just four years after the mission launched, a sensor stopped returning data related to extreme ultraviolet (EUV) radiation levels — information that correlates with a ballooning of the Earth's outer atmosphere and thus affects the longevity of satellites, including the International Space Station. So computer science doctoral students from Stanford University and University of Amsterdam, among others, with mentors from organizations including IBM, Lockheed Martin, and SETI, developed a technique that could, essentially, fill in the missing data from the broken sensor. Their computer program could do this by analyzing data from other SDO instruments, along with old data collected by the broken sensor during the four years it was working, to infer what EUV radiation levels that sensor would have detected based on what the other SDO instruments were observing at any given time. "We generated, basically, a virtual sensor," Guhathakurta says.

The potential of this type of this instrument is not lost on anyone. SETI head, Diamond, imagines a future where these virtual tools are incorporated on spacecraft, a practice that would allow for lighter, less complex and therefore cheaper missions. Domagal-Goldman and Arney envisage future exoplanet missions where AI technologies embedded on spacecraft are smart enough to make real-time science decisions, saving the many hours necessary to communicate with scientists on Earth.

"AI methods will help us free up processing power from our own brains by doing a lot of the initial legwork on difficult tasks," Arney says. "But these methods won't replace humans any time soon, because we'll still need to check the results."

By Lonnie ShekhtmanNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers Propose a Novel Method of Finding Atmospheres on Rocky Worlds

NASA Science Editorial Team

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Why Do Scientists Search for Exoplanets? Here Are 7 Reasons

4 min read

NASA Science Editorial Team

We asked seven researchers what drives the hunt for planets outside our solar system — and got some surprising answers:

“I search for exoplanets because I love the feeling of discovery — finding something new that no one has ever seen before! In particular I like discovering exoplanets because the planets in our solar system are so substantial and tangible to us that I can then imagine what exoplanets around other stars might look like.”

Matthew W. Smith, systems engineer, NASA’s Jet Propulsion Laboratory:

“I search for exoplanets because I want to know whether there’s another Earth-like world out there, and whether life could exist outside our solar system. I think about these questions every time I’m in a dark spot looking up at the night sky.”

“I search for exoplanets for the journey of exploration. It’s incredibly exciting to come across a planet that is different or new and exciting — even in some small way — from planets known before.”

Padi Boyd, project scientist for NASA’s TESS mission (Transiting Exoplanet Survey Satellite):

I search for exoplanets because I think one of the most profound and thought-provoking questions humanity has ever asked is, “Are we alone in the universe?” Philosophers and curious humans have been asking this question for thousands of years, but we are the first generation who have the tools at our fingertips to begin to answer this question with scientific observations. Not only do we now know of thousands of planets around other stars, and not only can we infer the existence of hundreds of billions more, but we are finding a dazzling array of planets, some very different from the ones in our own solar system. In a way, each new planetary system we discover teaches us a little bit more about how the universe works, and how the Earth, Sun and own planetary system fit into the whole.”

Jessie Dotson, project scientist, NASA Ames Research Center:

“There are so many reasons to search for exoplanets. But the core reason for me is that I’ve always wanted to know how things are made. (And really I mean how everything is made — bread, buildings, chocolate, roads, stars, planets, galaxies…I was the kid with the endless stream of annoying questions!) In graduate school I studied star formation regions. I’m now fascinated by how planetary systems (both our own and others) are formed. There are plenty of solid theories on how planetary systems form, but we’re in a really exciting time now, when we’re finding enough systems at enough different ages that we’re starting to really test those theories. So, I search for exoplanets because I want to know how they were made.”

Karl Stapelfeldt, chief scientist for NASA’s Exoplanet Exploration Program:

“People in many cultures can relate to the idea of a planet: They live on one, in Earth’s Moon they directly see another world, and from a young age they learn the names of the other planets in our solar system. More than nebulae, galaxies or even other stars, planets around other stars readily fit into our shared cultural understanding of the universe. Exoplanet exploration bridges the heavens into human consciousness, and that’s why we do it.”

Mary Voytek, senior scientist and director of NASA’s Astrobiology Program:

“I don’t do (direct) exoplanet research, but I happen to understand it well. We spent all of our research time before we knew about exoplanets understanding our own solar system — how the planets formed. Observing exoplanets allows us to determine whether or not we actually understand those processes, even in our own solar system. In fact, what we’ve seen so far is that most stellar systems don’t look like our solar system. What finding exoplanets does for us is open up a vast exploration area to look for other habitable worlds. And it has upped the likelihood that we are not alone.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Presents Panorama of Southern Sky

3 min read

The glow of the Milky Way — our galaxy seen edgewise — arcs across a sea of stars in a new mosaic of the southern sky produced from a year of observations by NASA’s Transiting Exoplanet Survey Satellite (TESS). Constructed from 208 TESS images taken during the mission’s first year of science operations, completed on July 18, the southern panorama reveals both the beauty of the cosmic landscape and the reach of TESS’s cameras.

“Analysis of TESS data focuses on individual stars and planets one at a time, but I wanted to step back and highlight everything at once, really emphasizing the spectacular view TESS gives us of the entire sky,” said Ethan Kruse, a NASA Postdoctoral Program Fellow who assembled the mosaic at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

Within this scene, TESS has discovered 29 exoplanets, or worlds beyond our solar system, and more than 1,000 candidate planets astronomers are now investigating.

TESS divided the southern sky into 13 sectors and imaged each one of them for nearly a month using four cameras, which carry a total of 16 charge-coupled devices (CCDs). Remarkably, the TESS cameras capture a full sector of the sky every 30 minutes as part of its search for exoplanet transits. Transits occur when a planet passes in front of its host star from our perspective, briefly and regularly dimming its light. During the satellite’s first year of operations, each of its CCDs captured 15,347 30-minute science images. These images are just a part of more than 20 terabytes of southern sky data TESS has returned, comparable to streaming nearly 6,000 high-definition movies.

In addition to its planet discoveries, TESS has imaged a comet in our solar system, followed the progress of numerous stellar explosions called supernovae, and even caught the flare from a star ripped apart by a supermassive black hole. After completing its southern survey, TESS turned north to begin a year-long study of the northern sky.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT’s Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory in Lexington, Massachusetts; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

Download higher-resolution images from NASA Goddard’s Scientific Visualization Studio

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Instrument to Probe Planet Clouds on European Mission

6 min read

NASA will contribute an instrument to a European space mission that will explore the atmospheres of hundreds of planets orbiting stars beyond our Sun, or exoplanets, for the first time.

The instrument, called the Contribution to ARIEL Spectroscopy of Exoplanets, or CASE, adds scientific capabilities to ESA’s (the European Space Agency’s) Atmospheric Remote-sensing Infrared Exoplanet Large-survey, or ARIEL, mission.

The ARIEL spacecraft with CASE on board is expected to launch in 2028. CASE will be managed by NASA’s Jet Propulsion Laboratory in Pasadena, California, with JPL astrophysicist Mark Swain as the principal investigator.

“I am thrilled that NASA will partner with ESA in this historic mission to push the envelope in our understanding of what the atmospheres of exoplanets are made of, and how these planets form and evolve,” said Thomas Zurbuchen, associate administrator for NASA’s Science Mission Directorate in Washington. “The more information we have about exoplanets, the closer we get to understanding the origins of our solar system, and advancing our search for Earth-like planets elsewhere.”

So far, scientists have found more than 4,000 confirmed exoplanets in the Milky Way. NASA’s retired Kepler space telescope and active Transiting Exoplanet Survey Satellite (TESS) are two observatories that have contributed to this count. These telescopes have discovered planets by observing brightness of a star’s light dimming as a planet crosses its face, an event called a “transit.” ARIEL, carrying CASE, will take planet-hunting through transits one step further, by delving deeper into planets already known to exist.

ARIEL will be able to see the chemical fingerprints, or “spectra,” of a planet’s atmosphere in the light of its star. To do this, the spacecraft will observe starlight streaming through the atmospheres of planets as they pass in front their stars, as well as light emitted by the planets’ atmospheres just before and after they disappear behind their stars. These fingerprints will allow scientists to study the compositions, temperatures, and chemical processes in the atmospheres of the planets ARIEL observes.

These chemical fingerprints of exoplanet atmospheres are extremely faint. Identifying them is a huge challenge for astronomers, and requires a telescope to stare at individual stars for a long time. But many space observatories are multi-purpose, and must split up their time among different kinds of scientific investigations. ARIEL will be the first spacecraft fully devoted to observing hundreds of exoplanet atmospheres, looking to identify their contents, temperatures and chemical processes. The addition of CASE, which will observe clouds and hazes, will provide a more comprehensive picture of the exoplanet atmospheres ARIEL observes.

So far, telescopes have only been able to carefully probe the atmospheres of a handful of exoplanets to determine their chemistries. ARIEL’s much larger, more diverse sample will enable scientists to look at these worlds not just as individual exotic objects, but as a population, and discover new trends in their commonalities and differences.

The CASE instrument will be sensitive to light at near-infrared wavelengths, which is invisible to human eyes, as well as visible light. This complements ARIEL’s other instrument, called an infrared spectrometer, which operates at longer wavelengths. CASE will specifically look at exoplanets’ clouds and hazes — determining how common they are, as well how they influence the compositions and other properties of planetary atmospheres. CASE will also allow measurements of each planet’s albedo, the amount of light the planet reflects.

The spacecraft will focus on exceptionally hot planets in our galaxy, with temperatures greater than 600 degrees Fahrenheit (320 degrees Celsius). Such planets are more likely to transit their star than planets orbiting farther out, and their short orbital periods provide more opportunities to observe transits in a given period of time. More transits give astronomers more data, allowing them to reveal the weak chemical fingerprint of a planet’s atmosphere.

ARIEL’s hot planet population will include gas giants like Jupiter, as well as smaller gaseous planets called mini-Neptunes and rocky worlds bigger than our planet called super-Earths. While these planets are too hot to host life as we know it, they will tell us a lot about how planets and planetary systems form and evolve. Additionally the techniques and insights learned in studying exoplanets with ARIEL and CASE will be useful when scientists use future telescopes to look toward smaller, colder, rockier worlds with conditions that more closely resemble Earth’s.

The CASE instrument consists of two detectors and associated electronics that contribute to ARIEL’s guidance system. CASE takes advantage of the same detectors and electronics that NASA is contributing to ESA’s Euclid mission, which will probe deep questions about the structure of the universe and its two biggest mystery components: dark matter and dark energy.

The ARIEL spacecraft with CASE on board will be in the same orbit as NASA’s James Webb Space Telescope, which is expected to launch in 2021. Both will travel some 1 million miles (1.5 million kilometers) from Earth to a special point of gravitational stability called Lagrange Point 2. This location allows the spacecraft to circle the Sun along with the Earth, while using little fuel to maintain its orbit.

While Webb will also be capable of studying exoplanet atmospheres, and its instruments cover a similar range of light as ARIEL, Webb will target a smaller sample of exoplanets to study in greater detail. Because Webb’s time will be divided, shared with investigations into other aspects of the universe, it will deliver detailed knowledge about particular exoplanets rather than surveying hundreds. ARIEL will launch several years after Webb, so it will be able to capitalize on lessons learned from Webb in terms of planning observations and selecting which planets to study.

“This is an exciting time for exoplanet science as we look toward the next generation of space telescopes and instruments,” said Paul Hertz, director of the astrophysics division at NASA Headquarters, Washington. “CASE adds to an exceptional set of technologies that will help us better understand our place in the galaxy.”

CASE is an Astrophysics Explorers Mission of Opportunity, managed by JPL. The Astrophysics Explorers Program is managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland, for the Science Mission Directorate at NASA Headquarters in Washington, DC.

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Felicia ChouNASA Headquarters, Washington202-358-0257felicia.chou@nasa.gov

Written by Elizabeth LandauNASA Headquarters, Washington

2019-225

NASA’s Latest Exoplanet Posters Are a Halloween Treat

4 min read

Just in time for Halloween, NASA has released two new posters celebrating some truly terrifying exoplanets, or planets outside our solar system. Free to download, the entertaining posters recall vintage horror movie advertisements but have a decidedly astronomical focus.

Dubbed Galaxy of Horrors, the fun but informative series resulted from a collaboration of scientists and artists and was produced by NASA’s Exoplanet Exploration Program Office, located at NASA’s Jet Propulsion Laboratory in Pasadena, California. The same program is behind the popular Exoplanet Travel Bureau poster series, which imagines humans visiting some of the thousands of known worlds outside our solar system.

Among the horrifyingly inhospitable worlds highlighted in the latest posters is HD 189733 b, a planet with an atmosphere full of silicates — the key component in sand and glass — and winds blowing at over 5,400 mph (6,700 kph). At those speeds, the silicates whipping through the air might create a perpetual storm of flying glass. If human or robotic explorers could travel 63 light-years from Earth to get there, they would never survive this planetary hellscape.

The second poster features three planets — Poltergeist, Draugr and Phobetor — orbiting the pulsar PSR B1257+12, located about 2,000 light-years from Earth. Sometimes called a “dead star,” a pulsar is the remains of a star that has ceased burning fuel at its core and collapsed. But it isn’t a quiet corpse. Like other pulsars, PSRB 1257+12 produces dual beams of intense radiation that can sometimes be seen across the galaxy. Stray radiation and high-energy particles would attack the three nearby planets. Life as we know it could never form on these worlds.

“People are often most interested in finding exoplanets that could resemble Earth or potentially support life as we know it,” said Thalia Rivera, an outreach specialist at JPL who led the development of the new poster series. “But there are so many other amazing, mystifying planets out there that are completely unlike Earth and that show us the huge variety of ways planets can form and evolve. My favorite thing about exoplanets is how extreme they can get!”

Scientists have discovered over 4,000 exoplanets, with a majority of those detected in the last 15 years by NASA’s now-retired Kepler space telescope. NASA has multiple missions searching for and studying exoplanets, including the Transiting Exoplanet Survey Satellite (TESS), the Hubble Space Telescope and the Spitzer Space Telescope. They will be joined by upcoming missions, including the James Webb Space Telescope, set to launch in 2021, and the Wide Field Infrared Survey Telescope (WFIRST), scheduled to launch in the mid-2020s.

The Exoplanet Exploration Program manages science and engineering tasks in support of NASA’s search for exoplanets. In addition, the program helps engage the public about exoplanet science and increases awareness of NASA’s exoplanet activities.

“In practical terms, I think for many people the posters are an entryway,” said Gary Blackwood, manager of the Exoplanet Exploration Program. “They make exoplanet science cool, and that opens a door for many members of the public — especially students — to learn more about the science behind the posters.”

To download the new posters for free and to learn more about these inhospitable exoplanets as well as other terrifying worlds visit the Galaxy of Horrors webpage:

https://exoplanets.nasa.gov/alien-worlds/galaxy-of-horrors/

Even more examples of weird worlds can be found in the Eyes on Exoplanet web application:

https://exoplanets.nasa.gov/eyes-on-exoplanets/

Click on “Explore Planets,” and go to the “Weird Worlds” tab.

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

2019-214

Observing Exoplanets: What Can We Really See?

4 min read

NASA Science Editorial Team

Exoplanets are far away, and they are often obscured by the bright light of the stars they orbit. So, taking pictures of them the same way you'd take pictures of, say, Jupiter or Venus, isn't easy.

The major problem astronomers face in trying to directly image exoplanets is that the stars they orbit are millions of times brighter than their planets. Any light reflected off of the planet or heat radiation from the planet itself is drowned out by the massive amounts of radiation coming from its host star. It's like trying to see a firefly flitting around a spotlight.

So, it takes new techniques and advancing technology to make it happen.

Even the world's best space telescope, NASA's James Webb, can't capture surface features of exoplanets. It is revealing them in other ways, including obtaining the first direct measurements of exoplanet atmospheres. The first exoplanet imaged by Webb, called HIP 65426 b, is about six to 12 times the mass of Jupiter. It is young as planets go — about 15 to 20 million years old, compared to our 4.5-billion-year-old Earth.

Since HIP 65426 b is about 100 times farther from its host star than Earth is from the Sun, it is far enough from the star that Webb can easily separate the planet from the star in the image.

Webb’s Near-Infrared Camera (NIRCam) and Mid-Infrared Instrument (MIRI) are both equipped with coronagraphs, which are sets of tiny masks that block out starlight, enabling Webb to take direct images of certain exoplanets.

These two planets – TYC 8998-760-1 b and now, c – are considered the first multi-planet system to be directly imaged around a Sun-like star. The star is a baby version of our Sun, only 17 million years old. The extreme youth of this system is a big part of why astronomers were able to capture direct images: The planets are so hot from their recent formation that they still glow brightly enough to be seen from our vantage point, even though they're hundreds of light-years away.

Planets b and c are much farther away from their star than, say, Jupiter and Saturn are from the Sun. Planet b is 160 times the Earth-Sun distance, planet c is about 320 times. Just for comparison, Jupiter is 5 times the Earth-Sun distance, Saturn 10 times.

Here, the black circle in the center of the image is part of the observing and analyzing effort to block the blinding light of the star, and thus make the planets visible. Four planets more massive than Jupiter can be seen orbiting the young star HR 8799 in a composite of sorts; it includes images taken over seven years at the W.M. Keck observatory in Hawaii.

The images were initially captured by Dr. Christian Marois of the National Research Council of Canada’s Herzberg Institute of Astrophysics. The movie animation was put together by Jason Wang, part of the Berkeley arm of the Nexus for Exoplanet System Science (NExSS), a NASA-sponsored group formed to encourage interdisciplinary exoplanet science.

The star, HR 8799, has continually played a pioneering role in the evolution of direct imaging of exoplanets. In 2008, the Marois group announced discovery of three of the four HR 8799 planets using direct imaging for the first time.

In 2004, the first exoplanet imaged directly was 2M1207b, four times more massive than Jupiter. European Southern Observatory astronomers using the VLT (Very Large Telescope) in Chile. This composite image shows the exoplanet formally known as 2MASS J12073346-3932539 b (the red spot on the lower left), orbiting a brown dwarf 2M1207 (center). It orbits the failed star at a distance 55 times greater than the Earth to the Sun, nearly twice as far as Neptune is from the Sun. Planets that are far from their stars can be easier to directly image because they are less obscured by the light from their stars. The system 2M1207 is 170 light-years from Earth, in the constellation of Hydra. The photo is based on three near-infrared exposures (in the H, K and L wavebands).

More than 10 years later, astronomers used the Hubble Space Telescope to take a closer look. An artist's concept, below, is based on their observations.

Hubble's image stability, high resolution, and high-contrast imaging capabilities allowed astronomers to precisely measure the planet's brightness changes as it spins. The researchers attribute the brightness variation to complex clouds patterns in the planet's atmosphere. The Hubble measurements not only verify the presence of these clouds, but also show that the cloud layers are patchy and colorless.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Discovery Alert: 2-planet System Is Close – and Weird

2 min read

Alicia Cermak

Planets: GJ 15 A b and c

The discovery: GJ 15 A b and c orbit a red-dwarf star just 11 light-years away, making them our nearest multi-planet neighbors – at least among the exoplanet systems discovered so far.

Date: Entered into NASA's Exoplanet Archive on October 10, 2019

Key facts: These planets have an abundance of strange properties. The innermost world, GJ 15 A b, takes just 11 days to make a full orbit around the star – a "year" on this planet. It weighs in at three times the mass of Earth, qualifying it for the size category known as "super Earth." It's also super-heated, with an estimated surface temperature of 530 degrees Fahrenheit (276 Celsius).

Its sister-world, GJ 15 A c, could hardly be more different. It's a gas giant 36 times the mass of Earth, and appears to have roughly a 20-year orbit around its cool and small parent star. While its temperature is not known, it's likely to be quite cold in this distant, possibly icy orbit, loosely comparable to the orbit of Saturn around our Sun.

Details: The orbit of at least the outer world might well have been sculpted by their parent star's distant companion, another red dwarf known as GJ 15 B, although more observations are needed to be sure.

Fun facts: GJ 15 A b is an on-again, off-again planet. It was first reported in 2014, then "refuted" after another team of astronomers could not detect it. The most recent paper "reinstates" the planet with more data backing up the original discovery of a super Earth in an 11-day orbit. The two planets are among a batch of 16 added on October 10 to NASA's Exoplanet Archive, bringing the total of confirmed exoplanets in our galaxy to 4,073.

The discoverers: The new discovery, planet c, and the confirmation of planet b were announced in a 2018 paper from a team led by Matteo Pinamonti using the Italian Telescopio Nazionale Galileo, along with archival data. The team relied on the "wobble" method of planet detection, or radial velocity: measuring the subtle back-and-forth motion of a star as it is tugged one way, then another, by the gravity of an orbiting planet. A team led by Andrew Howard of the University of Hawaii made the original discovery of planet b in 2014.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Latest Posters Are a Halloween Treat

4 min read

NASA Science Editorial Team

Just in time for Halloween, NASA has released two new posters celebrating some truly terrifying exoplanets, or planets outside our solar system. Free to download, the entertaining posters recall vintage horror movie posters but have a decidedly astronomical focus.

Dubbed "Galaxy of Horrors," the fun but informative series resulted from a collaboration of scientists and artists and was produced by NASA's Exoplanet Exploration Program Office, located at NASA's Jet Propulsion Laboratory in Pasadena, California. The same program is behind the popular Exoplanet Travel Bureau poster series, which imagines humans visiting some of the thousands of known worlds outside our solar system.

Among the horrifyingly inhospitable worlds highlighted in the latest posters is HD 189733 b, a planet with an atmosphere full of silicates — the key component in sand and glass — and winds blowing at over 5,400 mph (6,700 kph). At those speeds, the silicates whipping through the air might create a perpetual storm of flying glass. If human or robotic explorers could travel 63 light-years from Earth to get there, they would never survive this planetary hellscape.

The second poster features three planets — named Poltergeist, Drauger and Phobetor — orbiting the pulsar PSR B1257+12, located about 2,000 light years from Earth. Sometimes called a "dead star," a pulsar is the remains of a star that has ceased burning fuel at its core and collapsed, but it isn't a quiet corpse. Like other pulsars, PSRB 1257+12 produces dual beams of intense radiation that can sometimes be seen across the galaxy. Stray radiation and high energy particles would attack the three nearby planets. Life as we know it could never form on these worlds.

"People are often most interested in finding exoplanets that could resemble Earth or potentially support life as we know it," said Thalia Rivera, an outreach specialist at the Jet Propulsion Laboratory who led the development of the new poster series. "But there are so many other amazing, mystifying planets out there that are completely unlike Earth and that show us the huge variety of ways planets can form and evolve. Personally, my favorite thing about exoplanets is how extreme they can get!"

Scientists have discovered over 4,000 exoplanets, with a majority of those detected in the last 15 years by NASA's now-retired Kepler space telescope. NASA has multiple missions searching for and studying exoplanets, including the Transiting Exoplanet Survey Satellite (TESS), the Hubble Space Telescope and the Spitzer Space Telescope. They will be joined by upcoming missions including the James Webb Space Telescope, set to launch in 2021, and the Wide Field Infrared Survey Telescope (WFIRST), scheduled to launch in the mid-2020s.

The Exoplanet Exploration Program manages science and engineering tasks in support of NASA’s search for exoplanets. In addition, the Program helps engage the public about exoplanet science and increases awareness of NASA’s exoplanet activities.

"In practical terms, I think for many people the posters are an entryway," said Gary Blackwood, manager of the Exoplanet Exploration Program. "They make exoplanet science cool and that opens a door for many members of the public, especially students, to learn more about the science behind the posters."

Download the new posters for free and learn more about these inhospitable exoplanets, as well as other terrifying worlds, in our Galaxy of Horrors.

Even more examples of weird worlds can be found in the Eyes on Exoplanet web application: https://exoplanets.nasa.gov/eyes-on-exoplanets/

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Nobel Winners Changed Our Understanding with Exoplanet Discovery

3 min read

NASA Science Editorial Team

51 Pegasi b, also called "Dimidium," was the first exoplanet discovered orbiting a Sun-like star in 1995. In 2019, its discoverers, Michel Mayor and Didier Queloz, shared the Nobel Prize in Physics. 51 Peg b is a "hot Jupiter" – a gas giant exoplanet (a planet beyond our solar system). 51 Peg orbits its star every four days and has a temperature of 1,000-1,800 degrees F (538-982 degrees C). It's 51 light-years from Earth.

The Swiss team of Michel Mayor and Didier Queloz made a stunning announcement in October 1995: the first detection of a planet orbiting a star like our Sun. Though not quite the first “exoplanet” – a planet beyond our solar system – it captured the world’s attention and opened the floodgates of discovery. Today more than 5,500 exoplanets are confirmed to be in orbit around other stars.

The planet found by Mayor and Queloz, 51 Pegasi b, is a star-hugging gas giant known as a “hot Jupiter” that takes only four days to complete one orbit – a “year” for 51 Peg. It would join a menagerie of weird worlds that includes super Earths – mysterious planets larger than Earth and smaller than Neptune – mini-Neptunes, and big gas giants several times the size of our own Jupiter.

These large planets make such tight orbits that they cause a pronounced “wobble” in their stars, their gravity tugging them first this way, then that. That made them easier to find in the early days of planet hunting, using a detection method known as radial velocity.

This strange assortment would also include the first-ever exoplanet detections, “pulsar planets” that orbit the rapidly spinning remnant of an exploded star known as a pulsar. A significant portion of the exoplanets discovered so far also include rocky planets in Earth’s size range, some at the right distance from their stars to allow the possibility of liquid water pooling on their surfaces.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

WFIRST Space Telescope Fitted for ‘Starglasses’

7 min read

Editor’s note, Jan. 19, 2022: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

When a new NASA space telescope opens its eyes in the mid-2020s, it will peer at the universe through some of the most sophisticated sunglasses ever designed.

This multi-layered technology, the coronagraph instrument, might more rightly be called “starglasses”: a system of masks, prisms, detectors and even self-flexing mirrors built to block out the glare from distant stars — and reveal the planets in orbit around them.

Normally, that glare is overwhelming, blotting out any chance of seeing planets orbiting other stars, called exoplanets, said Jason Rhodes, the project scientist for the Wide-Field Infrared Survey Telescope (WFIRST) at NASA’s Jet Propulsion Laboratory in Pasadena, California.

A star’s photons — particles of light — vastly overpower any light coming from an orbiting planet when they hit the telescope.

“What we’re trying to do is cancel out a billion photons from the star for every one we capture from the planet,” Rhodes said.

And WFIRST’s coronagraph just completed a major milestone: a preliminary design review by NASA. That means the instrument has met all design, schedule and budget requirements, and can now proceed to the next phase: building hardware that will fly in space. It’s one of a series of such reviews examining every facet of the mission, said WFIRST Project Scientist Jeffrey Kruk of NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

“Every one of these reviews is comprehensive,” Kruk said. “We go over all aspects of the mission, to show that everything hangs together.”

The WFIRST mission’s coronagraph is meant to demonstrate the power of increasingly advanced technology. As it captures light directly from large, gaseous exoplanets, and from disks of dust and gas surrounding other stars, it will point the way to technologies for even larger space telescopes.

Future telescopes with even more sophisticated coronagraphs will be able to generate single pixel “images” of rocky planets the size of Earth. Then the light can be spread into a rainbow called a “spectrum,” revealing which gases are present in the planet’s atmosphere — perhaps oxygen, methane, carbon dioxide, and maybe even signs of life.

“With WFIRST we’ll be able to get images and spectra of these large planets, with the goal of proving technologies that will be used in a future mission — to eventually look at small rocky planets that could have liquid water on their surfaces, or even signs of life, like our own,” Rhodes said.

In this way, WFIRST is a kind of pioneer. That’s why NASA considers the coronagraph to be a “technology demonstration.” While it is likely to generate important scientific discoveries, its main job is to prove to the scientific community that complex coronagraphs really can work in space.

“This may be the most complicated astronomical instrument ever flown,” Rhodes said.

NASA’s Hubble Space Telescope, in orbit since 1990, is so far the only NASA astrophysics flagship mission to include coronagraphs — far simpler and less sophisticated versions than will fly on WFIRST.

But by the time it launches in the mid 2020s, WFIRST will be the third such mission to include coronagraph technology. NASA's massive James Webb Space Telescope, launching in 2021, will include a coronagraph with a sharpness of vision greater than Hubble's, but without the starlight suppression capability of WFIRST.

"WFIRST should be two or three orders of magnitude more powerful than any other coronagraph ever flown" in its ability to distinguish a planet from its star, Rhodes said. "There should be a chance for some really compelling science, even though it's just a tech demo."

The two flexible mirrors inside the coronagraph are key components. As light that has traveled tens of light-years from an exoplanet enters the telescope, thousands of actuators move like pistons, changing the shape of the mirrors in real time. The flexing of these "deformable mirrors" compensates for tiny flaws and changes in the telescope's optics.

Changes on the mirrors' surfaces are so precise they can compensate for errors smaller than the width of a strand of DNA.

These mirrors, in tandem with high-tech "masks," another major advance, squelch the star's diffraction — the bending of light waves around the edges of light-blocking elements inside the coronagraph.

The result: blinding starlight is sharply dimmed, and faintly glowing, previously hidden planets appear.

The star-dimming technology also could deliver the clearest-ever images of distant star systems' formative years — when they are still swaddled in disks of dust and gas as infant planets take shape inside.

"The debris disks we see today around other stars are brighter and more massive than what we have in our own solar system," said Vanessa Bailey, an astronomer at JPL and instrument technologist for the WFIRST coronagraph. "WFIRST's coronagraph instrument could study fainter, more diffuse disk material that's more like the Main Asteroid Belt, the Kuiper Belt, and other dust orbiting the Sun."

That could yield deep insights into how our solar system formed.

Kruk said the instrument's deformable mirrors and other advanced technology — known as "active wavefront control" — should mean a leap of 100 to 1,000 times the capability of previous coronagraphs.

"When you see an opportunity like this to really open new frontiers in a new field, you can't help but be excited by that," he said.

Once the coronagraph technology is successfully demonstrated over the mission's first 18 months, WFIRST's coronagraph could become open to the scientific community. A "Participating Scientist Program" would invite a broader variety of observers to conduct experiments beyond the demonstration phase.

The coronagraph's advancement through the design review milestone is part of a development schedule now moving at a fast clip. A giant camera that will also fly on the spacecraft, called the Wide-Field Instrument, cleared the same hurdle in June. It is considered the space telescope's main instrument.

Rhodes likes to compare WFIRST to the history-making Mars Pathfinder mission. After landing on the Red Planet in 1997, the Pathfinder lander unleashed a small rover, named Sojourner, to trundle on its own around the landing site and examine nearby rocks.

“That was a tech demo,” Rhodes said. “The goal was to show that a rover works on Mars. But it went on to do some very interesting science during its lifetime. So we’re hopeful the same is going to be true of WFIRST’s coronagraph tech demo.”

Download this video in HD formats from NASA Goddard’s Scientific Visualization Studio

By Pat BrennanNASA’s Jet Propulsion Laboratory, Pasadena, Calif.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Five Reasons You Wouldn’t Want to Live Near a Black Hole

6 min read

NASA Science Editorial Team

Black holes are mystifying yet terrifying cosmic phenomena. Unfortunately, people have a lot of ideas about them that are more science fiction than science. Black holes are not cosmic vacuum cleaners, sucking up anything and everything nearby. But in some ways, Hollywood has vastly underestimated how dangerous black holes really are.

Black holes are superdense objects with a gravitational pull so strong that not even light can escape them. Scientists have overwhelming evidence for two types of black holes – stellar and supermassive – and see hints of an in-between size that’s more elusive. A black hole’s type depends on its mass (a stellar black hole is five to 30 times the mass of the Sun, while a supermassive black hole is 100,000 to billions of times the mass of the Sun), and can determine where we’re most likely to find them, and how they formed.

Let's focus on supermassive black holes for now, shall we? Supermassive black holes exist in the centers of most large galaxies. One example is Sagittarius A* (Sgr A* for short, which is pronounced “Saj A-star”) at the center of our Milky Way. Another is the black hole at the center of galaxy Messier 87, which became famous when the Event Horizon Telescope released its picture – the first image ever captured of a black hole. As the name suggests, both of these are… well, supermassive. Why are they so enormous? Scientists suspect it has something to do with their locations in the centers of galaxies. With so many stars and lots of wayward gases drifting in that neighborhood for them to sweep up, they can grow large rapidly (astronomically speaking).

You may have seen a portrayal of planets around supermassive black holes in the movies. But what would the conditions on those worlds actually look like? What kinds of problems might you face, if you lived there?

“Space weather” describes the changing conditions in space caused by stellar activity. Solar eruptions produce intense radiation and clouds of charged particles that sweep through our planetary system and can affect the technology we rely on, damaging satellites and even causing electrical blackouts. Thankfully, Earth’s atmosphere and magnetic field protect us from most of the storms produced by the Sun.

On the other hand, space weather near a black hole would be much more striking, if that black hole is consuming matter. The showers of radiation and particles could be millions – perhaps even billions – of times stronger than those from the Sun, depending on how close the planet is to the black hole.

Even though black holes don’t emit light themselves, their surroundings can be very bright and hot. Accretion disks – swirling clouds of matter falling toward black holes – emit huge amounts of radiation and particles, and form incredible magnetic fields. Within that vortex, you’d also have to worry about debris traveling at nearly the speed of light, slamming into your planet. It’d be hard to avoid getting hit by anything coming at you that fast!

In 2018, NASA launched the Parker Solar Probe to learn more about the Sun. If you lived on a world around a supermassive black hole, you'd probably want to study it too. But it would be a lot more challenging!

You’d have to launch satellites that could withstand the extreme space weather. And then there would be major communication issues – a time delay in messages sent between the spacecraft and your planet.

On Earth we experience time gaps when talking to missions on Mars. It takes from 5 to 20 minutes to hear back from our spacecraft and rovers. Around a black hole, that effect would be much more extreme. Einstein theorized this, that high speed and extreme gravity could warp time. Objects closer to the black hole would experience time differently, making things seem slower than they actually are. That means the delay in communications with a satellite launched toward a black hole would become longer and longer as it got closer and closer to its target. By the time you hear back from your satellite, it might be gone!

Supermassive black holes at the centers of galaxies typically have a lot of nearby stars. In fact, if you were to live on a planet near the center of the Milky Way, there would be so many stars you could read at night without using electricity.

That sounds kind of cool, right? Maybe – unless your planet is actually orbiting the supermassive black hole. Being that close, the light from all those stars would be concentrated and amplified due to the extreme gravity around the black hole, making the light stronger and even causing scary beams of strong radiation. You would want to have a bucket of sunscreen ready to apply often – or simply never leave your home.

Not only would it be really bright, it would also be really toasty, thanks to radioactive heating! Those stars hanging around the black hole emit not just light but ghostly particles called neutrinos – speedy, tiny particles that weigh almost nothing and rarely interact with anything. While neutrinos coming from our Sun aren't enough to harm us on Earth, the volume that would be coming from the cluster of stars near a black hole would be enough to radioactively heat up whatever they slam into.

The planet would absorb neutrinos, warming up its core, eventually making the planet unbearably hot. It would be like living in a nuclear reactor. At least you’d be warm and could ditch your winter coats?

If your planet got too close to a black hole, you’d likely face a gruesome fate. The force of gravity from a black hole stretches matter, essentially turning it into a noodle. We call this spaghettification (yes, it’s a real word). Imagine yourself falling feet-first toward a black hole. Spaghettification happens because the gravity at your feet is sooooo much stronger than that at your head, and you start to stretch out! The black hole sucks you in like a slippery strand of buttered spaghetti.

Maybe you wish you could simply drift around a black hole in a spacecraft and enjoy the view, or travel through one like in science-fiction stories. Sadly, even if we had the means to get close to a black hole, it clearly wouldn’t be that simple or even very enjoyable. Or survivable. So, if you’re still pining for a visit after all these caveats, we have one final word:

Instead, we recommend you curl up here and watch Dr. Jeremy Schnittman, astrophysicist at NASA’s Goddard Space Flight Center, discuss the science behind the black hole in the 2014 movie “Interstellar.”

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Is Earth an Oddball?

4 min read

Pat Brennan

One of the strangest things in the cosmos might be – us.

Among the thousands of planets confirmed to be in orbit around other stars, we’ve found nothing quite like our home planet. Other planets in Earth’s size range? Sure, by the bushel. But also orbiting a star like our Sun, at a comparable distance? So far it’s just one, lonely example. The one beneath our feet.

A big part of this is likely to be the technical difficulty of finding a sister planet. Our telescopes, in space and on the ground, find planets around other stars by two main methods: wobbles and shadows.

The “wobble” method, or radial velocity, traces the subtle back-and-forth motion as orbiting planets tug their star this way, then that, because of gravity. The larger the tug, the “heavier” the planet — that is, the greater its mass.

In the search for shadows, planet-hunting telescopes wait for a tiny dip in starlight as a planet crosses the face of its star — a crossing known as a “transit.” The bigger the dip, the wider the planet.

In both cases, large planets are much easier to detect than small ones. And in the case of transits, small, rocky planets about the size of Earth show up much better against very small stars known as red dwarfs. In a sense, they cast a bigger shadow that blots out proportionally more of a small star’s light, so instruments like NASA’s TESS space telescope can more readily find them. A Sun-sized star won't dim as much when an Earth-size planet passes by, making their transits harder to detect.

And there’s another troubling issue: time. A planet orbiting a star at Earth’s distance from the Sun would take about 365 days to make one revolution – just like our planet's "year." But to confirm such an orbit, your telescope would have to stare at that star for, say, 365 days to catch even one transit — and to be sure it's truly a planet, you'll want to see at least two or three of these transit signals.

All of these difficulties have placed such planets largely out of reach for today’s instruments. We’ve found plenty of small, rocky planets, but they’re nearly all orbiting red dwarf stars.

In our galaxy, red dwarfs are far more common than larger yellow stars like our Sun. That still leaves room for billions of Sun-like stars and, maybe, a significant number of habitable, Earth-sized worlds circling them.

Or maybe not.

The apparent oddness of our home system doesn’t end with Earth. Our particular arrangement – small, rocky worlds in the nearest orbits, big gas giants farther out – also is something we haven’t yet detected in close parallel anywhere else. Whether this is because they are truly scarce or because they are hard to detect is unclear.

Jupiter takes one trip around the Sun every 12 years. But Jupiter-type planets in long orbits are comparatively rare around other stars, and that could be important. Theorists say Jupiter might well have cleared the way for Earth to become a habitable world, quite literally. The giant planet’s intense gravity could have hoovered up small rocky bits that might otherwise have smashed into

Earth, sterilizing it just as life was getting its start.

“The planetary systems we are finding do not look like our solar system,” said Jessie Christiansen, a research scientist at NASA’s Exoplanet Science Institute. “Is it important that our solar system is different? We don’t know yet.”

Christiansen, who studies exoplanet demographics, does not think “Earths” will turn out to be rare, but says scientific literature on the question “is all over the place.”

Far more data are needed, scientists tell us, to determine the frequency of planets similar to Earth in both size and circumstance.

Future space telescopes could examine the atmospheres of distant, rocky worlds for signs of oxygen, methane or carbon dioxide – in other words, an atmosphere that reminds us of home.

For now, we remain in the dark. Earth-like planets around Sun-like stars might be plentiful. Or, they could be the true oddballs of the galaxy.

Pat Brennan is a science writer for NASA's Exoplanet Exploration Program. He joined JPL in 2015 after a 30-year career as a newspaper journalist.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Telescope for NASA’s WFIRST Mission Advances to New Phase of Development

5 min read

Editor’s note, Sept. 23, 2020: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

On schedule to launch in the mid-2020s, NASA’s Wide Field Infrared Survey Telescope (WFIRST) mission will help uncover some of the biggest mysteries in the cosmos. The state-of-the-art telescope on the WFIRST spacecraft will play a significant role in this, providing the largest picture of the universe ever seen with the same depth and precision as the Hubble Space Telescope.

The telescope for WFIRST has successfully passed its preliminary design review, a major milestone for the mission. This means the telescope has met the performance, schedule, and budget requirements to advance to the next stage of development, where the team will finalize its design.

“It is an honor to work with such a dedicated and talented development team. Each individual has helped ensure the telescope is technically sound, safe, and capable of carrying out compelling science,” said Scott Smith, WFIRST telescope manager at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “It’s exciting to picture our new telescope out in space, exploring the universe, and we look forward to pushing the boundaries of human knowledge.”

WFIRST is leveraging existing hardware that was transferred to NASA, and the development is much further along at this point than it would be if the telescope had originated with WFIRST. While many of the inherited components are being modified or reconfigured to function as part of the final design, the telescope is already at a very advanced stage of design.

WFIRST is a high-precision survey mission that will advance our understanding of fundamental physics. WFIRST is similar to other space telescopes, like Spitzer and the James Webb Space Telescope, in that it will detect infrared light, which is invisible to human eyes. Earth’s atmosphere absorbs infrared light, which presents challenges for observatories on the ground. WFIRST has the advantage of flying in space, above the atmosphere.

The WFIRST telescope will collect and focus light using a primary mirror that is 2.4 meters in diameter. While it’s the same size as the Hubble Space Telescope’s main mirror, it is only one-fourth the weight, showcasing an impressive improvement in telescope technology.

The mirror gathers light and sends it on to a pair of science instruments. The spacecraft’s giant camera, the Wide Field Instrument (WFI), will enable astronomers to map the presence of mysterious dark matter, which is known only through its gravitational effects on normal matter. The WFI will also help scientists investigate the equally mysterious “dark energy,” which causes the universe’s expansion to accelerate. Whatever its nature, dark energy may hold the key to understanding the fate of the cosmos.

In addition, the WFI will survey our own galaxy to further our understanding of what planets orbit other stars, using the telescope’s ability to sense both smaller planets and more distant planets than any survey before (planets orbiting stars beyond our Sun are called “exoplanets“). This survey will help determine whether our solar system is common, unusual, or nearly unique in the galaxy. The WFI will have the same resolution as Hubble, yet has a field of view that is 100 times greater, combining excellent image quality with the power to conduct large surveys that would take Hubble hundreds of years to complete.

WFIRST’s Coronagraph Instrument (CGI) will directly image exoplanets by blocking out the light of their host stars. To date, astronomers have directly imaged only a small fraction of exoplanets, so WFIRST’s advanced techniques will expand our inventory and enable us to learn more about them. Results from the CGI will provide the first opportunity to observe and characterize exoplanets similar to those in our solar system, located between three and 10 times Earth’s distance from the Sun, or from about midway to Jupiter to about the distance of Saturn in our solar system. Studying the physical properties of exoplanets that are more similar to Earth will take us a step closer to discovering habitable planets.

“The science enabled by our telescope is extraordinary,” said Goddard’s Jeff Kruk, the WFIRST project scientist. “We are asking, ‘what is the fate of the universe?’ by looking at how the expansion of the universe is accelerating, and we are asking, ‘are we alone?’ by looking for exoplanets in neighboring planetary systems.”

“WFIRST will set out to address lofty questions and it is amazing to see our team come together with a robust technical solution to explore them,” said Smith. “I am grateful for all of our partners across the country that have contributed to mature this development, and I look forward to our future investigations in space with NASA’s next flagship mission.”

The team at Harris Corporation in Rochester, New York, the prime contractor for the telescope, is making significant strides in modifying the preexisting hardware for the spacecraft.

“Both mirrors are actively being shaped to the unique optical requirements of the telescope,” said Bill Gattle, president of Space Systems for L3Harris Technologies (Harris Corporation merged with L3 Technologies in July). “We’re very excited to be contributing to this world-class observatory and the groundbreaking science it will deliver.”

By Ashley BalzerNASA Goddard Space Flight Center

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Hubble Finds Water Vapor on Habitable-Zone Exoplanet for 1st Time

3 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Its size and surface gravity are much larger than Earth’s, and its radiation environment may be hostile, but a distant planet called K2-18b has captured the interest of scientists all over the world. For the first time, researchers have detected water vapor signatures in the atmosphere of a planet beyond our solar system that resides in the "habitable zone," the region around a star in which liquid water could potentially pool on the surface of a rocky planet.

Astronomers at the Center for Space Exochemistry Data at the University College London in the United Kingdom used data from NASA’s Hubble Space Telescope to find water vapor in the atmosphere of K2-18b, an exoplanet around a small red dwarf star about 110 light-years away in the constellation Leo. If confirmed by further studies, this will be the only exoplanet known to have both water in its atmosphere and temperatures that could sustain liquid water on a rocky surface. Liquid water would only be possible if the planet turns out to be terrestrial in nature, rather than resembling a small version of Neptune.

Given the high level of activity of its red dwarf star, K2-18b may be more hostile to life as we know it than Earth, as it is likely to be exposed to more high-energy radiation. The planet, discovered by NASA's Kepler Space Telescope in 2015, also has a mass eight times greater than Earth's. That means the surface gravity on this planet would be significantly higher than on our planet.

The team used archive data from 2016 and 2017 captured by Hubble and developed open-source algorithms to analyze the host star’s light filtered through K2-18b’s atmosphere. The results revealed the molecular signature of water vapor, and also suggest the presence of hydrogen and helium in the planet’s atmosphere.

The authors of the paper, published in Nature Astronomy, believe that other molecules, including nitrogen and methane, may be present but they remain undetectable with current observations. Further studies are required to estimate cloud coverage and the percentage of atmospheric water present. A paper from a different team of scientists using Hubble observations has been submitted to the Astronomical Journal.

K2-18b is one of hundreds of "super-Earths" — exoplanets with masses between those of Earth and Neptune — found by Kepler. NASA’s TESS mission is expected to detect hundreds more super-Earths in the coming years. The next generation of space telescopes, including the James Webb Space Telescope, will be able to characterize exoplanet atmospheres in more detail.

The Hubble Space Telescope is a project of international cooperation between ESA (the European Space Agency) and NASA.

Media Contact:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-1940claire.andreoli@nasa.gov

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

Hubble Space Telescope

Exoplanets

Stars Stories

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Follow That Planet! How Astronomers Chase New Worlds in TESS Data

12 min read

As pink liquid oozed around her shoes, astronomer Johanna Teske started to feel sick. She had been looking for new planets with the Planet Finder Spectrograph, an astronomical instrument resembling an industrial-sized refrigerator mounted to the Magellan II telescope. One night in October 2018, a hose leading to the instrument burst, causing pink coolant to spill onto sensitive parts of the instrument and the surrounding platform. Would Teske's search be ruined?

Teske uses the Magellan II telescope at Las Campanas Observatory in Chile to locate planets outside our solar system, or exoplanets, and find out what they are made of. To date, more than 4,000 exoplanets have been discovered, but science has shown that there must be billions, or even trillions, in our galaxy alone. NASA's newest planet hunter, the Transiting Exoplanet Survey Satellite (TESS), searches for possible planets around nearby bright stars.

Many teams of scientists around the world are currently combing through TESS data, choosing stars that could be promising to observe from the ground and booking time at powerful telescopes to follow up on new planet candidates. The race is on to see which of those TESS signals represent some sort of imposter, and which point to real new worlds.

As a NASA Hubble Postdoctoral Fellow at Carnegie Observatories in Pasadena, California, Teske was excited to join this race. Her group received NASA funding to look for planets with three times the radius of Earth or less, which would include oddball planets called "super-Earths." Super-Earths are thought to be rocky like Earth, but slightly bigger than our planet. In October 2018, Teske and colleagues began TESS follow-up observations for the first time. But about midway through their two-week run, during their clearest night, the pipe burst.

Could the pipe get fixed and the mess cleaned up soon enough to save the rest of Teske's observing time? Would she and her team gather any valuable data about exoplanets?

Teske's dramatic night in Chile isn't typical, but illustrates how searching for exoplanets from the ground can get complicated by Earthly concerns. Besides the occasional mechanical problem, astronomers must contend with wind, rain, snow, clouds and general atmospheric turbulence — any of which could ruin an entire night of sky watching. The Moon also presents challenges: While TESS stars are generally bright and can be observed during "bright time" – that is, when the Moon is about three-quarters full – astronomers looking at very faint stars or other galaxies must wait for "dark time" when there is little to no moonlight. And, since astronomers can only observe at night, they have to forgo sleep during hours of precious darkness.

But ground-based telescopes are essential for confirming the existence of planets that TESS and other space telescopes find, and for learning more about them. TESS, like the space-based planet-hunter Kepler, whose mission ended in 2018, stares at stars over periods of time, measuring how bright the star is every few minutes for weeks at a time. A dip in that brightness could represent an event called a "transit," in which a planet passes in front of its star. But the dip could just as well come from another star, or be another kind of transient phenomenon occurring on the star or within the detector electronics.

Scientists must turn to ground-based telescopes to figure this out. When Kepler was sending back data suggesting thousands of new planets, astronomers organized themselves to follow up on them, too. The results led to the realization that there are more planets than stars in the Milky Way.

“The brightness measurements from the spacecraft are only the first step,” said David Ciardi, astronomer at the California Institute of Technology, Pasadena. “You need a dedicated ground program to vet and clarify what you see. Without the ground data, you can’t understand what TESS has seen.”

In some cases, there may be data collected from a star in years past that contain the information necessary to confirm a planet candidate — such as in the case of TESS’s first confirmed planet Pi Mensae c. Otherwise, astronomers need fresh observations to learn all they can about these alien worlds.

And because they are accessible to human hands, ground-based telescopes can be upgraded, fixed and re-tooled much more easily than space observatories. In some cases, ground-based telescopes have higher resolution for taking images of stars than space telescopes.

“We have a lot of questions about every single planet,” said Lauren Weiss, the Parrent Postdoctoral Fellow at the University of Hawaii at Manoa. “There are a lot of small planets that we’re really excited about, but in order to answer all of these questions, we have to use a variety of new tools and techniques.”

Ground-based follow-up is more critical than ever now that astronomers are gearing up for NASA’s upcoming James Webb Space Telescope, which will study exoplanet atmospheres with greater sensitivity than any observatory yet. Webb will look for the fingerprints of chemicals in exoplanet atmospheres, including those allowing life as we know it to thrive. But because Webb will target many different scientific questions about the universe, it will only have a portion of its time for looking at exoplanets. Astronomers need to start finding the most promising targets now so that they’re ready to explore them further as soon as Webb starts operating.

But first, scientists need to be sure those planets are really there.

One of the first facts a scientist needs to know about a possible exoplanet is: Which star does the planet orbit? This fundamental puzzle piece isn’t immediately obvious from telescope data because all astronomers can see are individual pixels from the telescope camera, each corresponding to an area of the sky. If two stars appear extremely close to each other in these data, it may not be obvious which star seems to be dimming because of a transiting planet.

“The ground-based efforts can determine which star is the source of the signal,” said Knicole Colon, astronomer at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “That’s absolutely a major part of the ground-based follow-up: Which star is the host?”

Then, there’s a separate process of getting the mass of the planet. No one can put a planet on a scale. But a planet’s mass is often determined through the “radial velocity method”, or looking at how the star wobbles ever so slightly in response to the gravity of its planets. Currently, only ground-based telescopes are capable of exoplanet radial velocity measurements. Carnegie’s Planet Finder Spectrograph, which Teske uses at Las Campanas in Chile, is just one instrument that can determine a planet’s mass. The forthcoming NEID spectrograph, a collaboration between NASA and the National Science Foundation, at Kitt Peak Observatory in Arizona, is another example.

The mass of a planet is different from its size, which refers to its diameter. Scientists measure diameter by looking at how much the brightness of the host star dims during the transit.

Combining the size and the mass of the planet, scientists can determine its density — a big indicator of whether it is rocky, like Earth, gaseous, like Jupiter, or something in between, which would be unlike any of the planets we have in our solar system.

Astronomers also use Earth-based telescopes to thoroughly study the stars themselves to determine planet properties. Any size or mass measurement of a planet can only be calculated relative to the size and mass of its host star. And if the star is part of a double-star or multi-star system, that could change the calculations entirely unless astronomers can determine the fraction of light originating from other nearby stars, and factor it into their calculations.

With so many different properties of star and planet observations to consider, it often takes large groups of scientists working with different instruments to arrive at even a basic understanding of a planetary system.

“That’s why these teams are so big,” Weiss said. “Each of us has to address a very specific question, or set of questions, related to the validity of the planetary hypothesis, and the fundamental properties of the star and planet.”

A planet that Weiss helped discover, TOI-197b (also called HD 221416b), is a particularly good example of how a giant collaboration of people using observatories in space and on the ground can paint a picture of a new world. The study announcing it to the world, published in April 2019, was authored by more than 100 people representing five different continents. Astronomers found out a lot about the age and radius and mass of the star because of the special way they have been able to examine its properties.

“The star is ringing like a bell from internal pressure waves and gravity waves inside the star,” Weiss said. The study of these waves, called asteroseismology, is a powerful tool for characterizing a star.

Multiple observatories worldwide including Keck Observatory at Mauna Kea in Hawaii, where Weiss was situated, contributed observations. Dan Huber, the lead author, wrangled all of the different datasets together. Ashley Chontos at the University of Hawaii created a model to reconcile both the transit and radial velocity measurements. By matching their model to the observations, astronomers were able to put together a picture of the planet that could explain all of these different signals seen in all of the different telescopes.

Astronomers found that, at 63 times the mass of Earth, this planet is a little bit denser than Saturn. But they call it a “hot Saturn” because its orbit around its star is only 14 days (by contrast, Saturn makes a loop around our Sun every 29 years). There is nothing quite like it in our solar system.

So, what happened with Teske’s planet search after the burst pipe incident at Las Campanas? The search for new planets motivated her to snap into action. “Pretty quickly I moved into ‘how do we fix’ this mode,” she recalled. “It was a big team effort for sure.”

Fortunately, the observatory staff was able to resolve the issue in a few hours. After they finished mopping and carefully checked over the instrument, Teske and colleagues resumed their exploration of exoplanets that very night, and continued for the rest of their scheduled week. Despite overnight observing for about two weeks during the telescope run, Teske didn’t go home to Pasadena afterwards — she boarded a plane for Washington, D.C., where she ran a marathon.

Their observations from that trip helped scientists determine the mass of a planet around a star called HD 21749 or GJ 143. This so-called “sub-Neptune” planet is about 2.6 times the diameter of Earth and likely gaseous, but smaller than any gas giant in our solar system.

Combining the Las Campanas observations with data from TESS and archival data from the HARPS instrument at La Silla, Chile, astronomers were able to confirm this exoplanet and determine its mass, which is more than 20 times that of Earth.

“While we were looking at the data for that planet, we found that there is another planet in the same system around the same star; it’s about Earth’s size,” said Diana Dragomir, also a NASA Hubble Postdoctoral Fellow at MIT who was the first author on a study of this system, and part of the observing team with Teske at Las Campanas. “It’s a nice demonstration that TESS can indeed find Earth-size planets.”

During the same observing run, Teske and colleagues also got some measurements of Pi Mensae c, the very first planet confirmed in TESS data, that may help get a better handle on its mass. With more data left to sift through, discoveries may be yet to come from that same observing run in October 2018.

Since TESS recently turned its gaze to the northern hemisphere of the sky, the Chilean telescopes will be out of range for much of the next batch of data. That gives Teske and collaborators time to go back through what they've done so far, and figure out which southern TESS stars they want to keep following over the next two years. Their goal is to find out more about super-Earth and sub-Neptune exoplanet populations by establishing masses for such planets as precisely as possible.

At nearly 8,000 feet up, Las Campanas isn't high enough to make Teske feel dizzy from the altitude, but high enough that she might get out of breath from walking fast. A variety of wildlife, like foxes and rabbit-like animals called viscachas, sometimes approach the dome as Teske and her collaborators explore the galaxy. She knew she wanted to be an astronomer around age 10 or 11 when she saw the movie "Contact," based on the book by Carl Sagan, and related to the main character's drive and curiosity. Today, observing in Chile is one of Teske's favorite parts of her job.

"I am getting to see things that no one else is seeing. It's quiet, and it's just me and the stars," Teske said. "I hesitate to use the word 'magical' — but it's analogous to that."

By Elizabeth LandauNASA Headquarters, Washington

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Gets a Rare Look at a Rocky Exoplanet's Surface

6 min read

A new study using data from NASA's Spitzer Space Telescope provides a rare glimpse of conditions on the surface of a rocky planet orbiting a star beyond the Sun. The study, published today in the journal Nature, shows that the planet's surface may resemble those of Earth's Moon or Mercury: The planet likely has little to no atmosphere and could be covered in the same cooled volcanic material found in the dark areas of the Moon's surface, called mare.

Discovered in 2018 by NASA's Transiting Exoplanet Satellite Survey (TESS) mission, planet LHS 3844b is located 48.6 light-years from Earth and has a radius 1.3 times that of Earth. It orbits a small, cool type of star called an M dwarf — especially noteworthy because, as the most common and long-lived type of star in the Milky Way galaxy, M dwarfs may host a high percentage of the total number of planets in the galaxy.

TESS found the planet via the transit method, which involves detecting when the observed light of a parent star dims because of a planet orbiting between the star and Earth. Detecting light coming directly from a planet's surface — another method — is difficult because the star is so much brighter and drowns out the planet's light.

But during follow-up observations, Spitzer was able to detect light from the surface of LHS 3844b. The planet makes one full revolution around its parent star in just 11 hours. With such a tight orbit, LHS 3844b is most likely "tidally locked," which is when one side of a planet permanently faces the star. The star-facing side, or dayside, is about 1,410 degrees Fahrenheit (770 degrees Celsius). Being extremely hot, the planet radiates a lot of infrared light, and Spitzer is an infrared telescope. The planet's parent star is relatively cool (though still much hotter than the planet), making direct observation of LHS 3844b's dayside possible.

This observation marks the first time Spitzer data have been able to provide information about the atmosphere of a terrestrial world around an M dwarf.

By measuring the temperature difference between the planet's hot and cold sides, the team found that there is a negligible amount of heat being transferred between the two. If an atmosphere were present, hot air on the dayside would naturally expand, generating winds that would transfer heat around the planet. On a rocky world with little to no atmosphere, like the Moon, there is no air present to transfer heat.

"The temperature contrast on this planet is about as big as it can possibly be," said Laura Kreidberg, a researcher at the Harvard and Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and lead author of the new study. "That matches beautifully with our model of a bare rock with no atmosphere."

Understanding the factors that could preserve or destroy planetary atmospheres is part of how scientists plan to search for habitable environments beyond our solar system. Earth's atmosphere is the reason liquid water can exist on the surface, enabling life to thrive. On the other hand, the atmospheric pressure of Mars is now less than 1% of Earth's, and the oceans and rivers that once dotted the Red Planet's surface have disappeared.

"We've got lots of theories about how planetary atmospheres fare around M dwarfs, but we haven't been able to study them empirically," Kreidberg said. "Now, with LHS 3844b, we have a terrestrial planet outside our solar system where for the first time we can determine observationally that an atmosphere is not present."

Compared to Sun-like stars, M dwarfs emit high levels of ultraviolet light (though less light overall), which is harmful to life and can erode a planet's atmosphere. They're particularly violent in their youth, belching up a large number of flares, or bursts of radiation and particles that could strip away budding planetary atmospheres.

The Spitzer observations rule out an atmosphere with more than 10 times the pressure of Earth's. (Measured in units called bars, Earth's atmospheric pressure at sea level is about 1 bar.) An atmosphere between 1 and 10 bars on LHS 3844b has been almost entirely ruled out as well, although the authors note there's a slim chance it could exist if the stellar and planetary properties were to meet some very specific and unlikely criteria. They also argue that with the planet so close to a star, a thin atmosphere would be stripped away by the star's intense radiation and outflow of material (often called stellar winds).

"I'm still hopeful that other planets around M dwarfs could keep their atmospheres," Kreidberg said. "The terrestrial planets in our solar system are enormously diverse, and I expect the same will be true for exoplanet systems."

Spitzer and NASA's Hubble Space Telescope have previously gathered information about the atmospheres of multiple gas planets, but LHS 3844b appears to be the smallest planet for which scientists have used the light coming from its surface to learn about its atmosphere (or lack thereof). Spitzer previously used the transit method to study the seven rocky worlds around the TRAPPIST-1 star (also an M dwarf) and learn about their possible overall composition; for instance, some of them likely contain water ice.

The authors of the new study went one step further, using LHS 3844b's surface albedo (or its reflectiveness) to try to infer its composition.

The Nature study shows that LHS 3844b is "quite dark," according to co-author Renyu Hu, an exoplanet scientist at NASA's Jet Propulsion Laboratory in Pasadena, California, which manages the Spitzer Space Telescope. He and his co-authors believe the planet is covered with basalt, a kind of volcanic rock. "We know that the mare of the Moon are formed by ancient volcanism," Hu said, "and we postulate that this might be what has happened on this planet."

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Space operations are based at Lockheed Martin Space in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

For more information on Spitzer, visit:

www.nasa.gov/spitzer

www.spitzer.caltech.edu

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

2019-166

Discovery Alert: Rocky Planet Swelters Under Three Red Suns

2 min read

Alicia Cermak

Planet: LTT 1445 A b

The discovery: This overheated planet, about 1.4 times as big around as Earth, has a sky that one-ups Star Wars' Tatooine – three stars instead of two. It is one of 12 recent discoveries just added to NASA's Exoplanet Archive, and was found by a Harvard Center for Astrophysics team using data from the TESS space telescope.

Date: July 26, 2019

Key facts: Likely a rocky planet, LTT 1445 A b takes only five days to go once around its star – a "year" on this world, which is about 22 light-years away from Earth. Its scorchingly close orbit helps explain why its surface basks in temperatures on the order of 320 degrees Fahrenheit (160 Celsius) – comparable to a preheated oven.

Details: While the planet itself remains in what is probably a stable orbit around its star, that star also orbits, at greater distance, two sibling stars that are locked in close orbit around each other. This isn't the first three-star system to be found with at least one planet. Our nearest stellar neighbor, in fact, is Proxima Centauri, orbiting the more distant pair, Alpha Centauri A and B. Proxima is only 4.25 light-years away from Earth. In orbit around it is Proxima b, a small, probably rocky world that takes an estimated 11 days to circle its star.

Fun facts: All three stars in the LTT 1445 system are red dwarfs, cooler and far longer-burning than larger yellow stars like our Sun. The planet also is the second-closest discovered so far that "transits" its star – that is, the orbit of LTT 1445 A b is tilted at the correct angle to, from our vantage point, pass across the face of its star. The "transit" observing method allows space telescopes like TESS to detect planets orbiting other stars by the shadows they cast – the tiny dip in starlight as the planet makes its crossing.

The very nearest transiting planetary system so far discovered is HD 219134 bc, about 21 light-years away.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Follow That Planet! How Astronomers Chase New Worlds in TESS Data

12 min read

Elizabeth Landau

As pink liquid oozed around her shoes, astronomer Johanna Teske started to feel sick. She had been looking for new planets with the Planet Finder Spectrograph, an astronomical instrument resembling an industrial-sized refrigerator mounted to the Magellan II telescope. One night in October 2018, a hose leading to the instrument burst, causing pink coolant to spill onto sensitive parts of the instrument and the surrounding platform. Would Teske's search be ruined?

As a NASA Hubble Postdoctoral Fellow at Carnegie Observatories in Pasadena, California, Teske was excited to join this race. Her group received NASA funding to look for planets with three times the radius of Earth or less, which would include oddball planets called "super-Earths." Super-Earths are thought to be rocky like Earth, but slightly bigger than our planet. In October 2018, Teske and colleagues began TESS follow-up observations for the first time. But about midway through their two-week run, during their clearest night, the pipe burst.

Could the pipe get fixed and the mess cleaned up soon enough to save the rest of Teske's observing time? Would she and her team gather any valuable data about exoplanets?

Teske's dramatic night in Chile isn't typical, but illustrates how searching for exoplanets from the ground can get complicated by Earthly concerns. Besides the occasional mechanical problem, astronomers must contend with wind, rain, snow, clouds and general atmospheric turbulence — any of which could ruin an entire night of sky watching. The Moon also presents challenges: While TESS stars are generally bright and can be observed during "bright time" – that is, when the Moon is about three-quarters full – astronomers looking at very faint stars or other galaxies must wait for "dark time" when there is little to no moonlight. And, since astronomers can only observe at night, they have to forgo sleep during hours of precious darkness.

But ground-based telescopes are essential for confirming the existence of planets that TESS and other space telescopes find, and for learning more about them. TESS, like the space-based planet-hunter Kepler, whose mission ended in 2018, stares at stars over periods of time, measuring how bright the star is every few minutes for weeks at a time. A dip in that brightness could represent an event called a "transit," in which a planet passes in front of its star. But the dip could just as well come from another star, or be another kind of transient phenomenon occurring on the star or within the detector electronics.

Scientists must turn to ground-based telescopes to figure this out. When Kepler was sending back data suggesting thousands of new planets, astronomers organized themselves to follow up on them, too. The results led to the realization that there are more planets than stars in the Milky Way.

"The brightness measurements from the spacecraft are only the first step," said David Ciardi, astronomer at the California Institute of Technology, Pasadena. "You need a dedicated ground program to vet and clarify what you see. Without the ground data, you can't understand what TESS has seen."

In some cases, there may be data collected from a star in years past that contain the information necessary to confirm a planet candidate — such as in the case of TESS' first confirmed planet Pi Mensae c. Otherwise, astronomers need fresh observations to learn all they can about these alien worlds.

And because they are accessible to human hands, ground-based telescopes can be upgraded, fixed and re-tooled much more easily than space observatories. In some cases, ground-based telescopes have higher resolution for taking images of stars than space telescopes.

"We have a lot of questions about every single planet," said Lauren Weiss, the Parrent Postdoctoral Fellow at the University of Hawaii at Manoa. "There are a lot of small planets that we're really excited about, but in order to answer all of these questions, we have to use a variety of new tools and techniques."

Ground-based follow-up is more critical than ever now that astronomers are gearing up for NASA's upcoming James Webb Space Telescope, which will study exoplanet atmospheres with greater sensitivity than any observatory yet. Webb will look for the fingerprints of chemicals in exoplanet atmospheres, including those allowing life as we know it to thrive. But because Webb will target many different scientific questions about the universe, it will only have a portion of its time for looking at exoplanets. Astronomers need to start finding the most promising targets now so that they're ready to explore them further as soon as Webb starts operating.

But first, scientists need to be sure those planets are really there.

One of the first facts a scientist needs to know about a possible exoplanet is: Which star does the planet orbit? This fundamental puzzle piece isn't immediately obvious from telescope data because all astronomers can see are individual pixels from the telescope camera, each corresponding to an area of the sky. If two stars appear extremely close to each other in these data, it may not be obvious which star seems to be dimming because of a transiting planet.

"The ground-based efforts can determine which star is the source of the signal," said Knicole Colon, astronomer at NASA's Goddard Space Flight Center, Greenbelt, Maryland. "That's absolutely a major part of the ground-based follow-up: Which star is the host?"

Then, there's a separate process of getting the mass of the planet. No one can put a planet on a scale. But a planet's mass is often determined through the "radial velocity method," or looking at how the star wobbles ever so slightly in response to the gravity of its planets. Currently, only ground-based telescopes are capable of exoplanet radial velocity measurements. Carnegie's Planet Finder Spectrograph, which Teske uses at Las Campanas in Chile, is just one instrument that can determine a planet's mass. The forthcoming NEID spectrograph, a collaboration between NASA and the National Science Foundation, at Kitt Peak Observatory in Arizona, is another example.

The mass of a planet is different from its size, which refers to its diameter. Scientists measure diameter by looking at how much the brightness of the host star dims during the transit.Combining the size and the mass of the planet, scientists can determine its density – a big indicator of whether it is rocky, like Earth, gaseous, like Jupiter, or something in between, which would be unlike any of the planets we have in our solar system.

Astronomers also use Earth-based telescopes to thoroughly study the stars themselves to determine planet properties. Any size or mass measurement of a planet can only be calculated relative to the size and mass of its host star. And if the star is part of a double-star or multi-star system, that could change the calculations entirely unless astronomers can determine the fraction of light originating from other nearby stars, and factor it into their calculations.

With so many different properties of star and planet observations to consider, it often takes large groups of scientists working with different instruments to arrive at even a basic understanding of a planetary system.

"That's why these teams are so big," Weiss said. "Each of us has to address a very specific question, or set of questions, related to the validity of the planetary hypothesis, and the fundamental properties of the star and planet."

A planet that Weiss helped discover, TOI-197b (also called HD 221416b), is a particularly good example of how a giant collaboration of people using observatories in space and on the ground can paint a picture of a new world. The study announcing it to the world, published in April 2019, was authored by more than 100 people representing five different continents. Astronomers found out a lot about the age and radius and mass of the star because of the special way they have been able to examine its properties.

"The star is ringing like a bell from internal pressure waves and gravity waves inside the star," Weiss said. The study of these waves, called asteroseismology, is a powerful tool for characterizing a star.

Multiple observatories worldwide including Keck Observatory at Mauna Kea in Hawaii, where Weiss was situated, contributed observations. Dan Huber, the lead author, wrangled all of the different datasets together. Ashley Chontos at the University of Hawaii created a model to reconcile both the transit and radial velocity measurements. By matching their model to the observations, astronomers were able to put together a picture of the planet that could explain all of these different signals seen in all of the different telescopes.

Astronomers found that, at 63 times the mass of Earth, this planet is a little bit denser than Saturn. But they call it a "hot Saturn" because its orbit around its star is only 14 days (by contrast, Saturn makes a loop around our Sun every 29 years). There is nothing quite like it in our solar system.

So, what happened with Teske's planet search after the burst pipe incident at Las Campanas? The search for new planets motivated her to snap into action. "Pretty quickly I moved into 'how do we fix' this mode," she recalled. "It was a big team effort for sure."

Fortunately, the observatory staff was able to resolve the issue in a few hours. After they finished mopping and carefully checked over the instrument, Teske and colleagues resumed their exploration of exoplanets that very night, and continued for the rest of their scheduled week. Despite overnight observing for about two weeks during the telescope run, Teske didn't go home to Pasadena afterward — she boarded a plane for Washington, D.C., where she ran a marathon.

Their observations from that trip helped scientists determine the mass of a planet around a star called HD 21749 or GJ 143. This so-called "sub-Neptune" planet is about 2.6 times the diameter of Earth and likely gaseous, but smaller than any gas giant in our solar system.

Combining the Las Campanas observations with data from TESS and archival data from the HARPS instrument at La Silla, Chile, astronomers were able to confirm this exoplanet and determine its mass, which is more than 20 times that of Earth.

"While we were looking at the data for that planet, we found that there is another planet in the same system around the same star; it's about Earth's size," said Diana Dragomir, also a NASA Hubble Postdoctoral Fellow at MIT who was the first author on a study of this system, and part of the observing team with Teske at Las Campanas. "It's a nice demonstration that TESS can indeed find Earth-size planets."

During the same observing run, Teske and colleagues also got some measurements of Pi Mensae c, the very first planet confirmed in TESS data, that may help get a better handle on its mass. With more data left to sift through, discoveries may be yet to come from that same observing run in October 2018.

Since TESS recently turned its gaze to the Northern Hemisphere of the sky, the Chilean telescopes will be out of range for much of the next batch of data. That gives Teske and collaborators time to go back through what they've done so far, and figure out which southern TESS stars they want to keep following over the next two years. Their goal is to find out more about super-Earth and sub-Neptune exoplanet populations by establishing masses for such planets as precisely as possible.

At nearly 8,000 feet up, Las Campanas isn't high enough to make Teske feel dizzy from the altitude, but high enough that she might get out of breath from walking fast. A variety of wildlife, like foxes and rabbit-like animals called viscachas, sometimes approach the dome as Teske and her collaborators explore the galaxy. She knew she wanted to be an astronomer around age 10 or 11 when she saw the movie "Contact," based on the book by Carl Sagan, and related to the main character's drive and curiosity. Today, observing in Chile is one of Teske's favorite parts of her job.

"I am getting to see things that no one else is seeing. t's quiet, and it's just me and the stars," Teske said. "I hesitate to use the word 'magical' – but it’s analogous to that."

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Uncovers a ‘Heavy Metal’ Exoplanet Shaped Like a Football

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

How can a planet be "hotter than hot?" The answer is when heavy metals are detected escaping from the planet's atmosphere, instead of condensing into clouds.

Observations by NASA's Hubble Space Telescope reveal magnesium and iron gas streaming from the strange world outside our solar system known as WASP-121b. The observations represent the first time that so-called "heavy metals"—elements heavier than hydrogen and helium—have been spotted escaping from a hot Jupiter, a large, gaseous exoplanet very close to its star.

Normally, hot Jupiter-sized planets are still cool enough inside to condense heavier elements such as magnesium and iron into clouds.

But that's not the case with WASP-121b, which is orbiting so dangerously close to its star that its upper atmosphere reaches a blazing 4,600 degrees Fahrenheit. The WASP-121 system resides about 900 light-years from Earth."Heavy metals have been seen in other hot Jupiters before, but only in the lower atmosphere," explained lead researcher David Sing of the Johns Hopkins University in Baltimore, Maryland. "So you don't know if they are escaping or not. With WASP-121b, we see magnesium and iron gas so far away from the planet that they're not gravitationally bound."

Ultraviolet light from the host star, which is brighter and hotter than the Sun, heats the upper atmosphere and helps lead to its escape. In addition, the escaping magnesium and iron gas may contribute to the temperature spike, Sing said. "These metals will make the atmosphere more opaque in the ultraviolet, which could be contributing to the heating of the upper atmosphere," he explained.

The sizzling planet is so close to its star that it is on the cusp of being ripped apart by the star's gravity. This hugging distance means that the planet is football shaped due to gravitational tidal forces.

"We picked this planet because it is so extreme," Sing said. "We thought we had a chance of seeing heavier elements escaping. It's so hot and so favorable to observe, it's the best shot at finding the presence of heavy metals. We were mainly looking for magnesium, but there have been hints of iron in the atmospheres of other exoplanets. It was a surprise, though, to see it so clearly in the data and at such great altitudes so far away from the planet. The heavy metals are escaping partly because the planet is so big and puffy that its gravity is relatively weak. This is a planet being actively stripped of its atmosphere."

The researchers used the observatory's Space Telescope Imaging Spectrograph to search in ultraviolet light for the spectral signatures of magnesium and iron imprinted on starlight filtering through WASP-121b's atmosphere as the planet passed in front of, or transited, the face of its home star.

This exoplanet is also a perfect target for NASA's upcoming James Webb Space Telescope to search in infrared light for water and carbon dioxide, which can be detected at longer, redder wavelengths. The combination of Hubble and Webb observations would give astronomers a more complete inventory of the chemical elements that make up the planet's atmosphere.

The WASP-121b study is part of the Panchromatic Comparative Exoplanet Treasury (PanCET) survey, a Hubble program to look at 20 exoplanets, ranging in size from super-Earths (several times Earth's mass) to Jupiters (which are over 100 times Earth's mass), in the first large-scale ultraviolet, visible, and infrared comparative study of distant worlds.

The observations of WASP-121b add to the developing story of how planets lose their primordial atmospheres. When planets form, they gather an atmosphere containing gas from the disk in which the planet and star formed. These atmospheres consist mostly of the primordial, lighter-weight gases hydrogen and helium, the most plentiful elements in the universe. This atmosphere dissipates as a planet moves closer to its star.

"The hot Jupiters are mostly made of hydrogen, and Hubble is very sensitive to hydrogen, so we know these planets can lose the gas relatively easily," Sing said. "But in the case of WASP-121b, the hydrogen and helium gas is outflowing, almost like a river, and is dragging these metals with them. It's a very efficient mechanism for mass loss."

The results will appear online today in The Astronomical Journal.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Maryland301-286-1940claire.andreoli@nasa.gov

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

David SingJohns Hopkins University, Baltimore, Marylanddsing@jhu.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Shining (Star)light on the Search for Life

7 min read

UPDATE, Aug. 12, 2019: The Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet experiment, or SISTINE, was launched at 2:07 a.m. EDT, Sunday, Aug.11, from the White Sands Missile Range in New Mexico. The experiment flew to an altitude of 161 miles before descending by parachute. The experiment was recovered. The science team is conducting post flight analysis to determine the experiment's performance.

UPDATE, Aug. 6, 2019: The Aug. 5 launch attempt of the SISTINE mission was postponed due to winds. The launch has been rescheduled for Aug. 11 at 2:01 a.m. EDT.

In the hunt for life on other worlds, astronomers scour over planets that are light-years away. They need ways to identify life from afar — but what counts as good evidence?

Our own planet provides some inspiration. Microbes fill the air with methane; photosynthesizing plants expel oxygen. Perhaps these gases might be found wherever life has taken hold.

But on worlds very different from our own, putative signs of life can be stirred up by non-biological processes. To know a true sign when you see it, astronomer Kevin France at the University of Colorado, Boulder, says, you must look beyond the planet itself, all the way to the gleaming star it orbits.

To this end, France and his team designed the SISTINE mission. Flying on a sounding rocket for a 15-minute flight, it will observe far-off stars to help interpret signs of life on the planets that orbit them. The mission will launch from the White Sands Missile Range in New Mexico in the early morning hours of Aug. 5, 2019.

Shortly after Earth formed 4.6 billion years ago, it was enveloped by a noxious atmosphere. Volcanoes spewed methane and sulfur. The air teemed with up to 200 times more carbon dioxide than today's levels.

It wasn't for another billion and a half years that molecular oxygen, which contains two oxygen atoms, entered the scene. It was a waste product, discarded by ancient bacteria through photosynthesis. But it kick-started what became known as the Great Oxidization Event, permanently changing Earth's atmosphere and paving the way for more complex lifeforms.

"We would not have large amounts of oxygen in our atmosphere if we didn't have that surface life," France said.

Oxygen is known as a biomarker: a chemical compound associated with life. Its presence in Earth's atmosphere hints at the lifeforms lurking below. But as sophisticated computer models have now shown, biomarkers on Earth aren't always so trustworthy for exoplanets, or planets orbiting stars elsewhere in the universe.

France points to M-dwarf stars to make this case. Smaller and colder than our Sun, M-dwarfs account for nearly three-quarters of the Milky Way's stellar population. To understand exoplanets that orbit them, scientists simulated Earth-sized planets circling M-dwarfs. Differences from Earth quickly emerged.

M-dwarfs generate intense ultraviolet light. When that light struck the simulated Earth-like planet, it ripped the carbon from carbon dioxide, leaving behind free molecular oxygen. UV light also broke up molecules of water vapor, releasing single oxygen atoms. The atmospheres created oxygen — but without life.

“We call these false-positive biomarkers,” France said. “You can produce oxygen on an Earth-like planet through photochemistry alone.”

Earth’s low oxygen levels without life were a kind of fluke – thanks, in part, to our interaction with our Sun. Exoplanet systems with different stars might be different. “If we think we understand a planet’s atmosphere but don’t understand the star it orbits, we’re probably going to get things wrong,” France said.

France and his team designed SISTINE to better understand host stars and their effects on exoplanet atmospheres. Short for Suborbital Imaging Spectrograph for Transition region Irradiance from Nearby Exoplanet host stars, SISTINE measures the high-energy radiation from these stars. With knowledge about host stars’ spectra, scientists can better distinguish true biomarkers from false-positives on their orbiting planets.

To make these measurements, SISTINE uses a spectrograph, an instrument that separates light into its component parts.

“Spectra are like fingerprints,” said Jane Rigby, an astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, who uses the methodology. “It’s how we find out what things are made of, both on our planet and as we look out into the universe.”

SISTINE measures spectra in wavelengths from 100 to 160 nanometers, a range of far-UV light that, among other things, can create oxygen, possibly generating a false-positive. Light output in this range varies with the mass of the star — meaning stars of different masses will almost surely differ from our Sun.

SISTINE can also measure flares, or bright stellar explosions, which release intense doses of far-UV light all at once. Frequent flares could turn a habitable environment into a lethal one.

The SISTINE mission will fly on a Black Brant IX sounding rocket. Sounding rockets make short, targeted flights into space before falling back to Earth; SISTINE’s flight gives it about five minutes observing time. Though brief, SISTINE can see stars in wavelengths inaccessible to observatories like the Hubble Space Telescope.

Two launches are scheduled. The first, from White Sands in August, will calibrate the instrument. SISTINE will fly 174 miles above Earth’s surface to observe NGC 6826, a cloud of gas surrounding a white dwarf star located about 2,000 light-years away in the constellation Cygnus. NGC 6826 is bright in UV light and shows sharp spectral lines — a clear target for checking their equipment.

After calibration, the second launch will follow in 2020 from the Arnhem Space Centre in Nhulunbuy, Australia. There they will observe the UV spectra of Alpha Centauri A and B, the two largest stars in the three-star Alpha Centauri system. At 4.37 light-years away, these stars are our closest stellar neighbors and prime targets for exoplanet observations. (The system is home to Proxima Centauri B, the closest exoplanet to Earth.)

Both SISTINE’s observations and the technology used to acquire them are designed with future missions in mind.

One is NASA’s James Webb Space Telescope, currently set to launch in 2021. The deep space observatory will see visible to mid-infrared light — useful for detecting exoplanets orbiting M-dwarfs. SISTINE observations can help scientists understand the light from these stars in wavelengths that Webb can’t see.

SISTINE also carries novel UV detector plates and new optical coatings on its mirrors, designed to help them better reflect rather than absorb extreme UV light. Flying this technology on SISTINE helps test them for NASA’s future large UV/optical space telescopes.

By capturing stellar spectra and advancing technology for future missions, SISTINE links what we know with what we've yet to learn. That's when the real work starts. "Our job as astronomers is to piece those different data sets together to tell a complete story," Rigby said.

Banner Image: An artist's conception of an Earth-like exoplanet. Credits: NASA/GSFC/C. Meaney/B. Monroe/S. Wiessinger

Related:

By Miles HatfieldNASA's Goddard Space Flight Center, Greenbelt, Md.

Missions

Humans in Space

Climate Change

Solar System

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Confirmation of Toasty TESS Planet Leads to Surprising Find of Promising World

5 min read

A piping hot planet discovered by NASA’s Transiting Exoplanet Survey Satellite (TESS) has pointed the way to additional worlds orbiting the same star, one of which is located in the star’s habitable zone. If made of rock, this planet may be around twice Earth’s size.

The new worlds orbit a star named GJ 357, an M-type dwarf about one-third the Sun’s mass and size and about 40% cooler that our star. The system is located 31 light-years away in the constellation Hydra. In February, TESS cameras caught the star dimming slightly every 3.9 days, revealing the presence of a transiting exoplanet — a world beyond our solar system — that passes across the face of its star during every orbit and briefly dims the star’s light.

“In a way, these planets were hiding in measurements made at numerous observatories over many years,” said Rafael Luque, a doctoral student at the Institute of Astrophysics of the Canary Islands (IAC) on Tenerife who led the discovery team. “It took TESS to point us to an interesting star where we could uncover them.”

The transits TESS observed belong to GJ 357 b, a planet about 22% larger than Earth. It orbits 11 times closer to its star than Mercury does our Sun. This gives it an equilibrium temperature — calculated without accounting for the additional warming effects of a possible atmosphere — of around 490 degrees Fahrenheit (254 degrees Celsius).

“We describe GJ 357 b as a ‘hot Earth,’” explains co-author Enric Pallé, an astrophysicist at the IAC and Luque’s doctoral supervisor. “Although it cannot host life, it is noteworthy as the third-nearest transiting exoplanet known to date and one of the best rocky planets we have for measuring the composition of any atmosphere it may possess.”

But while researchers were looking at ground-based data to confirm the existence of the hot Earth, they uncovered two additional worlds. The farthest-known planet, named GJ 357 d, is especially intriguing.

“GJ 357 d is located within the outer edge of its star’s habitable zone, where it receives about the same amount of stellar energy from its star as Mars does from the Sun,” said co-author Diana Kossakowski at the Max Planck Institute for Astronomy in Heidelberg, Germany. “If the planet has a dense atmosphere, which will take future studies to determine, it could trap enough heat to warm the planet and allow liquid water on its surface.”

Without an atmosphere, it has an equilibrium temperature of -64 F (-53 C), which would make the planet seem more glacial than habitable. The planet weighs at least 6.1 times Earth’s mass, and orbits the star every 55.7 days at a range about 20% of Earth’s distance from the Sun. The planet’s size and composition are unknown, but a rocky world with this mass would range from about one to two times Earth’s size.

Even through TESS monitored the star for about a month, Luque’s team predicts any transit would have occurred outside the TESS observing window.

GJ 357 c, the middle planet, has a mass at least 3.4 times Earth’s, orbits the star every 9.1 days at a distance a bit more than twice that of the transiting planet, and has an equilibrium temperature around 260 F (127 C). TESS did not observe transits from this planet, which suggests its orbit is slightly tilted — perhaps by less than 1 degree — relative to the hot Earth’s orbit, so it never passes across the star from our perspective.

To confirm the presence of GJ 357 b and discover its neighbors, Luque and his colleagues turned to existing ground-based measurements of the star's radial velocity, or the speed of its motion along our line of sight. An orbiting planet produces a gravitational tug on its star, which results in a small reflex motion that astronomers can detect through tiny color changes in the starlight. Astronomers have searched for planets around bright stars using radial velocity data for decades, and they often make these lengthy, precise observations publicly available for use by other astronomers.

Luque's team examined ground-based data stretching back to 1998 from the European Southern Observatory and the Las Campanas Observatory in Chile, the W.M. Keck Observatory in Hawaii, and the Calar Alto Observatory in Spain, among many others.

A paper describing the findings was published on Wednesday, July 31, in the journal Astronomy & Astrophysics and is available online.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Center in California's Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT's Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

By Francis ReddyNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Confirmation of Toasty TESS Planet Leads to Surprising Find of Promising World

5 min read

NASA Science Editorial Team

A piping hot planet discovered by NASA's Transiting Exoplanet Survey Satellite (TESS) has pointed the way to additional worlds orbiting the same star, one of which is located in the star's habitable zone. If made of rock, this planet may be around twice Earth's size.

The new worlds orbit a star named GJ 357, an M-type dwarf about one-third the Sun's mass and size and about 40% cooler that our star. The system is located 31 light-years away in the constellation Hydra. In February, TESS cameras caught the star dimming slightly every 3.9 days, revealing the presence of a transiting exoplanet — a world beyond our solar system — that passes across the face of its star during every orbit and briefly dims the star's light.

"In a way, these planets were hiding in measurements made at numerous observatories over many years," said Rafael Luque, a doctoral student at the Institute of Astrophysics of the Canary Islands (IAC) on Tenerife who led the discovery team. "It took TESS to point us to an interesting star where we could uncover them."

The transits TESS observed belong to GJ 357 b, a planet about 22% larger than Earth. It orbits 11 times closer to its star than Mercury does our Sun. This gives it an equilibrium temperature — calculated without accounting for the additional warming effects of a possible atmosphere — of around 490 degrees Fahrenheit (254 degrees Celsius).

"We describe GJ 357 b as a 'hot Earth,'" explains co-author Enric Pallé, an astrophysicist at the IAC and Luque's doctoral supervisor. "Although it cannot host life, it is noteworthy as the third-nearest transiting exoplanet known to date and one of the best rocky planets we have for measuring the composition of any atmosphere it may possess."

But while researchers were looking at ground-based data to confirm the existence of the hot Earth, they uncovered two additional worlds. The farthest-known planet, named GJ 357 d, is especially intriguing.

"GJ 357 d is located within the outer edge of its star's habitable zone, where it receives about the same amount of stellar energy from its star as Mars does from the Sun," said co-author Diana Kossakowski at the Max Planck Institute for Astronomy in Heidelberg, Germany. "If the planet has a dense atmosphere, which will take future studies to determine, it could trap enough heat to warm the planet and allow liquid water on its surface."

Without an atmosphere, it has an equilibrium temperature of -64 F (-53 C), which would make the planet seem more glacial than habitable. The planet weighs at least 6.1 times Earth's mass, and orbits the star every 55.7 days at a range about 20% of Earth's distance from the Sun. The planet's size and composition are unknown, but a rocky world with this mass would range from about one to two times Earth's size.

Even through TESS monitored the star for about a month, Luque's team predicts any transit would have occurred outside the TESS observing window.

GJ 357 c, the middle planet, has a mass at least 3.4 times Earth's, orbits the star every 9.1 days at a distance a bit more than twice that of the transiting planet, and has an equilibrium temperature around 260 F (127 C). TESS did not observe transits from this planet, which suggests its orbit is slightly tilted — perhaps by less than 1 degree — relative to the hot Earth’s orbit, so it never passes across the star from our perspective.

To confirm the presence of GJ 357 b and discover its neighbors, Luque and his colleagues turned to existing ground-based measurements of the star’s radial velocity, or the speed of its motion along our line of sight. An orbiting planet produces a gravitational tug on its star, which results in a small reflex motion that astronomers can detect through tiny color changes in the starlight. Astronomers have searched for planets around bright stars using radial velocity data for decades, and they often make these lengthy, precise observations publicly available for use by other astronomers.

Luque’s team examined ground-based data stretching back to 1998 from the European Southern Observatory and the Las Campanas Observatory in Chile, the W.M. Keck Observatory in Hawaii, and the Calar Alto Observatory in Spain, among many others.

A paper describing the findings was published on Wednesday, July 31, in the journal Astronomy & Astrophysics and is available online.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Discovery Alert: Finding Planets Where They Shouldn't Be

3 min read

Pat Brennan

Planets: K2-146 b and c

The discoveries: Planet b, found by multiple science teams, was announced in 2018. A team led by astronomers at the University of Chicago announced the discovery of planet c in a just-published paper. Both discoveries relied on data from NASA's Kepler space telescope.

Date: The latest paper, from a team led by Aaron Hamann and Benjamin Montet, was published in July 2019.

Key facts: Both planets belong to a strange class known as "mini-Neptunes" (or sub-Neptunes) and orbit a red-dwarf star about 260 light-years from Earth. They orbit their small star very tightly: A "year" on planet b, once around its star, takes only 2.6 days, with a 4-day year for planet c. These planets are likely too hot to be habitable.

Details: The strangeness doesn't stop there. These planets are so close together they jostle each other's orbits because of mutual gravitational influence. This allowed unusually precise measurements of their masses and density. That led to another shock: Both are likely to possess thick or watery atmospheres. And in their size class, they seem to be outliers.

Astronomers have discovered a gap in planet size, or radius, between about 1.5 and two times Earth's size, that shows up in statistical samples of the thousands of planets found so far in our Milky Way galaxy. Both these planets are considered to fall near the gap. And based on their size and closeness to their parent star, they should not have held onto their atmospheres; a conventional analysis suggests that, instead, their atmospheres should have been stripped away by early blasts of stellar radiation.

What's next: These planets might be teaching us something new about the "gap" in planet sizes. The gap might shift back and forth, to larger or smaller planets, depending on the type of star the planets orbit. For red-dwarf stars, the gap might span a different size-range than it does for larger yellow stars like our Sun. This also could change our understanding of which planets are likely to retain their atmospheres as their systems change over time, and which are not.

Fun fact: These planets really do jostle each other's orbits. In fact, Montet said, the discoverers of planet b missed seeing planet c because, during the 2015 data gathering period, its orbit was not oriented correctly. From the vantage point of the Kepler space telescope, planet c did not quite cross the face of its parent star, so its "shadow" could not be easily revealed. But just two years later, planet c had been "torqued" into position by gravitational jostling. Now it was clearly cutting across the star's face, and could be readily observed by the University of Chicago team. It was the first time such a dramatic change in orbit had been observed.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Mission Scores ‘Hat Trick’ With 3 New Worlds

5 min read

NASA’s newest planet hunter, the Transiting Exoplanet Survey Satellite (TESS), has discovered three new worlds — one slightly larger than Earth and two of a type not found in our solar system — orbiting a nearby star. The planets straddle an observed gap in the sizes of known planets and promise to be among the most curious targets for future studies.

TESS Object of Interest (TOI) 270 is a faint, cool star more commonly identified by its catalog name: UCAC4 191-004642. The M-type dwarf star is about 40% smaller than the Sun in both size and mass, and it has a surface temperature about one-third cooler than the Sun’s. The planetary system lies about 73 light-years away in the southern constellation of Pictor.

“This system is exactly what TESS was designed to find — small, temperate planets that pass, or transit, in front of an inactive host star, one lacking excessive stellar activity, such as flares,” said lead researcher Maximilian Günther, a Torres Postdoctoral Fellow at the Massachusetts Institute of Technology’s (MIT) Kavli Institute for Astrophysics and Space Research in Cambridge. “This star is quiet and very close to us, and therefore much brighter than the host stars of comparable systems. With extended follow-up observations, we’ll soon be able to determine the make-up of these worlds, establish if atmospheres are present and what gases they contain, and more.”

A paper describing the system was published in the journal Nature Astronomy and is now available online.

The innermost planet, TOI 270 b, is likely a rocky world about 25% larger than Earth. It orbits the star every 3.4 days at a distance about 13 times closer than Mercury orbits the Sun. Based on statistical studies of known exoplanets of similar size, the science team estimates TOI 270 b has a mass around 1.9 times greater than Earth’s.

Due to its proximity to the star, planet b is an oven-hot world. Its equilibrium temperature — that is, the temperature based only on energy it receives from the star, which ignores additional warming effects from a possible atmosphere — is around 490 degrees Fahrenheit (254 degrees Celsius).

The other two planets, TOI 270 c and d, are, respectively, 2.4 and 2.1 times larger than Earth and orbit the star every 5.7 and 11.4 days. Although only about half its size, both may be similar to Neptune in our solar system, with compositions dominated by gases rather than rock, and they likely weigh around 7 and 5 times Earth’s mass, respectively.

All of the planets are expected to be tidally locked to the star, which means they only rotate once every orbit and keep the same side facing the star at all times, just as the Moon does in its orbit around Earth.

Planet c and d might best be described as mini-Neptunes, a type of planet not seen in our own solar system. The researchers hope further exploration of TOI 270 may help explain how two of these mini-Neptunes formed alongside a nearly Earth-size world.

“An interesting aspect of this system is that its planets straddle a well-established gap in known planetary sizes,” said co-author Fran Pozuelos, a postdoctoral researcher at the University of Liège in Belgium. “It is uncommon for planets to have sizes between 1.5 and two times that of Earth for reasons likely related to the way planets form, but this is still a highly controversial topic. TOI 270 is an excellent laboratory for studying the margins of this gap and will help us better understand how planetary systems form and evolve.”

Günther’s team is particularly interested in the outermost planet, TOI 270 d. The team estimates the planet’s equilibrium temperature to be about 150 degrees Fahrenheit (66 degrees C). This makes it the most temperate world in the system — and as such, a rarity among known transiting planets.

“TOI 270 is perfectly situated in the sky for studying the atmospheres of its outer planets with NASA’s future James Webb Space Telescope,” said co-author Adina Feinstein, a doctoral student at the University of Chicago. “It will be observable by Webb for over half a year, which could allow for really interesting comparison studies between the atmospheres of TOI 270 c and d.”

The team hopes further research may reveal additional planets beyond the three now known. If planet d has a rocky core covered by a thick atmosphere, its surface would be too warm for the presence of liquid water, considered a key requirement for a potentially habitable world. But follow-up studies may discover additional rocky planets at slightly greater distances from the star, where cooler temperatures could allow liquid water to pool on their surfaces.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

Download additional images from NASA Goddard’s Scientific Visualization Studio

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Profile: A Gas Giant Orbiting a Mysterious Star

2 min read

NASA Science Editorial Team

KMT-2017-BLG-1038L b is a gas giant exoplanet that orbits an unknown-type star. Its mass is two Jupiters. It takes four years to complete one orbit of its star and it's 1.8 AU from that star. An AU is an astronomical unit – the distance between Earth and the Sun, or about 93 million miles (150 million kilometers).

Discovered: 2019

Distance from Earth: 19,569 light-years

How was it found? Microlensing

Observations from the Korea Microlensing Telescope Network led to the planet's dicovery using gravitational microlensing.

This method derives from one of the insights of Einstein's theory of general relativity: gravity bends space. We normally think of light as traveling in a straight line, but light rays become bent when passing through space that is warped by the presence of a massive object such as a star. This effect has been proven by observations of the Sun's gravitational effect on starlight.

When a planet happens to pass in front of a star along our line of sight, the planet's gravity will behave like a lens. This focuses the light rays and causes a temporary sharp increase in brightness and change of the apparent position of the star. Astronomers can use the gravitational microlensing effect to find objects that emit no light or are otherwise undetectable.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA’s TESS Mission Completes First Year of Survey, Turns to Northern Sky

6 min read

NASA’s Transiting Exoplanet Survey Satellite (TESS) has discovered 21 planets outside our solar system and captured data on other interesting events occurring in the southern sky during its first year of science. TESS has now turned its attention to the Northern Hemisphere to complete the most comprehensive planet-hunting expedition ever undertaken.

TESS began hunting for exoplanets (or worlds orbiting distant stars) in the southern sky in July of 2018, while also collecting data on supernovae, black holes and other phenomena in its line of sight. Along with the planets TESS has discovered, the mission has identified over 850 candidate exoplanets that are waiting for confirmation by ground-based telescopes.

“The pace and productivity of TESS in its first year of operations has far exceeded our most optimistic hopes for the mission,” said George Ricker, TESS’s principal investigator at the Massachusetts Institute of Technology in Cambridge. “In addition to finding a diverse set of exoplanets, TESS has discovered a treasure trove of astrophysical phenomena, including thousands of violently variable stellar objects.”

To search for exoplanets, TESS uses four large cameras to watch a 24-by-96-degree section of the sky for 27 days at a time. Some of these sections overlap, so some parts of the sky are observed for almost a year. TESS is concentrating on stars closer than 300 light-years from our solar system, watching for transits, which are periodic dips in brightness caused by an object, like a planet, passing in front of the star.

On July 18, the southern portion of the survey was completed and the spacecraft turned its cameras to the north. When it completes the northern section in 2020, TESS will have mapped over three quarters of the sky.

“Kepler discovered the amazing result that, on average, every star system has a planet or planets around it,” said Padi Boyd, TESS project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “TESS takes the next step. If planets are everywhere, let’s find those orbiting bright, nearby stars because they’ll be the ones we can now follow up with existing ground and space-based telescopes, and the next generation of instruments for decades to come.”

Here are a few of the interesting objects and events TESS saw during its first year.

Exoplanets

To qualify as an exoplanet candidate, an object must make at least three transits in the TESS data, and then pass through several additional checks to make sure the transits were not a false positive caused by an eclipse or companion star, but may in fact be an exoplanet. Once a candidate is identified, astronomers deploy a large network of ground-based telescopes to confirm it.

“The team is currently focused on finding the best candidates to confirm by ground-based follow-up,” said Natalia Guerrero, who manages the team in charge of identifying exoplanet candidates at MIT. “But there are many more potential exoplanet candidates in the data yet to be analyzed, so we’re really just seeing the tip of the iceberg here. TESS has only scratched the surface.”

The planets TESS has discovered so far range from a world 80% the size of Earth to ones comparable to or exceeding the sizes of Jupiter and Saturn. Like Kepler, TESS is finding many planets smaller in size than Neptune, but larger than Earth.

While NASA is striving to put astronauts on some of our nearest neighbors — the Moon and Mars — in order to understand more about the planets in our own solar system, follow-up observations with powerful telescopes of the planets TESS discovers will enable us to better understand how Earth and the solar system formed.

With TESS's data, scientists using current and future observatories, like the James Webb Space Telescope, will be able to study other aspects of exoplanets, like the presence and composition of any atmosphere, which would impact the possibility of developing life.

Comets

Before science operations started, TESS snapped clear images of a newly discovered comet in our solar system. During on-orbit instrument testing, the satellite's cameras took a series of images that captured the motion of C/2018 N1, a comet found on June 29 by NASA's Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE).

TESS captured data on similar objects outside the solar system as well.

Exocomets

Data from the mission were also used to identify transits by comets orbiting another star: Beta Pictoris, located 63 light-years away. Astronomers were able to find three comets that were too small to be planets and had detectable tails, the first identification of its type in visible light.

Supernovae

Because TESS spends nearly a month looking in the same location, it can capture data on stellar events, like supernovae, as they begin. During its first months of science operations, TESS spotted six supernovae occurring in distant galaxies that were later discovered by ground-based telescopes.

Scientists hope to use these types of observations to better understand the origins of a specific kind of explosion known as a Type Ia supernova.

Type Ia supernovae occur either in star systems where one white dwarf draws gas from another star or when two white dwarfs merge. Astronomers don't know which case is more common, but with data from TESS, they'll have a clearer understanding of the origins of these cosmic blasts.

Type Ia supernovae are a class of objects called a “standard candle,” meaning astronomers know how luminous they are and can use them to calculate quantities like how quickly the universe is expanding. TESS data will help them understand differences between Type Ia supernovae created in both circumstances, which could have a large impact on how we understand events happening billions of light-years away and, ultimately, the fate of the universe.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT's Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Center in California's Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT's Lincoln Laboratory in Lexington, Massachusetts; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

By Ravyn CullorNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Atmosphere of Midsize Planet Revealed by Hubble, Spitzer

NASA Science Editorial Team

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Main Instrument for NASA’s WFIRST Mission Completes Milestone Review

6 min read

Editor’s note, Sept. 23, 2020: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

In order to know how the universe will end, we must know what has happened to it so far. This is just one mystery NASA’s forthcoming Wide Field Infrared Survey Telescope (WFIRST) mission will tackle as it explores the distant cosmos. The spacecraft’s giant camera, the Wide Field Instrument (WFI), will be fundamental to this exploration.

The WFI has just passed its preliminary design review, an important milestone for the mission. It means the WFI successfully met the design, schedule and budget requirements to advance to the next phase of development, where the team will begin detailed design and fabrication of the flight hardware.

“This was an outstanding preliminary design review, providing a snapshot of the tremendous amount of engineering this team has accomplished in a short period of time,” said Jamie Dunn, WFIRST project manager at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “The WFI team is well on their way down the path of building a world-class instrument for NASA’s next great observatory.”

“The preliminary design review is a vital step in the mission because it takes the engineering ideas and assesses them against stringent criteria to make sure they will perform as planned,” said Goddard’s Mary Walker, instrument manager for the WFI. “This is where we find the things we need to tweak so WFIRST can advance to the next stage in its journey.”

Engineers will feed the results of the review into the next design iteration, preparing the instrument for an even more rigorous test — the critical design review, currently planned for June 2020. This will involve data from WFI engineering test units in simulated space environments, including testing at cryogenic temperatures.

WFIRST is a next-generation space telescope that will survey the infrared universe from beyond the orbit of the Moon. Its two instruments are a technology demonstration called a coronagraph, and the WFI. The WFI features the same angular resolution as Hubble but with 100 times the field of view. Data it gathers will enable scientists to discover new and uniquely detailed information about planetary systems around other stars. The WFI will also map how matter is structured and distributed throughout the cosmos, which should ultimately allow scientists to discover the fate of the universe.

The WFI is designed to detect faint infrared light from across the universe. Infrared light is observed at wavelengths longer than the human eye can detect. The expansion of the universe stretches light emitted by distant galaxies, causing visible or ultraviolet light to appear as infrared by the time it reaches us. Such distant galaxies are difficult to observe from the ground because Earth’s atmosphere blocks some infrared wavelengths, and the upper atmosphere glows brightly enough to overwhelm light from these distant galaxies. By going into space and using a Hubble-size telescope, the WFI will be sensitive enough to detect infrared light from farther than any previous telescope. This will help scientists capture a new view of the universe that could help solve some of its biggest mysteries, one of which is how the universe became the way it is now.

The WFI will allow scientists to peer very far back in time. Seeing the universe in its early stages will help scientists unravel how it expanded throughout its history. This will illuminate how the cosmos developed to its present condition, enabling scientists to predict how it will continue to evolve.

“We’re going to try to discover the fate of the universe,” said Goddard’s Jeff Kruk, the WFIRST project scientist. “The expansion of the universe is accelerating, and one of the things the Wide Field Instrument will help us figure out is if the acceleration is increasing or slowing down.”

One possible explanation for this speed-up is dark energy, an unexplained phenomenon that currently makes up about 68 percent of the total content of the cosmos and may be changing as the universe evolves. Another possibility is that this apparent cosmic acceleration points to the breakdown of Einstein’s general theory of relativity across large swaths of the universe.

The WFI will test these ideas by measuring matter in hundreds of millions of distant galaxies through a phenomenon called weak gravitational lensing. Massive objects like galaxies and clusters of galaxies curve space-time, bending the path traveled by light that passes nearby. This creates a distorted, magnified view of far-off galaxies behind them. Viewing those distant galaxies will show how matter is structured throughout the universe and across time.

All of the astronomical surveys that WFIRST will conduct rely on the WFI. An extremely stable optical structure is necessary to make the high-precision measurements with both the WFI and the coronagraph. Further ensuring stability, WFIRST will orbit the second Sun-Earth Lagrange point, or L2. At this special location over 930,000 miles (1.5 million kilometers) from Earth, gravitational forces balance to keep objects in steady orbits with very little assistance. The thermal stability of an observatory at L2 will provide a ten-fold improvement beyond Hubble in much of the data the WFI will gather. This degree of stability is impractical with observatories in low-Earth orbit, such as Hubble.

With its large field of view, the WFI will provide a wealth of information in each image it takes. This will dramatically reduce the amount of time needed to gather data, allowing scientists to conduct research that would otherwise be impractical.

“You could do most of the WFIRST science with Hubble, but it might take a thousand years,” said Kruk. “We don’t want to wait that long.”

With the successful completion of the WFI’s preliminary design review, the WFIRST mission is on target for its planned launch in the mid-2020s. Scientists will soon be able to explore some of the biggest mysteries in the cosmos thanks to the WFI’s wide field of view and precision optics.

Download this video in HD formats from NASA Goddard’s Scientific Visualization Studio

By Ashley BalzerNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Mission Finds Its Smallest Planet Yet

6 min read

NASA’s Transiting Exoplanet Survey Satellite (TESS) has discovered a world between the sizes of Mars and Earth orbiting a bright, cool, nearby star. The planet, called L 98-59b, marks the tiniest discovered by TESS to date.

Two other worlds orbit the same star. While all three planets’ sizes are known, further study with other telescopes will be needed to determine if they have atmospheres and, if so, which gases are present. The L 98-59 worlds nearly double the number of small exoplanets — that is, planets beyond our solar system — that have the best potential for this kind of follow-up.

“The discovery is a great engineering and scientific accomplishment for TESS,” said Veselin Kostov, an astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and the SETI Institute in Mountain View, California. “For atmospheric studies of small planets, you need short orbits around bright stars, but such planets are difficult to detect. This system has the potential for fascinating future studies.”

A paper on the findings, led by Kostov, was published in the June 27 issue of The Astronomical Journal and is now available online.

L 98-59b is around 80% Earth’s size and about 10% smaller than the previous record holder discovered by TESS. Its host star, L 98-59, is an M dwarf about one-third the mass of the Sun and lies about 35 light-years away in the southern constellation Volans. While L 98-59b is a record for TESS, even smaller planets have been discovered in data collected by NASA’s Kepler satellite, including Kepler-37b, which is only 20% larger than the Moon.

The two other worlds in the system, L 98-59c and L 98-59d, are respectively around 1.4 and 1.6 times Earth’s size. All three were discovered by TESS using transits, periodic dips in the star’s brightness caused when each planet passes in front of it.

TESS monitors one 24-by-96-degree region of the sky, called a sector, for 27 days at a time. When the satellite finishes its first year of observations in July, the L 98-59 system will have appeared in seven of the 13 sectors that make up the southern sky. Kostov’s team hopes this will allow scientists to refine what’s known about the three confirmed planets and search for additional worlds.

“If you have more than one planet orbiting in a system, they can gravitationally interact with each other,” said Jonathan Brande, a co-author and astrophysicist at Goddard and the University of Maryland, College Park. “TESS will observe L 98-59 in enough sectors that it may be able to detect planets with orbits around 100 days. But if we get really lucky, we might see the gravitational effects of undiscovered planets on the ones we currently know.”

M dwarfs like L 98-59 account for three-quarters of our Milky Way galaxy’s stellar population. But they are no larger than about half the Sun’s mass and are much cooler, with surface temperatures less than 70% of the Sun’s. Other examples include TRAPPIST-1, which hosts a system of seven Earth-size planets, and Proxima Centauri, our nearest stellar neighbor, which has one confirmed planet. Because these small, cool stars are so common, scientists want to learn more about the planetary systems that form around them.

L 98-59b, the innermost world, orbits every 2.25 days, staying so close to the star it receives as much as 22 times the amount of energy Earth receives from the Sun. The middle planet, L 98-59c, orbits every 3.7 days and experiences about 11 times as much radiation as Earth. L 98-59d, the farthest planet identified in the system so far, orbits every 7.5 days and is blasted with around four times the radiant energy as Earth.

None of the planets lie within the star’s “habitable zone,” the range of distances from the star where liquid water could exist on their surfaces. However, all of them occupy what scientists call the Venus zone, a range of stellar distances where a planet with an initial Earth-like atmosphere could experience a runaway greenhouse effect that transforms it into a Venus-like atmosphere. Based on its size, the third planet could be either a Venus-like rocky world or one more like Neptune, with a small, rocky core cocooned beneath a deep atmosphere.

One of TESS’s goals is to build a catalog of small, rocky planets on short orbits around very bright, nearby stars for atmospheric study by NASA’s upcoming James Webb Space Telescope. Four of the TRAPPIST-1 worlds are prime candidates, and Kostov’s team suggests the L 98-59 planets are as well.

The TESS mission feeds our desire to understand where we came from and whether we’re alone in the universe.

“If we viewed the Sun from L 98-59, transits by Earth and Venus would lead us to think the planets are almost identical, but we know they’re not,” said Joshua Schlieder, a co-author and an astrophysicist at Goddard. “We still have many questions about why Earth became habitable and Venus did not. If we can find and study similar examples around other stars, like L 98-59, we can potentially unlock some of those secrets.”

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

Download related multimedia in HD formats from NASA Goddard’s Scientific Visualization Studio

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Whirlpool ‘Warhol’ from NASA’s Spitzer Telescope

4 min read

NASA Science Editorial Team

Unlike Andy Warhol's famous silkscreen grids of repeating images rendered in different colors, the varying hues of this galaxy represent how its appearance changes in different wavelengths of light — from visible light to the infrared light seen by NASA's Spitzer Space Telescope.

The Whirlpool galaxy, also known as Messier 51 and NGC 5194/5195, is actually a pair of galaxies that are tugging and distorting each other through their mutual gravitational attraction. Located approximately 23 million light-years away, it resides in the constellation Canes Venatici.

The leftmost panel (a) shows the Whirlpool in visible light, much as our eye might see it through a powerful telescope. In fact, this image comes from the Kitt Peak National Observatory 2.1-meter (6.8-foot) telescope. The spiraling arms are laced with dark threads of dust that radiate little visible light and obscure stars positioned within or behind them.

The second panel from the left (b) includes two visible-light wavelengths (in blue and green) from Kitt Peak but adds Spitzer's infrared data in red. This emphasizes how the dark dust veins that block our view in visible light begin to light up at these longer, infrared wavelengths.

Spitzer's full infrared view can be seen in the right two panels, which cover slightly different ranges of infrared light.

In the middle-right panel (c), we see three wavelengths of infrared light: 3.6 microns (shown in blue), 4.5 microns (green) and 8 microns (red). The blended light from the billions of stars in the Whirlpool is brightest at the shorter infrared wavelengths and is seen here as a blue haze. The individual blue dots across the image are mostly nearby stars and a few distant galaxies. Red features show us dust composed mostly of carbon that is lit up by the stars in the galaxy.

This glowing dust helps astronomers see where the densest areas of gas pile up in the spaces between the stars. Dense gas clouds are difficult to see in visible or infrared light, but they will always be present where there is dust.

The far-right panel (d) expands our infrared view to include light at a wavelength of 24 microns (in red), which is particularly good for highlighting areas where the dust is especially hot. The bright reddish-white spots trace regions where new stars are forming and, in the process, heating their surroundings.

The infrared views of the Whirlpool galaxy also show how dramatically different its two component parts are: The smaller companion galaxy at the top of the image has been stripped nearly clean of dust features that stand out so brilliantly in the lower spiral galaxy. The faint bluish haze seen around the upper galaxy is likely the blended light from stars thrown out of the galaxies as these two objects pull at each other during their close approach.

The Kitt Peak visible-light image (a) shows light at 0.4 and 0.7 microns (blue and red). The rightmost two images (c and d) are from Spitzer with red, green and blue corresponding to wavelengths of 3.6, 4.5 and 8.0 microns (middle right) and 3.6, 8.0 and 24 microns (far right). The middle-left (b) image blends visible wavelengths (blue/green) and infrared (yellow/red). All of the data shown here were released as part of the Spitzer Infrared Nearby Galaxies Survey (SINGS) project, captured during Spitzer's cryogenic and warm missions.

The Jet Propulsion Laboratory in Pasadena, California, manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Space operations are based at Lockheed Martin Space Systems in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

For more information on Spitzer, visit:

www.nasa.gov/spitzer and www.spitzer.caltech.edu/

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Oceans, Beaches, Cosmic Shorelines: Our Changing Views of Habitable Planets

9 min read

NASA Science Editorial Team

By Pat Brennan, NASA's Exoplanet Exploration Program

The main idea is easy to grasp: Set Goldilocks loose in our galaxy and let her choose a planet that's "just right."

For decades, the Goldilocks zone has been the go-to shorthand for scientists. More formally known as the "habitable zone," it's the region around a star where the temperature is just right for liquid water to pool on the surface of planets with suitable atmospheres.

The habitable zone, also known as the Goldilocks zone, is the region around a star where the temperature is just right for liquid water to pool on the surface of a planet.

As tens, then hundreds, then thousands of planets were confirmed to circle stars across the Milky Way, the question kept bubbling up: Might any of these worlds be capable of supporting some form of life?

And Goldilocks offered a glimmer of an answer. All earthly life requires liquid water; it seems reasonable that unearthly life would too. We are most likely to find life where we find liquid water – on planets in the habitable zone.

These days, however, researchers tell us it might not be that simple. While the traditional definition of the habitable zone is still a useful first approximation, the dizzying variety of planets and planetary systems – so far none that resemble our own – is prompting a wholesale re-evaluation of what it takes for a planet to be habitable.

Might rogue planets hurtling through the galaxy, without a star but perhaps with their own internal heat, be habitable? Could Earth-sized planets locked in a close, habitable-zone orbit around a red dwarf star, and prone to sterilizing stellar flares, still harbor life? What about larger worlds that might resemble scaled-up versions of our home planet, and orbit in the habitable zone of their star?

Such depictions of potentially habitable worlds emerge from the bare bones data on actual planets – that is, once scientists apply their best conceptual ideas, plus a little computer modeling. But some of these worlds can play havoc with traditional ideas of habitable zones.

"It's very important to realize, it's not just the location," said Mary Voytek, the senior scientist for astrobiology at NASA headquarters in Washington, D.C. "There are many other factors that contribute to establishing habitable conditions."

Even well-known worlds close to home, in our own solar system, hint at far more variety than the chalk outline of the standard "habitable zone" suggests.

In our system, Venus by some measures grazes the inner edge of our Sun's habitable zone, and Mars falls just inside the outer boundary. Neither appears to be habitable. Broiling, barbecued Venus with its sulfuric acid clouds is much too hot for life as we know it; freezing, desiccated Mars and its wisp of a carbon dioxide atmosphere is unpromising as well.

“The Moon is in the habitable zone in our solar system,” Voytek said. “Is it habitable? It can’t retain an atmosphere. It doesn’t have water on its surface. It’s something in the habitable zone that isn’t.”

Or cast the net much farther out, beyond our system’s “ice line.” Our biggest gas giants are both orbited by frozen moons concealing oceans beneath the surface. Jupiter’s Europa or Saturn’s Enceladus might also harbor some form of ocean-dwelling life – though well outside the traditional habitable zone around our Sun.

Do gas giants preside over their own habitable zones, in our solar system or around other stars? If so, it would be governed by tidal forces instead of radiant temperature – the push and pull of a moon’s innards by the gas giant’s gravity, causing tidal heating to keep subsurface oceans in a liquid state.

Open the lens a bit and pull back to take in a view of our entire, pinwheeling Milky Way galaxy. Might the galaxy also have its own habitable zone – the distance from the galactic center with enough metal to seed rocky planets, yet free of killer supernovae or smothering molecular clouds?

Such concepts are intriguing, and might one day contribute to the search for habitable worlds, but we don’t have enough data so far to make them useful for studies of exoplanets – planets around other stars.

So researchers are trying instead to narrow the focus and flesh out the potential habitability of the planets themselves. They are tasking our increasingly sophisticated computer models, originally designed to model Earth’s climate, with simulating exotic (if idealized) worlds instead.

“We’re using our understanding from Earth to inform our search for life, for habitability, on other planets,” said Nancy Kiang, an astrobiologist at NASA’s Goddard Institute for Space Studies in New York.

The extraordinary portraits these modelers paint are teaching us about previously unimagined possibilities – not only for potentially habitable worlds, but for the dynamic atmospheres of enormous, hot, gaseous planets, oddballs known as mini-Neptunes, or rocky, terrestrial planets locked in a deep freeze.

Modeling by several researchers, including Aomawa Shields of the University of California, Irvine, shows that small, rocky worlds orbiting red-dwarf stars – like the seven roughly Earth-sized planets orbiting TRAPPIST-1 – could, under some conditions, have stable climates and reduced susceptibility to deep-freeze.

Shields uses computer models to simulate the effects of host stars on their planets’ likely habitability. She says such findings suggest that the traditional habitable zone, by itself, is a limited way to define the potential habitability of these distant worlds.

“Our solar system is not the standard model,” Shields told an audience at a recent American Astronomical Society conference in Seattle. “It’s one of many possible configurations we’re seeing out there. Some push the boundaries of the traditional habitable zone.”

Astronomers say the habitable zone concept is mainly useful for targeting stars and the planets around them for closer study. That’s a big help in an era of explosive discovery of these distant planets, but one so far lacking enough telescopic power to read the atmospheres of smaller, rocky worlds for signs of habitability. Such telescopes are being designed with the help of ideas about the habitable zone. And new, more powerful instruments will be lofted into space in the years and decades to come, starting with the James Webb Space Telescope, expected to launch in 2021.

The Webb telescope might be able to scrutinize the atmospheres of large, mysterious worlds known as “super Earths” – larger than Earth but smaller than Neptune – and perhaps even planets in Earth’s size-range as well, though that would likely push the limits of the telescope’s capability.

“If something looks like a terrestrial planet within the habitable zone, what can we actually say about that?” asks Stephen Kane of the University of California, Riverside, who is also a member of the NASA Astrobiology Institute and who specializes in habitable zones. “The answer, at the moment, is very little.”

He calls the habitable zone “one of the most misunderstood concepts” in astronomy – and one that might one day pass out of use as our instruments grow sharp enough to reveal exoplanet characteristics in detail.

For now, however, it’s a key “target selection tool.”

“There are many candidates to choose from,” he said. “How do we prioritize our list? The answer is the habitable zone.”

And as we sail this sea of unfamiliar planets, we finally fetch up on the cosmic shoreline. The shoreline is metaphorical, but might be a very real statistical trend that links all planets – those in our solar system and the exoplanets around other stars.

It’s a dividing line that appears when we compare two factors: how much light a planet receives from its star, and how readily the planet’s atmosphere escapes into space.

An updated version of the “shoreline” was revealed in a 2017 paper by Kevin Zahnle of the NASA Ames Research Center in Moffett Field, California, and David Catling of the University of Washington Astrobiology Program.

They first considered the planets and moons of our own solar system, sketching out a standard graph like most of us drew in grade school. The vertical axis shows tick marks for solar radiation, increasing by factors of 10 in the upward direction. The horizontal axis shows the “escape velocity” that atmospheric particles must reach to leave the planet, increasing, in kilometers per second, to the right by a factor of 1,000.

And along the roughly diagonal line that cuts across the graph – the cosmic shoreline – were planets and moons with atmospheres. Add in the exoplanets with known masses and radii, and the number of dots near the line increases.

The line was where the solar radiation was low but escape velocity – really, a measure of gravity – was high. And sure enough, gathered on one side of the line like sunbathers on a summer beach were solar system bodies, planets and moons, known to have atmospheres: Earth, Venus, our gas giants Jupiter and Saturn, and even Saturn’s moon, Titan, with its atmosphere of cold, dense hydrocarbons.

Anything below the line was more likely to have an atmosphere. Anything above probably didn’t. And planets right on the line, or very close to it, might have thin atmospheres if any at all (think Mars, or Pluto).

Initial indications suggest that exoplanets also should divide reliably along this line – that is, if the relationship turns out to be real and not simply a statistical fluke.

“It’s certainly a testable hypothesis,” Zahnle said. “It would be kind of fun to know if this is actually a (physically based) general feature or just an accident of plotting two unlike things that coincidentally line up.”

As our space telescopes, in future years, gain the power to probe the atmospheres of exoplanets, and if the shoreline idea holds up, the relationship could become important – a way to choose among the menagerie of planets to find those most likely to possess atmospheres.

And Goldilocks, now confronted with thousands of planets to choose from, might more easily find a small, rocky, habitable world.

Just right.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Discovery Alert: New Twin Planets Prompt Comparisons to Earth

2 min read

NASA Science Editorial Team

Planets: Teegarden's Star b and c

Discovered by: An international team of astronomers using the CARMENES spectrographic instrument at the Calar Alto Observatory in Spain.

Date: June 12, 2019

Key facts: Two new planets were detected orbiting Teegarden's Star, an ultracool, red dwarf less than 13 light-years away. At a minimum, the new planets both weigh in at about 1.1 times the mass of Earth.

Details: These planets, among the "lightest" found so far in orbit around other stars, were detected using the wobble method – watching for subtle motions in the star as orbiting planets tug them one way, then another.

The star itself could be 8 to 10 billion years old, or roughly twice the age of our Sun.

Although the heft of the two planets is comparable to Earth's, their other characteristics are unknown. Planet b, which completes one orbit around the star (a "year") in just under five days, might be habitable despite its close proximity to its star. But Planet c, with an orbit of about 11-1/2 days, falls "comfortably" within the star's habitable zone, or the distance from the star that could allow liquid water on the planet's surface.

What's next: These planets might be prime targets for future follow-up with the next generation of large, ground-based telescopes, which could reveal more of their properties.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Discovery Alert: A Record Haul — Planet Count Hits 4,000

2 min read

NASA Science Editorial Team

Planets: NASA's planet counter ticked up to 4,000, then passed it by three, with 31 new discoveries.

Date: June 13, 2019

What's new: NASA's Exoplanet Archive announces 31 newly confirmed exoplanets – planets beyond our solar system – discovered by ground and space-based telescopes. Five were detected by the recently launched TESS space telescope.

They push the official planet count past the 4,000 mark for the first time. And this record-breaking haul spans a range of weird worlds: rocky planets in Earth's size range, "super Earths" that are larger than Earth but smaller then Neptune, and huge gas giants 14 times more weighty than Jupiter.

They include:

Details: Along with TESS, the instruments astronomers used to find these new worlds include the Kepler space telescope, recently decommissioned after nine years in space. Twenty of the new planets were found in data from Kepler, including 19 from its second mission, called K2. One was found using various ground-based instruments to measure variations in eclipsing timing by a method called photometry. Others include:

Congratulations to NASA's Exoplanet Archive!

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

How NASA’s Spitzer Has Stayed Alive for So Long

7 min read

After nearly 16 years of exploring the cosmos in infrared light, NASA’s Spitzer Space Telescope will be switched off permanently on Jan. 30, 2020. By then, the spacecraft will have operated for more than 11 years beyond its prime mission, thanks to the Spitzer engineering team’s ability to address unique challenges as the telescope slips farther and farther from Earth.

Managed and operated by NASA’s Jet Propulsion Laboratory in Pasadena, California, Spitzer is a small but transformational observatory. It captures infrared light, which is often emitted by “warm” objects that aren’t quite hot enough to radiate visible light. Spitzer has lifted the veil on hidden objects in nearly every corner of the universe, from a new ring around Saturn to observations of some of the most distant galaxies known. It has spied stars in every stage of life, mapped our home galaxy, captured gorgeous images of nebulas and probed newly discovered planets orbiting distant stars.

But as Spitzer’s deputy mission manager, Joseph Hunt, said, “You can have a world-class spacecraft, but it doesn’t mean anything if you can’t get the data back home.”

Spitzer orbits the Sun on a path similar to Earth’s but moves slightly slower. Today it trails about 158 million miles (254 million kilometers) behind our planet — more than 600 times the distance between Earth and the Moon. That distance, along with the curve of Spitzer’s orbit, means that when the spacecraft points its fixed antenna at Earth to download data or receive commands, its solar panels tilt away from the Sun. During those periods, the spacecraft must rely on a combination of solar power and battery power to operate.

The angle at which the panels point away from the Sun has increased every year that the mission has been operating. These days, to communicate with Earth, Spitzer has to position its panels at a 53-degree angle away from the Sun (90 degrees would be fully facing away), even though the mission planners never intended for it to tilt more than 30 degrees from the Sun. Spitzer can communicate with Earth for about 2.5 hours before it has to turn its solar panels back toward the Sun to recharge its batteries. That communications window would grow shorter year after year if Spitzer continued operating, which means there is a limit to how long it would be possible to operate the spacecraft efficiently.

Teaching the spacecraft to accept new conditions — such as the increasing angle of the solar panels during communications with Earth — isn’t as simple as flipping a switch. There are multiple ways these changes could trigger safety mechanisms in the spacecraft’s flight software. For instance, if the panels tilted more than 30 degrees from the Sun during the mission’s early years, the software would have hit “pause,” putting the spacecraft into “safe mode” until the mission team could figure out what was wrong. The changing angle of Spitzer to the Sun could also trigger safety mechanisms intended to prevent spacecraft parts from overheating.

Entering safe mode can be particularly hazardous for the spacecraft, both because of its growing distance from Earth (which makes communicating more difficult) and because the aging onboard systems might not restart once they shut off.

To deal with these challenges, the project engineers and scientists at JPL and Caltech have worked with the observatory engineering team at Lockheed Martin Space’s Littleton, Colorado, facility to find a path forward. (Lockheed Martin built the Spitzer spacecraft for NASA.) Bolinda Kahr, Spitzer’s mission manager, leads this multi-center team. Over the years she and her colleagues have successfully figured out how to override safety mechanisms designed for the prime mission while also making sure that such alterations don’t introduce other unwanted side effects.

But as Spitzer ages and gets farther from Earth, the challenge of keeping the spacecraft operating and the risk that it will suffer a major anomaly are only increasing.

“I can genuinely say that no one involved in the mission planning thought we’d be running in 2019,” said Lisa Storrie-Lombardi, Spitzer’s project manager. “But we have an incredibly robust spacecraft and an incredible team. And we’ve been lucky. You have to have some luck, because you can’t anticipate everything.”

Most infrared detectors have to be cooled to very low temperatures, because excess infrared light from “warm” objects — including the Sun, Earth, the spacecraft and even the instruments themselves — can overwhelm the infrared sensors. This cooling is typically done with a chemical coolant.

The Spitzer planners instead came up with a passive-cooling system that included flying the spacecraft far from Earth (a major infrared heat source). They also chose materials for the spacecraft exterior that would both reflect sunlight away before it could heat the telescope and radiate absorbed heat back into space. In this configuration, coolant is required only to lower the instrument temperatures a few degrees further. Reducing the onboard coolant supply also drastically allowed the engineers to cut the total size of the spacecraft by more than 80% and helped curtail the anticipated mission budget by more than 75%.

Although Spitzer’s coolant supply ran out in 2009, rendering two of its three instruments unusable, the team was able to keep half of the remaining instrument operating. (The instrument was designed to detect four wavelengths of infrared light; in the “warm” mode, it can still detect two of them.)

Lasting more than twice as long as the primary mission, Spitzer’s extended mission has yielded some of the observatory’s most transformational results. In 2017, the telescope revealed the presence of seven rocky planets around the TRAPPIST-1 star. In many cases, Spitzer’s exoplanet observations were combined with observations by other missions, including NASA’s Kepler and Hubble space telescopes.

Spitzer’s final year and a half of science operations include a number of exoplanet-related investigations. One program will investigate 15 dwarf stars (similar to the TRAPPIST-1 star) likely to host exoplanets. An additional 650 hours are dedicated to follow-up observations of planets discovered by NASA’s Transiting Exoplanet Survey Satellite (TESS), which launched just over a year ago.

Every mission must end at some point. As the challenges associated with operating Spitzer continue to grow and as the risk of a mission-ending anomaly on the spacecraft rises, NASA has made the decision to close out the mission in a controlled manner.

“There have been times when the Spitzer mission could have ended in a way we didn’t plan for,” said Kahr. “I’m glad that in January we’ll be able to retire the spacecraft deliberately, the way we want to do it.”

While Spitzer’s mission is ending, it has helped set the stage for NASA’s James Webb Space Telescope, set to launch in 2021, which will study the universe in many of the same wavelengths observed by Spitzer. Webb’s primary mirror is about 7.5 times larger than Spitzer’s mirror, meaning Webb will be able to study many of the same targets in much higher resolution and objects much farther away from Earth than what Spitzer can observe.

Thirteen science programs have already been selected for Webb’s first five months of operations, four of which build directly on Spitzer observations. Webb will greatly expand on the legacy begun by Spitzer and answer questions that Spitzer has only begun to investigate.

JPL manages the Spitzer Space Telescope mission for NASA’s Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Space operations are based at Lockheed Martin Space. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

For more information on Spitzer, visit:

www.nasa.gov/spitzer

www.spitzer.caltech.edu/

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

2019-113

How NASA’s Spitzer Has Stayed Alive for So Long

7 min read

NASA Science Editorial Team

This artist's concept shows NASA's Spitzer Space Telescope in front of an infrared image of the Milky Way galaxy. Credit: NASA/JPL-Caltech

› Full image and caption

After nearly 16 years of exploring the cosmos in infrared light, NASA's Spitzer Space Telescope will be switched off permanently on Jan. 30, 2020. By then, the spacecraft will have operated for more than 11 years beyond its prime mission, thanks to the Spitzer engineering team's ability to address unique challenges as the telescope slips farther and farther from Earth.

Managed and operated by NASA's Jet Propulsion Laboratory in Pasadena, California, Spitzer is a small but transformational observatory. It captures infrared light, which is often emitted by "warm" objects that aren't quite hot enough to radiate visible light. Spitzer has lifted the veil on hidden objects in nearly every corner of the universe, from a new ring around Saturn to observations of some of the most distant galaxies known. It has spied stars in every stage of life, mapped our home galaxy, captured gorgeous images of nebulas and probed newly discovered planets orbiting distant stars.

But as Spitzer's deputy mission manager, Joseph Hunt, said, "You can have a world-class spacecraft, but it doesn't mean anything if you can't get the data back home."

Spitzer orbits the Sun on a path similar to Earth's but moves slightly slower. Today it trails about 158 million miles (254 million kilometers) behind our planet - more than 600 times the distance between Earth and the Moon. That distance, along with the curve of Spitzer's orbit, means that when the spacecraft points its fixed antenna at Earth to download data or receive commands, its solar panels tilt away from the Sun. During those periods, the spacecraft must rely on a combination of solar power and battery power to operate.

The angle at which the panels point away from the Sun has increased every year that the mission has been operating. These days, to communicate with Earth, Spitzer has to position its panels at a 53-degree angle away from the Sun (90 degrees would be fully facing away), even though the mission planners never intended for it to tilt more than 30 degrees from the Sun. Spitzer can communicate with Earth for about 2.5 hours before it has to turn its solar panels back toward the Sun to recharge its batteries. That communications window would grow shorter year after year if Spitzer continued operating, which means there is a limit to how long it would be possible to operate the spacecraft efficiently.

Teaching the spacecraft to accept new conditions - such as the increasing angle of the solar panels during communications with Earth - isn't as simple as flipping a switch. There are multiple ways these changes could trigger safety mechanisms in the spacecraft's flight software. For instance, if the panels tilted more than 30 degrees from the Sun during the mission's early years, the software would have hit "pause," putting the spacecraft into "safe mode" until the mission team could figure out what was wrong. The changing angle of Spitzer to the Sun could also trigger safety mechanisms intended to prevent spacecraft parts from overheating.

Entering safe mode can be particularly hazardous for the spacecraft, both because of its growing distance from Earth (which makes communicating more difficult) and because the aging onboard systems might not restart once they shut off.

To deal with these challenges, the project engineers and scientists at JPL and Caltech have worked with the observatory engineering team at Lockheed Martin Space's Littleton, Colorado, facility to find a path forward. (Lockheed Martin built the Spitzer spacecraft for NASA.) Bolinda Kahr, Spitzer's mission manager, leads this multi-center team. Over the years she and her colleagues have successfully figured out how to override safety mechanisms designed for the prime mission while also making sure that such alterations don't introduce other unwanted side effects.

But as Spitzer ages and gets farther from Earth, the challenge of keeping the spacecraft operating and the risk that it will suffer a major anomaly are only increasing.

"I can genuinely say that no one involved in the mission planning thought we'd be running in 2019," said Lisa Storrie-Lombardi, Spitzer's project manager. "But we have an incredibly robust spacecraft and an incredible team. And we've been lucky. You have to have some luck, because you can't anticipate everything."

Most infrared detectors have to be cooled to very low temperatures, because excess infrared light from "warm" objects - including the Sun, Earth, the spacecraft and even the instruments themselves - can overwhelm the infrared sensors. This cooling is typically done with a chemical coolant.

The Spitzer planners instead came up with a passive-cooling system that included flying the spacecraft far from Earth (a major infrared heat source). They also chose materials for the spacecraft exterior that would both reflect sunlight away before it could heat the telescope and radiate absorbed heat back into space. In this configuration, coolant is required only to lower the instrument temperatures a few degrees further. Reducing the onboard coolant supply also drastically allowed the engineers to cut the total size of the spacecraft by more than 80% and helped curtail the anticipated mission budget by more than 75%.

Although Spitzer's coolant supply ran out in 2009, rendering two of its three instruments unusable, the team was able to keep half of the remaining instrument operating. (The instrument was designed to detect four wavelengths of infrared light; in the "warm" mode, it can still detect two of them.)

Lasting more than twice as long as the primary mission, Spitzer's extended mission has yielded some of the observatory's most transformational results. In 2017, the telescope revealed the presence of seven rocky planets around the TRAPPIST-1 star. In many cases, Spitzer's exoplanet observations were combined with observations by other missions, including NASA's Kepler and Hubble space telescopes.

Spitzer's final year and a half of science operations include a number of exoplanet-related investigations. One program will investigate 15 dwarf stars (similar to the TRAPPIST-1 star) likely to host exoplanets. An additional 650 hours are dedicated to follow-up observations of planets discovered by NASA's Transiting Exoplanet Survey Satellite (TESS), which launched just over a year ago.

Every mission must end at some point. As the challenges associated with operating Spitzer continue to grow and as the risk of a mission-ending anomaly on the spacecraft rises, NASA has made the decision to close out the mission in a controlled manner.

"There have been times when the Spitzer mission could have ended in a way we didn't plan for," said Kahr. "I'm glad that in January we'll be able to retire the spacecraft deliberately, the way we want to do it."

While Spitzer's mission is ending, it has helped set the stage for NASA's James Webb Space Telescope, set to launch in 2021, which will study the universe in many of the same wavelengths observed by Spitzer. Webb's primary mirror is about 7.5 times larger than Spitzer's mirror, meaning Webb will be able to study many of the same targets in much higher resolution and objects much farther away from Earth than what Spitzer can observe.

Thirteen science programs have already been selected for Webb's first five months of operations, four of which build directly on Spitzer observations. Webb will greatly expand on the legacy begun by Spitzer and answer questions that Spitzer has only begun to investigate.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Space operations are based at Lockheed Martin Space. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

For more information on Spitzer, visit:

www.nasa.gov/spitzer

www.spitzer.caltech.edu/

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Starshade Would Take Formation Flying to Extremes

7 min read

Anyone who's ever seen aircraft engaged in formation flying can appreciate the feat of staying highly synchronized while airborne. In work sponsored by NASA's Exoplanet Exploration Program (ExEP), engineers at the Jet Propulsion Laboratory in Pasadena, California, are taking formation flying to a new extreme.

Their work marks an important milestone within a larger program to test the feasibility of a technology called a starshade. Although starshades have never flown in space, they hold the potential to enable groundbreaking observations of planets beyond our solar system, including pictures of planets as small as Earth.

A future starshade mission would involve two spacecraft. One would be a space telescope on the hunt for planets orbiting stars outside of our solar system. The other spacecraft would fly some 25,000 miles (40,000 kilometers) in front of it, carrying a large, flat shade. The shade would unfurl like a blooming flower — complete with "petals" — and block the light from a star, allowing the telescope to get a clearer glimpse of any orbiting planets. But it would work only if the two spacecraft were to stay, despite the great distance between them, aligned to within 3 feet (1 meter) of each other. Any more, and starlight would leak around the starshade into the telescope's view and overwhelm faint exoplanets.

"The distances we're talking about for the starshade technology are kind of hard to imagine," said JPL engineer Michael Bottom. "If the starshade were scaled down to the size of a drink coaster, the telescope would be the size of a pencil eraser and they'd be separated by about 60 miles [100 kilometers]. Now imagine those two objects are free-floating in space. They're both experiencing these little tugs and nudges from gravity and other forces, and over that distance we're trying to keep them both precisely aligned to within about 2 millimeters."

Researchers have found thousands of exoplanets without the use of a starshade, but in most instances scientists have discovered these worlds indirectly. The transit method, for example, detects the presence of a planet as it passes in front of its parent star and causes a temporary drop in the star's brightness. Only in relatively few cases have scientists taken direct images of exoplanets.

Blocking out starlight is key to performing more direct imaging and, eventually, to carrying out in-depth studies of planetary atmospheres or finding hints about the surface features of rocky worlds. Such studies have the potential to reveal signs of life beyond Earth for the first time.

The idea of using a space-based starshade to study exoplanets was initially proposed in the 1960s, four decades before the discovery of the first exoplanets. And while the ability to point a single spacecraft steadily at a distant object is not new, either, keeping two spacecraft aligned with each other toward a background object represents a different kind of challenge.

Researchers working on ExEP's Starshade Technology Development, known as S5, have been tasked by NASA with developing starshade technology for possible future space telescope missions. The S5 team is addressing three technology gaps that would need to be closed before a starshade mission could be ready to go to space.

The work done by Bottom and fellow JPL engineer Thibault Flinois closes one of those gaps by confirming that engineers could realistically produce a starshade mission that met these stringent "formation sensing and control" requirements. Their results are described in the S5 Milestone 4 report, available on the ExEP website.

The specifics of a particular starshade mission — including the exact distance between the two spacecraft and the size of the shade — would depend on the size of the telescope. The S5 Milestone 4 report looked primarily at a separation range of between 12,500 to 25,000 miles (20,000 to 40,000 kilometers), with a shade 85 feet (26 meters) in diameter. These parameters would work for a mission the size of NASA's Wide Field Infrared Survey Telescope (WFIRST), a telescope with a 2.4-meter-diameter primary mirror set to launch in the mid-2020s.

WFIRST will carry a different starlight-blocking technology, called a coronagraph, that sits inside the telescope and offers its own unique strengths in the study of exoplanets. This technology demonstration will be the first high-contrast stellar coronagraph to go into space, enabling WFIRST to directly image giant exoplanets similar to Neptune and Jupiter.

Starshade and coronagraph technologies work separately, but Bottom tested a technique by which WFIRST could detect when a hypothetical starshade drifted subtly out of alignment. A small amount of starlight would inevitably bend around the starshade and form a light-and-dark pattern on the front of the telescope. The telescope would see the pattern by using a pupil camera, which can image the front of the telescope from inside — akin to photographing a windshield from inside a car.

Previous starshade investigations had considered this approach, but Bottom made it a reality by building a computer program that could recognize when the light-and-dark pattern was centered on the telescope and when it had drifted off-center. Bottom found that the technique works extremely well as a way to detect the starshade's movement.

“We can sense a change in the position of the starshade down to an inch, even over these huge distances,” Bottom said.

But detecting when the starshade is out of alignment is an entirely different proposition from actually keeping it aligned. To that end, Flinois and his colleagues developed a set of algorithms that use information provided by Bottom's program to determine when the starshade thrusters should fire to nudge it back into position. The algorithms were created to autonomously keep the starshade aligned with the telescope for days at a time.

Combined with Bottom's work, this shows that keeping the two spacecraft aligned is feasible using automated sensors and thruster controls. In fact, the work by Bottom and Flinois demonstrates that engineers could reasonably meet the alignment demands of an even larger starshade (in conjunction with a larger telescope), positioned up to 46,000 miles (74,000 kilometers) from the telescope.

“With such an unusually large range of scales at play here, it can be very counterintuitive that this would be possible at first glance,” Flinois said.

A starshade project has not yet been approved for flight, but one could potentially join WFIRST in space in the late 2020s. Meeting the formation-flying requirement is just one step toward demonstrating that the project is feasible.

“This to me is a fine example of how space technology becomes ever more extraordinary by building upon its prior successes,” said Phil Willems, manager of NASA's Starshade Technology Development activity. “We use formation flying in space every time a capsule docks at the International Space Station. But Michael and Thibault have gone far beyond that, and shown a way to maintain formation over scales larger than Earth itself.”

JPL manages ExEP for NASA's Astrophysics Division.

Calla Cofield Jet Propulsion Laboratory, Pasadena, Calif. 626-808-2469
calla.e.cofield@jpl.nasa.gov

2019-108

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New Discovery Shows ‘Habitable Zone for Complex Life’ is Much More Narrow than Original Estimates

3 min read

A study released today is the first to refine where environments suitable for life, more complex than microorganisms, might be able to exist beyond our own solar system.

Research funded by the NASA Astrobiology Program through the NASA Astrobiology Institute (NAI) concludes that increased levels of toxic gases significantly narrow the habitable zone for complex life. Scientists define the traditional habitable zone as the distance from a star where there is enough heat for liquid water to persist on a planet’s surface.

Life as we know it requires liquid water to survive, and planets within the habitable zone of a star are thought to be the best candidates for supporting microbial life. However, microorganisms are able to thrive in conditions that are not suitable for more complex life. The new study provides the first estimation of a narrow habitable zone for complex life, where planets might be able to support animal-like organisms.

Using models for atmospheric climate and photochemistry, scientists compared predicted carbon dioxide (CO2) and carbon monoxide (CO) levels to previously determined toxicity limits that quantitatively designate the safe zone for macroscopic life on exoplanets.

“This is the first time the physiological limits of life on Earth have been considered to predict the distribution of complex life elsewhere in the universe,” said Timothy Lyons, study co-author, distinguished professor of biogeochemistry at the University of California, Riverside’s Department of Earth and Planetary Sciences, and director of the NAI’s Alternative Earths Astrobiology Center, which sponsored the project.

The study has important implications in the the search for biological complexity in the universe, and in determining the best places to look for signs of intelligent life or potential evidence of technology.

“This study will shape the development of new technologies, missions, and more powerful telescopes that we will use to search the sky for signatures of life beyond the solar System,” said Mary Voytek, NASA Astrobiology Program director.

According to Voytek, studies like this are important in helping us decide where to focus our search, and the instruments we will need. Ultimately this increases the likelihood of finding evidence that Earth isn’t the only planet in the vastness of space where life exists.

This newly-revealed science is also a critical part of NASA’s work to understand the universe, advance human exploration, and inspire the next generation. As NASA’s Artemis program moves forward with human exploration of the Moon, the search for life on other worlds remains a top priority for the agency.

Lead author of the study, Edward Schwieterman, is supported through the NASA Astrobiology Program as a NASA Postdoctoral Program fellow with the Alternative Earths Astrobiology Center at UCR. Timothy Lyons, co-author of the study and Schwieterman’s advisor at UCR, is a project co-lead for the new NASA Astrobiology RCN Prebiotic Chemistry and Early Earth Environments Consortium (PCE3). Additional co-authors of the study include Christopher Reinhard, assistant professor at the Georgia Institute of Technology, Stephanie Olson of the University of Chicago, and Chester E. Harman of Columbia University.

The paper, “A Limited Habitable Zone for Complex Life”is published in The Astrophysical Journal and can be found at: https://iopscience.iop.org/article/10.3847/1538-4357/ab1d52

-end-

Dwayne Brown / Alana Johnson

Headquarters, Washington

202-358-1726 / 202-358-1501

dwayne.c.brown@nasa.gov/ alana.r.johnson@nasa.gov

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

In a surprise finding, astronomers using NASA’s Hubble Space Telescope have discovered that the blowtorch-like…

Universe

Overview Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way.…

Galaxies Stories

Overview Our planetary system is located in an outer spiral arm of the Milky Way galaxy. We call it the…

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Starshade Would Take Formation Flying to Extremes

6 min read

NASA Science Editorial Team

Anyone who's ever seen aircraft engaged in formation flying can appreciate the feat of staying highly synchronized while airborne. In work sponsored by NASA's Exoplanet Exploration Program (ExEP), engineers at the Jet Propulsion Laboratory in Pasadena, California, are taking formation flying to a new extreme.

Their work marks an important milestone within a larger program to test the feasibility of a technology called a starshade. Although starshades have never flown in space, they hold the potential to enable groundbreaking observations of planets beyond our solar system, including pictures of planets as small as Earth.

A future starshade mission would involve two spacecraft. One would be a space telescope on the hunt for planets orbiting stars outside of our solar system. The other spacecraft would fly some 25,000 miles (40,000 kilometers) in front of it, carrying a large, flat shade. The shade would unfurl like a blooming flower - complete with "petals" - and block the light from a star, allowing the telescope to get a clearer glimpse of any orbiting planets. But it would work only if the two spacecraft were to stay, despite the great distance between them, aligned to within 3 feet (1 meter) of each other. Any more, and starlight would leak around the starshade into the telescope's view and overwhelm faint exoplanets.

"The distances we're talking about for the starshade technology are kind of hard to imagine," said JPL engineer Michael Bottom. "If the starshade were scaled down to the size of a drink coaster, the telescope would be the size of a pencil eraser and they'd be separated by about 60 miles [100 kilometers]. Now imagine those two objects are free-floating in space. They're both experiencing these little tugs and nudges from gravity and other forces, and over that distance we're trying to keep them both precisely aligned to within about 2 millimeters."

Researchers have found thousands of exoplanets without the use of a starshade, but in most instances scientists have discovered these worlds indirectly. The transit method, for example, detects the presence of a planet as it passes in front of its parent star and causes a temporary drop in the star's brightness. Only in relatively few cases have scientists taken direct images of exoplanets.

Blocking out starlight is key to performing more direct imaging and, eventually, to carrying out in-depth studies of planetary atmospheres or finding hints about the surface features of rocky worlds. Such studies have the potential to reveal signs of life beyond Earth for the first time.

The idea of using a space-based starshade to study exoplanets was initially proposed in the 1960s, four decades before the discovery of the first exoplanets. And while the ability to point a single spacecraft steadily at a distant object is not new, either, keeping two spacecraft aligned with each other toward a background object represents a different kind of challenge.

Researchers working on ExEP's Starshade Technology Development, known as S5, have been tasked by NASA with developing starshade technology for possible future space telescope missions. The S5 team is addressing three technology gaps that would need to be closed before a starshade mission could be ready to go to space.

The work done by Bottom and fellow JPL engineer Thibault Flinois closes one of those gaps by confirming that engineers could realistically produce a starshade mission that met these stringent "formation sensing and control" requirements. Their results are described in the S5 Milestone 4 report, available on the ExEP website.

The specifics of a particular starshade mission - including the exact distance between the two spacecraft and the size of the shade - would depend on the size of the telescope. The S5 Milestone 4 report looked primarily at a separation range of between 12,500 to 25,000 miles (20,000 to 40,000 kilometers), with a shade 85 feet (26 meters) in diameter. These parameters would work for a mission the size of NASA's Wide Field Infrared Survey Telescope (WFIRST), a telescope with a 2.4-meter-diameter primary mirror set to launch in the mid-2020s.

WFIRST will carry a different starlight-blocking technology, called a coronagraph, that sits inside the telescope and offers its own unique strengths in the study of exoplanets. This technology demonstration will be the first high-contrast stellar coronagraph to go into space, enabling WFIRST to directly image giant exoplanets similar to Neptune and Jupiter.

Starshade and coronagraph technologies work separately, but Bottom tested a technique by which WFIRST could detect when a hypothetical starshade drifted subtly out of alignment. A small amount of starlight would inevitably bend around the starshade and form a light-and-dark pattern on the front of the telescope. The telescope would see the pattern by using a pupil camera, which can image the front of the telescope from inside - akin to photographing a windshield from inside a car.

Previous starshade investigations had considered this approach, but Bottom made it a reality by building a computer program that could recognize when the light-and-dark pattern was centered on the telescope and when it had drifted off-center. Bottom found that the technique works extremely well as a way to detect the starshade's movement.

"We can sense a change in the position of the starshade down to an inch, even over these huge distances," Bottom said.

But detecting when the starshade is out of alignment is an entirely different proposition from actually keeping it aligned. To that end, Flinois and his colleagues developed a set of algorithms that use information provided by Bottom's program to determine when the starshade thrusters should fire to nudge it back into position. The algorithms were created to autonomously keep the starshade aligned with the telescope for days at a time.

Combined with Bottom's work, this shows that keeping the two spacecraft aligned is feasible using automated sensors and thruster controls. In fact, the work by Bottom and Flinois demonstrates that engineers could reasonably meet the alignment demands of an even larger starshade (in conjunction with a larger telescope), positioned up to 46,000 miles (74,000 kilometers) from the telescope.

"With such an unusually large range of scales at play here, it can be very counterintuitive that this would be possible at first glance," Flinois said.

A starshade project has not yet been approved for flight, but one could potentially join WFIRST in space in the late 2020s. Meeting the formation-flying requirement is just one step toward demonstrating that the project is feasible.

"This to me is a fine example of how space technology becomes ever more extraordinary by building upon its prior successes," said Phil Willems, manager of NASA's Starshade Technology Development activity. "We use formation flying in space every time a capsule docks at the International Space Station. But Michael and Thibault have gone far beyond that, and shown a way to maintain formation over scales larger than Earth itself."

JPL manages ExEP for NASA's Astrophysics Division.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Spitzer Captures Stellar Family Portrait

NASA Science Editorial Team

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The Planet Hunter and the ‘Unseen Giant’

6 min read

Pat Brennan

It was March 1988, and astronomer David Latham was working into the night, puzzling over an odd result from an experimental instrument at Harvard’s Oak Ridge Observatory in Massachusetts.

At the time, planets around other stars were an unproven – if thrilling – idea. The decades since have revealed them in stunning variety.

Thanks to space telescopes such as NASA's Kepler spacecraft, we now know that there are more planets than stars in the galaxy. Nearly 4,000 planets that orbit stars other than our Sun – exoplanets – have been confirmed.

But first, pioneering scientists had to lay the foundations, chasing clues to the possible presence of these distant worlds when the technology was still in its infancy.

By 1988, Latham and his colleagues had been searching for signs of “extrasolar planets” for years, and had come up dry. Teasing out the presence of planets by tracking the wobbling motions of stars was turning out to be extremely difficult. But now he was seeing something remarkable: a spike in the side-to-side motion of a star, suggesting a companion in orbit around it. The data had been gathered using an experimental fiber feed – now standard equipment – from the “digital speedometer” instrument at Oak Ridge, which measures stellar motions.

In an email on a primitive system, which took two hours to reach his colleagues in Geneva, Latham described his findings. He ended with a modest observation: that it would be “very exciting” if the anomaly he’d seen “was due to an unseen giant planet in an orbit similar to Mercury’s.”

The result, published the following year, was HD 114762 b, one of the earliest known potential planets beyond our solar system. That publication marks its 30th anniversary in May 2019.

The early days of planet hunting were filled with such moments – more “That’s funny” than “Eureka” in Isaac Asimov’s famous phrase. In August 1988, a buzz of press excitement greeted Latham’s description of his finding at a science conference. Another planet detection had been announced by a Canadian team in 1987, then withdrawn – only to be reconfirmed more than a decade later.

While his 1989 paper identified the new discovery as a “probable brown dwarf” – a kind of failed star that is not considered a planet – Latham wrote that the object “may even be a giant planet.”

Latham ran immediately into scientific headwinds. The planet he seemed to have found was just too strange – too unlike anything in our solar system. The astronomical community was not convinced.

“It’s my three strikes analogy,” Latham said recently. “The first strike is, it had an eccentric orbit (tracing an elongated ellipse around its star). Everybody was convinced giant planets had to have circular orbits; it’s that way in our solar system.”

Strike two: The planet’s “year” was much too short – just 84 days to go once around its star, comparable to Mercury’s orbit in our solar system. In those days, “everybody knew” giant planets had to be formed much farther out, Latham said. Such a big planet just couldn’t be that close to its star.

And this was a really big planet: at least 11 times the mass of Jupiter.

Strike three. Theorists at the time couldn't find a way for nature to make a planet more than about twice the mass of Jupiter.

Just a few years later, all that cautious reasoning would be cast to the wind. That's when 51 Pegasi b (51 Peg for short) arrived on the scene. It was one of the first discoveries of an exoplanet to capture the world's attention. And it was very strange.

About half the size of Jupiter, 51 Peg had a scorching 3.5-day orbit. A number of such "hot Jupiters" have been discovered since. About 1 percent of Sun-like stars are estimated to host a hot Jupiter.

51 Peg showed that big planets could, indeed, hug their stars tightly – in fact, far more tightly than the possible planet Latham had found.

The discovery also validated the planet-hunting method Latham and others employed: watching the stretching and compressing of light from a star as an orbiting planet tugs it one way, then another. Light from stars moving away from us is "Doppler shifted" and appears more red; from those moving closer, light is shifted toward the blue.

This technique is called radial velocity, or simply the "wobble" method, and it's yielded hundreds of exoplanet discoveries. In the years since those early finds, it's been surpassed only by the "transit" method, which looks for the tiny dip in starlight as a planet passes in front of its star. Confirmed transiting planets number in the thousands; many of these were confirmed using radial velocity.

The discovery of 51 Peg is not without irony. Michel Mayor, who made the 1995 discovery with Didier Queloz, had been a co-author with Latham on his 1989 paper.

"Michel Mayor said, 'No, it can't possibly be a planet,'" Latham said. Mayor did, however, use an approach similar to that of Latham's team to devise the instrument that would reveal 51 Peg.

Early detections such as these were tantalizing, suggesting there were more planetary systems out there, just waiting to be uncovered. As scientists continued their exoplanet searches into the 1990s and early 2000s, they became ever more certain that new technologies, especially in space, could pave the way to even more discoveries.

This allowed NASA to invest confidently in increasingly sophisticated space missions, to discover and characterize these worlds in far greater numbers and with far greater sensitivity. More than 2,500 exoplanets were found with Kepler, which launched in 2009 and ended its mission in 2018. Groundbreaking observatories such as NASA's Transiting Exoplanet Survey Satellite, TESS, and the upcoming James Webb Space Telescope, have been developed because of these advances, and will teach us even more about our galactic neighbors.

And Latham's discovery?

Though the astronomical community now catalogs the unseen companion as a likely planet among thousands of others discovered since, Latham still considers his 30-year-old find a candidate. Still at Harvard and still hunting for exoplanets, he is awaiting data from the European Space Agency's Gaia probe to help further pin down the object's true size. Oak Ridge, which yielded his early, exciting result, closed in 2009.

Based on the initial reactions to his historic discovery, Latham reaches farther back into history for advice to astronomers of the future. In 1963, he attended a final lecture by astronomer Cecilia Payne-Gaposchkin. She found in 1925 that stars were mostly made of hydrogen; her work was roundly rejected before, much later, being proved correct. The thrust of her talk still echoes.

"Be prepared for surprises," Latham remembered her saying. "And recognize things that look anomalous. Try to understand what it is, make the best case for what it might be, then go ahead and publish. If someone is so upset that they don't believe it, they will take up the experiment to show you where you were wrong. Sometimes all that does is show you where you were right.”

Pat Brennan is a science writer for NASA's Exoplanet Exploration Program. He joined JPL in 2015 after a 30-year career as a newspaper journalist.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A New View of Exoplanets With NASA’s Upcoming Webb Telescope

7 min read

While we now know of thousands of exoplanets — planets around other stars — the vast majority of our knowledge is indirect. That is, scientists have not actually taken many pictures of exoplanets, and because of the limits of current technology, we can only see these worlds as points of light. However, the number of exoplanets that have been directly imaged is growing over time. When NASA’s James Webb Space Telescope launches in 2021, it will open a new window on these exoplanets, observing them in wavelengths at which they have never been seen before and gaining new insights about their nature.

Exoplanets are close to much brighter stars, so their light is generally overwhelmed by the light of the host stars. Astronomers usually find an exoplanet by inferring its presence based on the dimming of its host star’s light as the planet passes in front of the star – an event called a “transit.” Sometimes a planet tugs on its star, causing the star to wobble slightly.

In a few cases, scientists have captured pictures of exoplanets by using instruments called coronagraphs. These devices block the glare of the star in much the same way you might use your hand to block the light of the Sun. However, finding exoplanets with this technique has proven to be very difficult. All that will change with the sensitivity of Webb. Its onboard coronagraphs will allow scientists to view exoplanets at infrared wavelengths they’ve never seen them in before.

Coronagraphs have something important in common with eclipses. During an eclipse, the Moon blocks the light of the Sun, allowing us to view stars that would normally be overwhelmed by the Sun’s glare. Astronomers took advantage of this during the 1919 eclipse, 100 years ago on May 29, in order to test Albert Einstein’s theory of general relativity. Similarly, a coronagraph acts as an “artificial eclipse” to block the light from a star, allowing planets that would otherwise be lost in the star’s glare to be seen.

“Most of the planets that we have detected so far are roughly 10,000 to 1 million times fainter than their host star,” explained Sasha Hinkley of the University of Exeter. Hinkley is the principal investigator on one of Webb’s first observation programs to study exoplanets and exoplanetary systems.

“There is, no doubt, a population of planets that are fainter than that, that have higher contrast ratios, and are possibly farther out from their stars,” Hinkley said. “With Webb, we will be able to see planets that are more like 10 million, or optimistically, 100 million times fainter.” To observe their targets, the team will use high-contrast imaging, which discerns this large difference in brightness between the planet and the star.

Webb will have the capability of observing its targets in the mid-infrared, which is invisible to the human eye, but with sensitivity that is vastly superior to any other observatory ever built. This means that Webb will be sensitive to a class of planet not yet detected. Specifically, Saturn-like planets at very wide orbital separations from their host star may be within reach of Webb.

“Our program is looking at young, newly formed planets and the systems they inhabit,” explained co-principal investigator Beth Biller of the University of Edinburgh. “Webb is going to allow us to do this in much more detail and at wavelengths we’ve never explored before. So it’s going to be vital for understanding how these objects form, and what these systems are like.”

The team’s observations will be part of the Director’s Discretionary-Early Release Science program, which provides time to selected projects early in the telescope’s mission. This program allows the astronomical community to quickly learn how best to use Webb's capabilities, while also yielding robust science.

“With our ERS program, we will really be ‘testing the waters’ to get an understanding of how Webb performs,” said Hinkley. “We really need the best understanding of the instruments, of the stability, of the most effective way to post-process the data. Our observations are going to tell our community the most efficient way to use Webb.”

Hinkley's team will use all four of Webb's instruments to observe three targets: A recently discovered exoplanet; an object that is either an exoplanet or a brown dwarf; and a well-studied ring of dust and planetesimals orbiting a young star.

Exoplanet HIP 65426b: This newly discovered, directly imaged exoplanet has a mass between six and 12 times that of Jupiter and is orbiting a star that is hotter than and about twice as massive as our Sun. The exoplanet is roughly 92 times farther from its star than Earth is from the Sun. The wide separation of this young planet from its star means that the team's observations will be much less affected by the bright glare of the host star. Hinkley and his team plan to use Webb's full suite of coronagraphs to view this target.

Planetary-mass companion VHS 1256b: An object somewhere around the planet/brown dwarf boundary, VHS 1256b also is widely separated from its red dwarf host star—about 100 times the distance that the Earth is from the Sun. Because of its wide separation, observations of this object are much less likely to be affected by unwanted light from the host star. In addition to high-contrast imaging, the team expects to get one of the first “uncorrupted” spectra of a planet-like body at wavelengths where these objects have never before been studied.

Circumstellar debris disk: For more than 20 years, scientists have been studying a ring of dust and planetesimals orbiting a young star called HR 4796A, which is about twice as massive as our own Sun. Astronomers think that most planetary systems probably looked a lot like HR 4796A and its debris ring at their earliest ages, making this a particularly interesting target to study. The team will use the high-contrast imaging of Webb's coronagraphs to view the disk in different wavelengths. Their goal is to see if the structures of the disk look different from wavelength to wavelength.

To plan this Early Release Science program, Hinkley asked as many members of the astronomical community as possible the simple question: If you want to plan a survey to search for exoplanets, what are the questions that you need the answers to for planning your surveys?

“What we came up with was a set of observations that we think is going [to] answer those questions. We are going to tell the community that this is the way Webb performs in this mode, this is the kind of sensitivity we get, and this is the kind of contrast we achieve. And we need to rapidly turn that around and inform the community so that they can prepare their proposals really, really quickly.”

The team is excited to view their targets in wavelengths never before detected, and to share their knowledge. According to Biller, “We could see years ago that for some of the planets we've already discovered, Webb would be really transformational.”

The James Webb Space Telescope will be the world's premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

For more information about Webb, visit www.nasa.gov/webb.

By Ann JenkinsSpace Telescope Science Institute, Baltimore Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A New View of Exoplanets With Webb

7 min read

NASA Science Editorial Team

By Ann Jenkins, Space Telescope Science Institute

While we now know of thousands of exoplanets — planets around other stars — the vast majority of our knowledge is indirect. That is, scientists have not actually taken many pictures of exoplanets, and because of the limits of current technology, we can only see these worlds as points of light. However, the number of exoplanets that have been directly imaged is growing over time. When NASA's James Webb Space Telescope launches in 2021, it will open a new window on these exoplanets, observing them in wavelengths at which they have never been seen before and gaining new insights about their nature.

Exoplanets are close to much brighter stars, so their light is generally overwhelmed by the light of the host stars. Astronomers usually find an exoplanet by inferring its presence based on the dimming of its host star's light as the planet passes in front of the star – an event called a "transit." Sometimes a planet tugs on its star, causing the star to wobble slightly.

In a few cases, scientists have captured pictures of exoplanets by using instruments called coronagraphs. These devices block the glare of the star in much the same way you might use your hand to block the light of the Sun. However, finding exoplanets with this technique has proven to be very difficult. All that will change with the sensitivity of Webb. Its onboard coronagraphs will allow scientists to view exoplanets at infrared wavelengths they've never seen them in before.

Coronagraphs have something important in common with eclipses. During an eclipse, the Moon blocks the light of the Sun, allowing us to view stars that would normally be overwhelmed by the Sun's glare. Astronomers took advantage of this during the 1919 eclipse, 100 years ago on May 29, in order to test Albert Einstein's theory of general relativity. Similarly, a coronagraph acts as an "artificial eclipse" to block the light from a star, allowing planets that would otherwise be lost in the star's glare to be seen.

"Most of the planets that we have detected so far are roughly 10,000 to 1 million times fainter than their host star," explained Sasha Hinkley of the University of Exeter. Hinkley is the principal investigator on one of Webb's first observation programs to study exoplanets and exoplanetary systems.

"There is, no doubt, a population of planets that are fainter than that, that have higher contrast ratios, and are possibly farther out from their stars," Hinkley said. "With Webb, we will be able to see planets that are more like 10 million, or optimistically, 100 million times fainter." To observe their targets, the team will use high-contrast imaging, which discerns this large difference in brightness between the planet and the star.

Webb will have the capability of observing its targets in the mid-infrared, which is invisible to the human eye, but with sensitivity that is vastly superior to any other observatory ever built. This means that Webb will be sensitive to a class of planet not yet detected. Specifically, Saturn-like planets at very wide orbital separations from their host star may be within reach of Webb.

"Our program is looking at young, newly formed planets and the systems they inhabit," explained co-principal investigator Beth Biller of the University of Edinburgh. "Webb is going to allow us to do this in much more detail and at wavelengths we've never explored before. So it's going to be vital for understanding how these objects form, and what these systems are like."

The team’s observations will be part of the Director's Discretionary-Early Release Science program, which provides time to selected projects early in the telescope's mission. This program allows the astronomical community to quickly learn how best to use Webb's capabilities, while also yielding robust science.

“With our ERS program, we will really be ‘testing the waters’ to get an understanding of how Webb performs,” said Hinkley. “We really need the best understanding of the instruments, of the stability, of the most effective way to post-process the data. Our observations are going to tell our community the most efficient way to use Webb.”

Hinkley’s team will use all four of Webb’s instruments to observe three targets: A recently discovered exoplanet; an object that is either an exoplanet or a brown dwarf; and a well-studied ring of dust and planetesimals orbiting a young star.

Exoplanet HIP 65426b: This newly discovered, directly imaged exoplanet has a mass between six and 12 times that of Jupiter and is orbiting a star that is hotter than and about twice as massive as our Sun. The exoplanet is roughly 92 times farther from its star than Earth is from the Sun. The wide separation of this young planet from its star means that the team’s observations will be much less affected by the bright glare of the host star. Hinkley and his team plan to use Webb’s full suite of coronagraphs to view this target.

Planetary-mass companion VHS 1256b: An object somewhere around the planet/brown dwarf boundary, VHS 1256b also is widely separated from its red dwarf host star—about 100 times the distance that the Earth is from the Sun. Because of its wide separation, observations of this object are much less likely to be affected by unwanted light from the host star. In addition to high-contrast imaging, the team expects to get one of the first "uncorrupted" spectra of a planet-like body at wavelengths where these objects have never before been studied.

Circumstellar debris disk: For more than 20 years, scientists have been studying a ring of dust and planetesimals orbiting a young star called HR 4796A, which is about twice as massive as our own Sun. Astronomers think that most planetary systems probably looked a lot like HR 4796A and its debris ring at their earliest ages, making this a particularly interesting target to study. The team will use the high-contrast imaging of Webb’s coronagraphs to view the disk in different wavelengths. Their goal is to see if the structures of the disk look different from wavelength to wavelength.

To plan this Early Release Science program, Hinkley asked as many members of the astronomical community as possible the simple question: If you want to plan a survey to search for exoplanets, what are the questions that you need the answers to for planning your surveys?

“What we came up with was a set of observations that we think is going [to] answer those questions. We are going to tell the community that this is the way Webb performs in this mode, this is the kind of sensitivity we get, and this is the kind of contrast we achieve. And we need to rapidly turn that around and inform the community so that they can prepare their proposals really, really quickly.”

The team is excited to view their targets in wavelengths never before detected, and to share their knowledge. According to Biller, “We could see years ago that for some of the planets we’ve already discovered, Webb would be really transformational.”

The James Webb Space Telescope will be the world’s premier space science observatory when it launches in 2021. Webb will solve mysteries in our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international program led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing.

Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: TESS Serves up Two New Planets

1 min read

NASA Science Editorial Team

Planets: TOI 216 b, TOI 216 c

Discovered by: Kipping et al.

Date: February 2019

Key facts: The newest discoveries from TESS – the Transiting Exoplanet Survey Satellite – add to a growing catalog of giant, gaseous planets orbiting other stars. A third gas giant, HD 221420, was also announced, a planet about 10 times the mass of Jupiter discovered with a ground-based telescope.

Details: TOI 216 b and c both orbit a star about 580 light years from Earth. TOI 216 b is a little more than half as big around as Jupiter. TOI 216 c is about as big around as Jupiter. The two planets also are in "orbital resonance" – that is, the outer planet, c, takes almost exactly twice as long to orbit the star as the inner planet. TOI 216 b takes 17 days to go once around its star – a year on this planet. TOI 216 c takes 34 days.

What's new: The latest discoveries bring to 13 the number of TESS planets confirmed so far. This planet hunter, launched in April 2018, looks for the tiny dip in starlight as a planet crosses the face of its star.

Read the paper: A resonant pair of warm giant planets revealed by TESS

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet-Hunter CubeSat Images Los Angeles

3 min read

NASA Science Editorial Team

By Calla Cofield, NASA's Jet Propulsion Laboratory

A small satellite designed to hunt for new planets beyond the solar system recently looked down at Earth to capture an image of California's "City of Stars."

The greater Los Angeles area stands out in these images from ASTERIA, the Arcsecond Space Telescope Enabling Research in Astrophysics, a satellite not much larger than a briefcase. ASTERIA is a CubeSat, or a small satellite composed of cubic units that measure 10 centimeters (4.5 inches) on each side. This particular CubeSat is made up of six units.

The images, taken March 29, reveal a massive grid of illuminated city streets and freeways. A bright spot near the center of the first image marks the location of Dodger Stadium. (The Dodgers played the Arizona Diamondbacks at home that night.) To the northeast, near the darkness of the San Gabriel Mountains, is NASA's Jet Propulsion Laboratory in Pasadena, California, which built and operates ASTERIA, and the nearby Rose Bowl Stadium. The close-cropped image shows a region of about 43.5 square miles (70 square kilometers), with a resolution of about 100 feet (30 meters) per pixel.

Lots of orbiting small satellites can take higher-quality pictures of Earth than this one. But ASTERIA is the only CubeSat in orbit that can also look for exoplanets, or planets orbiting stars other than our Sun. Its primary mission objective was to demonstrate precision-pointing technology in a small satellite.

With precision pointing, ASTERIA can stare at a star for long periods of time and measure small changes in its brightness. A slight decrease in a star's brightness as detected by ASTERIA could indicate that a planet is orbiting the star and passed in front of the star. This is called a planet transit. (NASA missions that use or have used the transit method to find exoplanets include the Transiting Exoplanet Survey Satellite, or TESS, which launched in 2018, and the recently retired Kepler space telescope.) ASTERIA took these images of Los Angeles in order to further explore the capabilities of its onboard hardware.

ASTERIA met its primary mission requirements – demonstrating that the spacecraft could point very precisely – by January 2018. Now ASTERIA is operating in an extended mission phase that includes conducting exoplanet science and testing new software capabilities.

Engineers will test an onboard navigation system that could enable the satellite to autonomously determine its own orbit using only ASTERIA's imaging system. This will establish whether a CubeSat system has the capability to navigate by itself in a low-Earth orbit environment in which GPS services are unavailable or ground communication is intermittent.

ASTERIA was developed under the Phaeton Program at JPL. Phaeton provided early-career hires, under the guidance of experienced mentors, with the challenges of a flight project. The mission is a collaboration with the Massachusetts Institute of Technology (MIT) in Cambridge. Sara Seager, a professor of planetary science and physics at MIT, is the mission's principal investigator.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The Giant Galaxy Around the Giant Black Hole

3 min read

Pat Brennan

On April 10, 2019, the Event Horizon Telescope (EHT) unveiled the first-ever image of a black hole's event horizon, the area beyond which light cannot escape the immense gravity of the black hole. That giant black hole, with a mass of 6.5 billion Suns, is located in the elliptical galaxy Messier 87 (M87). EHT is an international collaboration whose support in the U.S. includes the National Science Foundation.

This image from NASA's Spitzer Space Telescope shows the entire M87 galaxy in infrared light. The EHT image, by contrast, relied on light in radio wavelengths and showed the black hole's shadow against the backdrop of high-energy material around it.

Located about 55 million light-years from Earth, M87 has been a subject of astronomical study for more than 100 years and has been imaged by many NASA observatories, including the Hubble Space Telescope, the Chandra X-ray Observatory and NuSTAR. In 1918, astronomer Heber Curtis first noticed "a curious straight ray" extending from the galaxy's center. This bright jet of high-energy material, produced by a disk of material spinning rapidly around the black hole, is visible in multiple wavelengths of light, from radio waves through X-rays. When the particles in the jet impact the interstellar medium (the sparse material filling the space between stars in M87), they create a shockwave that radiates in infrared and radio wavelengths of light but not visible light. In the Spitzer image, the shockwave is more prominent than the jet itself.

The brighter jet, located to the right of the galaxy's center, is traveling almost directly toward Earth. Its brightness is amplified due to its high speed in our direction, but even more so because of what scientists call "relativistic effects," which arise because the material in the jet is traveling near the speed of light. The jet's trajectory is just slightly offset from our line of sight with respect to the galaxy, so we can still see some of the length of the jet. The shockwave begins around the point where the jet appears to curve down, highlighting the regions where the fast-moving particles are colliding with gas in the galaxy and slowing down.

The second jet, by contrast, is moving so rapidly away from us that the relativistic effects render it invisible at all wavelengths. But the shockwave it creates in the interstellar medium can still be seen here.

Located on the left side of the galaxy's center, the shockwave looks like an inverted letter "C." While not visible in optical images, the lobe can also be seen in radio waves, as in this image from the National Radio Astronomy Observatory's Very Large Array.

By combining observations in the infrared, radio waves, visible light, X-rays and extremely energetic gamma rays, scientists can study the physics of these powerful jets. Scientists are still striving for a solid theoretical understanding of how gas being pulled into black holes creates outflowing jets.

Infrared light at wavelengths of 3.6 and 4.5 microns are rendered in blue and green, showing the distribution of stars, while dust features that glow brightly at 8.0 microns are shown in red. The image was taken during Spitzer's initial "cold" mission.

The Jet Propulsion Laboratory in Pasadena, California, manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Space operations are based at Lockheed Martin Space Systems in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

More information on Spitzer can be found at its website:

http://www.spitzer.caltech.edu/

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: These Giants are Hot

2 min read

NASA Science Editorial Team

Planets: Qatar-8b, Qatar-9b, Qatar-10b

Discovered by: Qatar Exoplanet Survey

Date: March 2019

Key facts: The theme for three new planets added to the Exoplanet Archive is hot, hot, hot. All orbit their stars in between 1.5 to about 4 days. Because they are so close to their suns, they hover between 1,457 degrees to 3,000 degrees F.

Details: Qatar-8b, 9b and 10b are all gas giants like our own Jupiter and Saturn, but in tight orbits around their parent stars. Qatar-8b is just over a third of Jupiter's mass, and is considered a "hot Saturn." It takes less than four days to orbit its star, which is about 900 light-years from Earth. Qatar-9b, a "hot Jupiter," takes only a day and a half to make a complete orbit -– a "year" on this planet. This gas giant, about 1.2 times Jupiter's mass, orbits a star 688 light-years away. And while Qatar-10b has a very similar orbital period – 1.6 days – and is also a hot Jupiter, it would look much larger than Jupiter at 1.5 times the distance across. Oddly, Qatar-10b is significantly less dense than Jupiter, with only about three quarters of its mass. It orbits a star more than 1,700 light-years away.

What's new: We're getting ever closer to the 4,000 mark for confirmed exoplanets. The new planets bring the total on the Exoplanet Archive counter to 3,949 – only 51 planets to go.

Read the paper: Qatar Exoplanet Survey: Qatar-8b, 9b and 10b -- A Hot Saturn and Two Hot Jupiters

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: A Third Planet in Kepler-47 System

4 min read

Astronomers have discovered a third planet in the Kepler-47 system, securing the system’s title as the most interesting of the binary-star worlds. Using data from NASA’s Kepler space telescope, a team of researchers, led by astronomers at San Diego State University, detected the new Neptune-to-Saturn-size planet orbiting between two previously known planets.

With its three planets orbiting two suns, Kepler-47 is the only known multi-planet circumbinary system. Circumbinary planets are those that orbit two stars.

The planets in the Kepler-47 system were detected via the “transit method.” If the orbital plane of the planet is aligned edge-on as seen from Earth, the planet can pass in front of the host stars, leading to a measurable decrease in the observed brightness. The new planet, dubbed Kepler-47d, was not detected earlier due to weak transit signals.

As is common with circumbinary planets, the alignment of the orbital planes of the planets change with time. In this case, the middle planet’s orbit has become more aligned, leading to a stronger transit signal. The transit depth went from undetectable at the beginning of the Kepler Mission to the deepest of the three planets over the span of just four years.

The SDSU researchers were surprised by both the size and location of the new planet. Kepler-47d is the largest of the three planets in the Kepler-47 system.

“We saw a hint of a third planet back in 2012, but with only one transit we needed more data to be sure,” said SDSU astronomer Jerome Orosz, the paper’s lead author. “With an additional transit, the planet’s orbital period could be determined, and we were then able to uncover more transits that were hidden in the noise in the earlier data.”

William Welsh, SDSU astronomer and the study’s co-author, said he and Orosz expected any additional planets in the Kepler-47 system to be orbiting exterior to the previously known planets. “We certainly didn’t expect it to be the largest planet in the system. This was almost shocking,” said Welsh. Their research was recently published in the Astronomical Journal.

With the discovery of the new planet, a much better understanding of the system is possible. For example, researchers now know the planets in in this circumbinary system are very low density – less than that of Saturn, the Solar System planet with the lowest density.

While a low density is not that unusual for the sizzling hot-Jupiter type exoplanets, it is rare for mild-temperature planets. Kepler-47d’s equilibrium temperature is roughly 50 degrees F (10 degrees C), while Kepler-47c is ■26 degrees F (■32 degrees C). The innermost planet, which is the smallest circumbinary planet known, is a much hotter 336 degrees F (169 degrees C).

The inner, middle, and outer planets are 3.1, 7 and 4.7 times the size of the Earth, and take 49, 187 and 303 days, respectively, to orbit around their suns. The stars themselves orbit each other in only 7.45 days; one star is similar to the Sun, while the other has a third of the mass of the Sun. The entire system is compact and would fit inside the orbit of the Earth. It is approximately 3340 light-years away in the direction of the constellation Cygnus.

“This work builds on one of the Kepler’s most interesting discoveries: that systems of closely-packed, low-density planets are extremely common in our galaxy,” said University of California, Santa Cruz astronomer Jonathan Fortney, who was not part of the study. “Kepler■47 shows that whatever process forms these planets – an outcome that did not happen in our solar system – is common to single-star and circumbinary planetary systems."

This work was supported in part by grants from NASA and the National Science Foundation.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: TESS Finds Its First Earth-Sized Planet

2 min read

NASA Science Editorial Team

NASA’s Transiting Exoplanet Survey Satellite (TESS) has discovered its first Earth-size world. The planet, HD 21749c, is about 89% Earth’s diameter. It orbits HD 21749, a K-type star with about 70% of the Sun’s mass located 53 light-years away in the southern constellation Reticulum, and is the second planet TESS has identified in the system. The new world is likely rocky and circles very close to its star, completing one orbit in just under eight days. The planet is likely very hot, with surface temperatures perhaps as high as 800 degrees F (427 degrees C).

This is the 10th confirmed planet discovered by TESS, and hundreds of additional candidates are now being studied.

Scientists at the Massachusetts Institute of Technology and the Carnegie Institution for Science analyzed TESS transit data from the first four sectors of TESS observations to detect 11 periodic dips in the star’s brightness. From this, they determined that the star’s light was being partially blocked by a planet about the size of Earth.

The star that HD 21749c orbits is bright and relatively nearby, and therefore well suited to more detailed follow-up studies, which could provide critical information about the planet’s properties, including potentially the first mass measurement of an Earth-size planet found by TESS.

For more information about this result:
https://iopscience.iop.org/article/10.3847/2041-8213/ab12ed/meta

For more updates about TESS discoveries, visit nasa.gov/tess

Media Contact: Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Md.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA’s TESS Discovers its First Earth-size Planet

2 min read

NASA’s Transiting Exoplanet Survey Satellite (TESS) has discovered its first Earth-size world. The planet, HD 21749c, is about 89% Earth’s diameter. It orbits HD 21749, a K-type star with about 70% of the Sun’s mass located 53 light-years away in the southern constellation Reticulum, and is the second planet TESS has identified in the system. The new world is likely rocky and circles very close to its star, completing one orbit in just under eight days. The planet is likely very hot, with surface temperatures perhaps as high as 800 degrees F (427 degrees C).

This is the 10th confirmed planet discovered by TESS, and hundreds of additional candidates are now being studied.

Scientists at the Massachusetts Institute of Technology and the Carnegie Institution for Science analyzed TESS transit data from the first four sectors of TESS observations to detect 11 periodic dips in the star’s brightness. From this, they determined that the star’s light was being partially blocked by a planet about the size of Earth.

The star that HD 21749c orbits is bright and relatively nearby, and therefore well suited to more detailed follow-up studies, which could provide critical information about the planet’s properties, including potentially the first mass measurement of an Earth-size planet found by TESS.

For more information about this result:
https://iopscience.iop.org/article/10.3847/2041-8213/ab12ed/meta

For more updates about TESS discoveries, visit nasa.gov/tess

Media Contact: Claire AndreoliNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: A Third Planet in Kepler-47 System

NASA Science Editorial Team

Our Milky Way Galaxy: How Big is Space?

4 min read

Pat Brennan

When we talk about the enormity of the cosmos, it’s easy to toss out big numbers – but far more difficult to wrap our minds around just how large, how far, and how numerous celestial bodies really are.

To get a better sense, for instance, of the true distances to exoplanets – planets around other stars – we might start with the theater in which we find them, the Milky Way galaxy.

Our galaxy is a gravitationally bound collection of stars, swirling in a spiral through space. Based on the deepest images obtained so far, it’s one of about 2 trillion galaxies in the observable universe. Groups of them are bound into clusters of galaxies, and these into superclusters; the superclusters are arranged in immense sheets stretching across the universe, interspersed with dark voids and lending the whole a kind of spiderweb structure. Our galaxy probably contains 100 to 400 billion stars, and is about 100,000 light-years across. That sounds huge, and it is, at least until we start comparing it to other galaxies. Our neighboring Andromeda galaxy, for example, is some 220,000 light-years wide. Another galaxy, IC 1101, spans as much as 4 million light-years.

Glad you asked. It’s one of the most commonly used celestial yardsticks, the distance light travels in one year. Light zips along through interstellar space at 186,000 miles (300,000 kilometers) per second (more than 66 trips across the entire United States, in one second). Multiply that by all the seconds in one year, and you get 5.8 trillion miles (9.5 trillion kilometers). Just for reference, Earth is about eight light minutes from the Sun. A trip at light speed to the very edge of our solar system – the farthest reaches of the Oort Cloud, a collection of dormant comets way, way out there – would take about 1.87 years. Keep going to Proxima Centauri, our nearest neighboring star, and plan on arriving in 4.25 years at light speed.

If you could travel at light speed. Which, unless you’re a photon (a particle of light), you can’t, and, by current physics, might never be possible. But I digress.

Exoplanets. Let’s toss around some more big numbers. First, how many are there? Based on observations made by NASA’s Kepler space telescope, we can confidently predict that every star you see in the sky probably hosts at least one planet. Realistically, we’re most likely talking about multi-planet systems rather than just single planets. In our galaxy of hundreds of billions of stars, this pushes the number of planets potentially into the trillions. Confirmed exoplanet detections (made by Kepler and other telescopes, both in space and on the ground) now come to more than 3,900 – and that’s from looking at only tiny slices of our galaxy. Many of these are small, rocky worlds that might be at the right temperature for liquid water to pool on their surfaces.

It’s a small, probably rocky planet orbiting Proxima Centauri – as mentioned before, the next star over. A little more than four light-years away, or 24 trillion miles as the crow flies. If an airline offered a flight there by jet, it would take 5 million years. Not much is known about this world; its close orbit and the periodic flaring of its star lower its chances of being habitable.

I’d also point you to the TRAPPIST-1 system: seven planets, all roughly in Earth’s size range, orbiting a red dwarf star about 40 light-years away. They are very likely rocky, with four in the “habitable zone” – the orbital distance allowing potential liquid water on the surface. And computer modeling shows some have a good chance of being watery – or icy – worlds. In the next few years, we might learn whether they have atmospheres or oceans, or even signs of habitability.

I understand. You’re short on time. That reminds me: Did you know time slows down in the presence of gravity?

I guess that’s a discussion for another time.

Pat Brennan is a science writer for NASA's Exoplanet Exploration Program. He joined JPL in 2015 after a 30-year career as a newspaper journalist.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Black Hole Image Makes History; NASA Telescopes Coordinated Observations

5 min read

NASA Science Editorial Team

A black hole and its shadow have been captured in an image for the first time, a historic feat by an international network of radio telescopes called the Event Horizon Telescope (EHT). EHT is an international collaboration whose support in the U.S. includes the National Science Foundation.

A black hole is an extremely dense object from which no light can escape. Anything that comes within a black hole's "event horizon," its point of no return, will be consumed, never to re-emerge, because of the black hole's unimaginably strong gravity. By its very nature, a black hole cannot be seen, but the hot disk of material that encircles it shines bright. Against a bright backdrop, such as this disk, a black hole appears to cast a shadow.

The stunning new image shows the shadow of the supermassive black hole in the center of Messier 87 (M87), an elliptical galaxy some 55 million light-years from Earth. This black hole is 6.5 billion times the mass of the Sun. Catching its shadow involved eight ground-based radio telescopes around the globe, operating together as if they were one telescope the size of our entire planet.

"This is an amazing accomplishment by the EHT team," said Paul Hertz, director of the astrophysics division at NASA Headquarters in Washington. "Years ago, we thought we would have to build a very large space telescope to image a black hole. By getting radio telescopes around the world to work in concert like one instrument, the EHT team achieved this, decades ahead of time."

To complement the EHT findings, several NASA spacecraft were part of a large effort, coordinated by the EHT's Multiwavelength Working Group, to observe the black hole using different wavelengths of light. As part of this effort, NASA's Chandra X-ray Observatory, Nuclear Spectroscopic Telescope Array (NuSTAR) and Neil Gehrels Swift Observatory space telescope missions, all attuned to different varieties of X-ray light, turned their gaze to the M87 black hole around the same time as the EHT in April 2017. NASA's Fermi Gamma-ray Space Telescope was also watching for changes in gamma-ray light from M87 during the EHT observations. If EHT observed changes in the structure of the black hole's environment, data from these missions and other telescopes could be used to help figure out what was going on.

While NASA observations did not directly trace out the historic image, astronomers used data from NASA's Chandra and NuSTAR satellites to measure the X-ray brightness of M87's jet. Scientists used this information to compare their models of the jet and disk around the black hole with the EHT observations. Other insights may come as researchers continue to pore over these data. There are many remaining questions about black holes that the coordinated NASA observations may help answer. Mysteries linger about why particles get such a huge energy boost around black holes, forming dramatic jets that surge away from the poles of black holes at nearly the speed of light. When material falls into the black hole, where does the energy go?

"X-rays help us connect what's happening to the particles near the event horizon with what we can measure with our telescopes," said Joey Neilsen, an astronomer at Villanova University in Pennsylvania, who led the Chandra and NuSTAR analysis on behalf of the EHT's Multiwavelength Working Group.

NASA space telescopes have previously studied a jet extending more than 1,000 light-years away from the center of M87. The jet is made of particles traveling near the speed of light, shooting out at high energies from close to the event horizon. The EHT was designed in part to study the origin of this jet and others like it. A blob of matter in the jet called HST-1, discovered by Hubble astronomers in 1999, has undergone a mysterious cycle of brightening and dimming.

Chandra, NuSTAR, Swift and Fermi, as well as NASA’s Neutron star Interior Composition Explorer (NICER) experiment on the International Space Station, also looked at the black hole at the center of our own Milky Way galaxy, called Sagittarius A*, in coordination with EHT.

Getting so many different telescopes on the ground and in space to all look toward the same celestial object is a huge undertaking in and of itself, scientists emphasize.

“Scheduling all of these coordinated observations was a really hard problem for both the EHT and the Chandra and NuSTAR mission planners,” Neilsen said. “They did really incredible work to get us the data that we have, and we’re exceedingly grateful.”

Neilsen and colleagues who were part of the coordinated observations will be working on dissecting the entire spectrum of light coming from the M87 black hole, all the way from low-energy radio waves to high-energy gamma rays. With so much data from EHT and other telescopes, scientists may have years of discoveries ahead.

Elizabeth LandauNASA Headquarters, Washington818-359-3241elandau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Discovery Alert! Two new planets – found by AI

1 min read

NASA Science Editorial Team

Planets: K2-293b, K2-294b

Discovered by: Dattilo et al. using NASA's Kepler space telescope and a neural network, AstroNet-K2

Date: March 2019

Key Facts: Two new "super Earths" – planets larger than Earth but smaller than Neptune – were discovered using artificial intelligence.

Details: The new planets are called K2-293b and K2-294b. The first is about 2.5 times as big around as Earth, the second about 1.7 times. K2-293b orbits a star about 1,300 light years away, K2-294b orbits a star a little over 1,200 light years distant.

What's new: The planets were spotted by a machine-learning algorithm called AstroNet-K2, a neural network modified to hunt through data from the Kepler space telescope's K2 campaign. The "deep learning" algorithm is able to separate real exoplanet signals from false positives.

Read the paper: Identifying Exoplanets with Deep Learning II: Two New Super-Earths Uncovered by a Neural Network in K2 Data

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

‘Space Butterfly’ Is Home to Hundreds of Baby Stars

3 min read

NASA Science Editorial Team

What looks like a red butterfly in space is in reality a nursery for hundreds of baby stars, revealed in this infrared image from NASA's Spitzer Space Telescope. Officially named Westerhout 40 (W40), the butterfly is a nebula — a giant cloud of gas and dust in space where new stars may form. The butterfly's two "wings" are giant bubbles of hot, interstellar gas blowing from the hottest, most massive stars in this region.

Besides being beautiful, W40 exemplifies how the formation of stars results in the destruction of the very clouds that helped create them. Inside giant clouds of gas and dust in space, the force of gravity pulls material together into dense clumps. Sometimes these clumps reach a critical density that allows stars to form at their cores. Radiation and winds coming from the most massive stars in those clouds — combined with the material spewed into space when those stars eventually explode — sometimes form bubbles like those in W40. But these processes also disperse the gas and dust, breaking up dense clumps and reducing or halting new star formation.

The material that forms W40's wings was ejected from a dense cluster of stars that lies between the wings in the image. The hottest, most massive of these stars, W40 IRS 1a, lies near the center of the star cluster. W40 is about 1,400 light-years from the Sun, about the same distance as the well-known Orion nebula, although the two are almost 180 degrees apart in the sky. They are two of the nearest regions in which massive stars — with masses upwards of 10 times that of the Sun — have been observed to be forming.

Another cluster of stars, named Serpens South, can be seen to the upper right of W40 in this image. Although both Serpens South and the cluster at the heart of W40 are young in astronomical terms (less than a few million years old), Serpens South is the younger of the two. Its stars are still embedded within their cloud but will someday break out to produce bubbles like those of W40. Spitzer has also produced a more detailed image of the Serpens South cluster.

A mosaic of Spitzer's observation of the W40 star-forming region was originally published as part of the Massive Young stellar clusters Study in Infrared and X-rays (MYStIX) survey of young stellar objects.

The Spitzer picture is composed of four images taken with the telescope's Infrared Array Camera (IRAC) during Spitzer's prime mission, in different wavelengths of infrared light: 3.6, 4.5, 5.8 and 8.0 µm (shown as blue, green, orange and red). Organic molecules made of carbon and hydrogen, called polycyclic aromatic hydrocarbons (PAHs), are excited by interstellar radiation and become luminescent at wavelengths near 8.0 microns, giving the nebula its reddish features. Stars are brighter at the shorter wavelengths, giving them a blue tint. Some of the youngest stars are surrounded by dusty disks of material, which glow with a yellow or red hue.

The Jet Propulsion Laboratory in Pasadena, California, manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Space operations are based at Lockheed Martin Space Systems in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

More information on Spitzer can be found at its website:

http://www.spitzer.caltech.edu/

News Media Contact

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

Search for Life

Stars

Universe

Black Holes

‘Goldilocks’ Stars and the Hunt for Habitable Worlds

5 min read

NASA Science Editorial Team

Scientists looking for signs of life beyond our solar system face major challenges, one of which is that there are hundreds of billions of stars in our galaxy alone to consider. To narrow the search, they must figure out: What kinds of stars are most likely to host habitable planets?

A new study finds a particular class of stars called K stars, which are dimmer than the Sun but brighter than the faintest stars, may be particularly promising targets for searching for signs of life.

Why? First, K stars live a very long time — 17 billion to 70 billion years, compared to 10 billion years for the Sun — giving plenty of time for life to evolve. Also, K stars have less extreme activity in their youth than the universe’s dimmest stars, called M stars or “red dwarfs.”

M stars do offer some advantages for in the search for habitable planets. They are the most common star type in the galaxy, comprising about 75 percent of all the stars in the universe. They are also frugal with their fuel, and could shine on for over a trillion years. One example of an M star, TRAPPIST-1, is known to host seven Earth-size rocky planets.

But the turbulent youth of M stars presents problems for potential life. Stellar flares – explosive releases of magnetic energy – are much more frequent and energetic from young M stars than young Sun-like stars. M stars are also much brighter when they are young, for up to a billion years after they form, with energy that could boil off oceans on any planets that might someday be in the habitable zone.

“I like to think that K stars are in a ‘sweet spot’ between Sun-analog stars and M stars,” said Giada Arney of NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

Arney wanted to find out what biosignatures, or signs of life, might look like on a hypothetical planet orbiting a K star. Her analysis is published in the Astrophysical Journal Letters.

Scientists consider the simultaneous presence of oxygen and methane in a planet’s atmosphere to be a strong biosignature because these gases like to react with each other, destroying each other. So, if you see them present in an atmosphere together, that implies something is producing them both quickly, quite possibly life, according to Arney.

However, because planets around other stars (exoplanets) are so remote, there needs to be significant amounts of oxygen and methane in an exoplanet’s atmosphere for it to be seen by observatories at Earth. Arney’s analysis found that the oxygen-methane biosignature is likely to be stronger around a K star than a Sun-like star.

Arney used a computer model that simulates the chemistry and temperature of a planetary atmosphere, and how that atmosphere responds to different host stars. These synthetic atmospheres were then run through a model that simulates the planet’s spectrum to show what it might look like to future telescopes.

“When you put the planet around a K star, the oxygen does not destroy the methane as rapidly, so more of it can build up in the atmosphere,” said Arney. “This is because the K star’s ultraviolet light does not generate highly reactive oxygen gases that destroy methane as readily as a Sun-like star.”

This stronger oxygen-methane signal has also been predicted for planets around M stars, but their high activity levels might make M stars unable to host habitable worlds. K stars can offer the advantage of a higher probability of simultaneous oxygen-methane detection compared to Sun-like stars without the disadvantages that come along with an M star host.

Additionally, exoplanets around K stars will be easier to see than those around Sun-like stars simply because K stars are dimmer. “The Sun is 10 billion times brighter than an Earthlike planet around it, so that’s a lot of light you have to suppress if you want to see an orbiting planet. A K star might be ‘only’ a billion times brighter than an Earth around it,” said Arney.

Arney’s research also includes discussion of which of the nearby K stars may be the best targets for future observations. Since we don’t have the ability to travel to planets around other stars due to their enormous distances from us, we are limited to analyzing the light from these planets to search for a signal that life might be present. By separating this light into its component colors, or spectrum, scientists can identify the constituents of a planet’s atmosphere, since different compounds emit and absorb distinct colors of light.

“I find that certain nearby K stars like 61 Cyg A/B, Epsilon Indi, Groombridge 1618, and HD 156026 may be particularly good targets for future biosignature searches,” said Arney.

Bill SteigerwaldGoddard Space Flight Center, Greenbelt, Md.william.a.steigerwald@nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

High School Senior Uncovers Potential for Hundreds of Earth-Sized Planets in Kepler Data

5 min read

NASA Science Editorial Team

An 18-year-old high school senior has won a $250,000 prize for calculating the potential for finding more planets outside our solar system, called exoplanets, using data from NASA's Kepler space telescope.

Kepler, whose mission ended in 2018, discovered over 2,600 confirmed exoplanets, with thousands more candidate planets still being considered. But are there more planets that have yet to be found around stars Kepler looked at, leaving traces in the telescope's data? Ana Humphrey, a student at T.C. Williams High School in Alexandria, Virginia, has developed a mathematical model to find out. Her work calculated that there could be as many as 560 of these hidden planets and identified 96 areas of the sky where they might be found.

For this research, Humphrey recently won first-place in the Regeneron Science Talent Search, the oldest science and math competition for high school seniors in the United States. As a Cuban-American student, she is the first Hispanic winner of the top award in the last 20 years.

"I think it's hard for a lot of students to see themselves doing something like astrophysics," said Humphrey. "I hope my background will allow me to connect with students, especially Hispanic students, and get them to think about going into science."

For Humphrey, winning this award is a dream she's had since the sixth grade and the culmination of two years of research. Her inspiration for the project was the idea that new worlds could be discovered based on data from other objects, before being directly observed. Neptune, for example, was discovered in 1846 by looking at data from Uranus and its orbit, and there have been recent predictions of a hypothetical ninth planet beyond Pluto, based on the orbits of objects at the very edges of our solar system. Using this concept to search for exoplanets was a natural next step, she said.

"I was completely fascinated by this idea of finding new planets using mass, based on data that we already had," said Humphrey. "I think it just shows that even if your data collection is complete, there's always new questions that can be asked and can be answered."

We know exoplanets are abundant – in fact, thanks to Kepler, we know there are more planets than stars in our galaxy. But in order to detect a planet, Kepler had to observe repeated dimmings of the brightness of a star as a planet passed by. This is called the "transit method." There are many planets left to be found that do not "transit" from the viewpoint of our telescopes, which means Kepler could not have found them. But Kepler data can lead to later discoveries of more planets that weren't immediately obvious.

Astrophysicist Elisa Quintana at NASA's Goddard Space Flight Center, Greenbelt, Maryland is working with Humphrey as her mentor, exploring the idea that more planets could fit into systems that are already known. Quintana, who worked on the Kepler mission, also led the first discovery of an Earth-size planet in a habitable zone: Kepler-186f. The habitable zone is the area around a star where a planet could host liquid water. Kepler-186, a red dwarf star, is known to have five planets, but could potentially have more.

"Take a system like Kepler-186," Quintana said. "When we discovered the system, we noticed a big space between the four planets really close to the star and outer planet, enough where there could be another planet the size of Earth."

Many multi-planetary systems have similar gaps with the potential to house hidden Earth-size planets. Humphrey's research aims to find out how many extra planets could fit into these systems, without disrupting the orbits we can observe.

Her mathematical model places an "imagined" planet between two known exoplanets discovered by Kepler. Then, she uses two equations to describe how tight the space between the imagined planet and its two neighbors can be without disrupting their orbits. From this, she can use simple algebra to derive the possible mass and orbital distances of the hypothetical hidden planet. Using statistics, this model can determine not just if such a planet could exist, but the likelihood it's actually there. When this technique is applied on the scale of a multi-planet star system, it reveals all the places planets might be hidden, and what those planets might look like.

Humphrey designed her model so that it can be quickly applied to any exoplanet database. That means as more data comes in from the Transiting Exoplanet Survey Satellite (TESS), NASA's active planet-hunting spacecraft, and other future missions, scientists can predict which planetary systems may have hidden planets there as well. She will continue working with Quintana to explore how likely it is that the hidden planets exist, and whether they can be detected with additional observations from other telescopes.

Even before embarking on an astrophysics degree next year, Humphrey has already added an instrumental piece to the puzzle of searching for another life-harboring Earth in the cosmos. She plans to put her prize money toward her education and future research.

"My goal going into any project is always to be the best scientist that I can be, to do the best research that I can do," said Humphrey. "To get recognized by such a great award… I feel incredibly honored."

NASA's Ames Research Center in California's Silicon Valley manages the Kepler and K2 missions for NASA's Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operated the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

What Scientists Found After Sifting Through Dust in the Solar System

12 min read

Just as dust gathers in corners and along bookshelves in our homes, dust piles up in space too. But when the dust settles in the solar system, it's often in rings. Several dust rings circle the Sun. The rings trace the orbits of planets, whose gravity tugs dust into place around the Sun, as it drifts by on its way to the center of the solar system.

The dust consists of crushed-up remains from the formation of the solar system, some 4.6 billion years ago — rubble from asteroid collisions or crumbs from blazing comets. Dust is dispersed throughout the entire solar system, but it collects at grainy rings overlying the orbits of Earth and Venus, rings that can be seen with telescopes on Earth. By studying this dust — what it's made of, where it comes from, and how it moves through space — scientists seek clues to understanding the birth of planets and the composition of all that we see in the solar system.

Two recent studies report new discoveries of dust rings in the inner solar system. One study uses NASA data to outline evidence for a dust ring around the Sun at Mercury's orbit. A second study from NASA identifies the likely source of the dust ring at Venus' orbit: a group of never-before-detected asteroids co-orbiting with the planet.

"It's not every day you get to discover something new in the inner solar system," said Marc Kuchner, an author on the Venus study and astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "This is right in our neighborhood."

Guillermo Stenborg and Russell Howard, both solar scientists at the Naval Research Laboratory in Washington, D.C., did not set out to find a dust ring. "We found it by chance," Stenborg said, laughing. The scientists summarized their findings in a paper published in The Astrophysical Journal on Nov. 21, 2018.

They describe evidence of a fine haze of cosmic dust over Mercury's orbit, forming a ring some 9.3 million miles wide. Mercury — 3,030 miles wide, just big enough for the continental United States to stretch across — wades through this vast dust trail as it circles the Sun.

Ironically, the two scientists stumbled upon the dust ring while searching for evidence of a dust-free region close to the Sun. At some distance from the Sun, according to a decades-old prediction, the star's mighty heat should vaporize dust, sweeping clean an entire stretch of space. Knowing where this boundary is can tell scientists about the composition of the dust itself, and hint at how planets formed in the young solar system.

So far, no evidence has been found of dust-free space, but that's partly because it would be difficult to detect from Earth. No matter how scientists look from Earth, all the dust in between us and the Sun gets in the way, tricking them into thinking perhaps space near the Sun is dustier than it really is.

Stenborg and Howard figured they could work around this problem by building a model based on pictures of interplanetary space from NASA's STEREO satellite — short for Solar and Terrestrial Relations Observatory.

Ultimately, the two wanted to test their new model in preparation for NASA's Parker Solar Probe, which is currently flying a highly elliptic orbit around the Sun, swinging closer and closer to the star over the next seven years. They wanted to apply their technique to the images Parker will send back to Earth and see how dust near the Sun behaves.

Scientists have never worked with data collected in this unexplored territory, so close to the Sun. Models like Stenborg and Howard's provide crucial context for understanding Parker Solar Probe's observations, as well as hinting at what kind of space environment the spacecraft will find itself in — sooty or sparkling clean.

Two kinds of light show up in STEREO images: light from the Sun's blazing outer atmosphere — called the corona — and light reflected off all the dust floating through space. The sunlight reflected off this dust, which slowly orbits the Sun, is about 100 times brighter than coronal light.

"We're not really dust people," said Howard, who is also the lead scientist for the cameras on STEREO and Parker Solar Probe that take pictures of the corona. "The dust close to the Sun just shows up in our observations, and generally, we have thrown it away." Solar scientists like Howard — who study solar activity for purposes such as forecasting imminent space weather, including giant explosions of solar material that the Sun can sometimes send our way — have spent years developing techniques to remove the effect of this dust. Only after removing light contamination from dust can they clearly see what the corona is doing.

The two scientists built their model as a tool for others to get rid of the pesky dust in STEREO — and eventually Parker Solar Probe — images, but the prediction of dust-free space lingered in the back of their minds. If they could devise a way of separating the two kinds of light and isolate the dust-shine, they could figure out how much dust was really there. Finding that all the light in an image came from the corona alone, for example, could indicate they'd found dust-free space at last.

Mercury's dust ring was a lucky find, a side discovery Stenborg and Howard made while they were working on their model. When they used their new technique on the STEREO images, they noticed a pattern of enhanced brightness along Mercury's orbit — more dust, that is — in the light they'd otherwise planned to discard.

"It wasn't an isolated thing," Howard said. "All around the Sun, regardless of the spacecraft's position, we could see the same five percent increase in dust brightness, or density. That said something was there, and it's something that extends all around the Sun."

Scientists never considered that a ring might exist along Mercury's orbit, which is maybe why it's gone undetected until now, Stenborg said. "People thought that Mercury, unlike Earth or Venus, is too small and too close to the Sun to capture a dust ring," he said. "They expected that the solar wind and magnetic forces from the Sun would blow any excess dust at Mercury's orbit away."

With an unexpected discovery and sensitive new tool under their belt, the researchers are still interested in the dust-free zone. As Parker Solar Probe continues its exploration of the corona, their model can help others reveal any other dust bunnies lurking near the Sun.

This isn't the first time scientists have found a dust ring in the inner solar system. Twenty-five years ago, scientists discovered that Earth orbits the Sun within a giant ring of dust. Others uncovered a similar ring near Venus' orbit, first using archival data from the German-American Helios space probes in 2007, and then confirming it in 2013, with STEREO data.

Since then, scientists determined the dust ring in Earth's orbit comes largely from the asteroid belt, the vast, doughnut-shaped region between Mars and Jupiter where most of the solar system's asteroids live. These rocky asteroids constantly crash against each other, sloughing dust that drifts deeper into the Sun's gravity, unless Earth's gravity pulls the dust aside, into our planet's orbit.

At first, it seemed likely that Venus' dust ring formed like Earth's, from dust produced elsewhere in the solar system. But when Goddard astrophysicist Petr Pokorny modeled dust spiraling toward the Sun from the asteroid belt, his simulations produced a ring that matched observations of Earth's ring — but not Venus'.

This discrepancy made him wonder if not the asteroid belt, where else does the dust in Venus' orbit come from? After a series of simulations, Pokorny and his research partner Marc Kuchner hypothesized it comes from a group of never-before-detected asteroids that orbit the Sun alongside Venus. They published their work in The Astrophysical Journal Letters on March 12, 2019.

"I think the most exciting thing about this result is it suggests a new population of asteroids that probably holds clues to how the solar system formed," Kuchner said. If Pokorny and Kuchner can observe them, this family of asteroids could shed light on Earth and Venus' early histories. Viewed with the right tools, the asteroids could also unlock clues to the chemical diversity of the solar system.

Because it's dispersed over a larger orbit, Venus' dust ring is much larger than the newly detected ring at Mercury's. About 16 million miles from top to bottom and 6 million miles wide, the ring is littered with dust whose largest grains are roughly the size of those in coarse sandpaper. It's about 10 percent denser with dust than surrounding space. Still, it's diffuse — pack all the dust in the ring together, and all you'd get is an asteroid two miles across.

Using a dozen different modeling tools to simulate how dust moves around the solar system, Pokorny modeled all the dust sources he could think of, looking for a simulated Venus ring that matched the observations. The list of all the sources he tried sounds like a roll call of all the rocky objects in the solar system: Main Belt asteroids, Oort Cloud comets, Halley-type comets, Jupiter-family comets, recent collisions in the asteroid belt.

"But none of them worked," Kuchner said. "So, we started making up our own sources of dust."

Perhaps, the two scientists thought, the dust came from asteroids much closer to Venus than the asteroid belt. There could be a group of asteroids co-orbiting the Sun with Venus — meaning they share Venus' orbit, but stay far away from the planet, often on the other side of the Sun. Pokorny and Kuchner reasoned a group of asteroids in Venus' orbit could have gone undetected until now because it's difficult to point earthbound telescopes in that direction, so close to the Sun, without light interference from the Sun.

Co-orbiting asteroids are an example of what's called a resonance, an orbital pattern that locks different orbits together, depending on how their gravitational influences meet. Pokorny and Kuchner modeled many potential resonances: asteroids that circle the Sun twice for every three of Venus' orbits, for example, or nine times for Venus' ten, and one for one. Of all the possibilities, one group alone produced a realistic simulation of the Venus dust ring: a pack of asteroids that occupies Venus' orbit, matching Venus' trips around the Sun one for one.

But the scientists couldn't just call it a day after finding a hypothetical solution that worked. "We thought we'd discovered this population of asteroids, but then had to prove it and show it works," Pokorny said. "We got excited, but then you realize, 'Oh, there's so much work to do.'"

They needed to show that the very existence of the asteroids makes sense in the solar system. It would be unlikely, they realized, that asteroids in these special, circular orbits near Venus arrived there from somewhere else like the asteroid belt. Their hypothesis would make more sense if the asteroids had been there since the very beginning of the solar system.

The scientists built another model, this time starting with a throng of 10,000 asteroids neighboring Venus. They let the simulation fast forward through 4.5 billion years of solar system history, incorporating all the gravitational effects from each of the planets. When the model reached present-day, about 800 of their test asteroids survived the test of time.

Pokorny considers this an optimistic survival rate. It indicates that asteroids could have formed near Venus' orbit in the chaos of the early solar system, and some could remain there today, feeding the dust ring nearby.

The next step is actually pinning down and observing the elusive asteroids. “If there’s something there, we should be able to find it,” Pokorny said. Their existence could be verified with space-based telescopes like Hubble, or perhaps interplanetary space-imagers similar to STEREO’s. Then, the scientists will have more questions to answer: How many of them are there, and how big are they? Are they continuously shedding dust, or was there just one break-up event?

The dust rings that Mercury and Venus shepherd are just a planet or two away, but scientists have spotted many other dust rings in distant star systems. Vast dust rings can be easier to spot than exoplanets, and could be used to infer the existence of otherwise hidden planets, and even their orbital properties.

But interpreting extrasolar dust rings isn’t straightforward. “In order to model and accurately read the dust rings around other stars, we first have to understand the physics of the dust in our own backyard,” Kuchner said. By studying neighboring dust rings at Mercury, Venus and Earth, where dust traces out the enduring effects of gravity in the solar system, scientists can develop techniques for reading between the dust rings both near and far.

By Lina TranNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cooking up Alien Atmospheres on Earth

5 min read

NASA Science Editorial Team

This artist's concept shows planet KELT-9b, an example of a 'hot Jupiter,' or a gas giant planet orbiting very close to its parent star. KELT-9b is an extreme example of a hot Jupiter, with dayside temperatures reaching 7,800 degrees Fahrenheit (4,300 Celcius). Credit: NASA/JPL-Caltech

› Full image and caption

Researchers at NASA's Jet Propulsion Laboratory in Pasadena, California, are cooking up an alien atmosphere right here on Earth. In a new study, JPL scientists used a high-temperature "oven" to heat a mixture of hydrogen and carbon monoxide to more than 2,000 degrees Fahrenheit (1,100 Celsius), about the temperature of molten lava. The aim was to simulate conditions that might be found in the atmospheres of a special class of exoplanets (planets outside our solar system) called "hot Jupiters."

Hot Jupiters are gas giants that orbit very close to their parent star, unlike any of the planets in our solar system. While Earth takes 365 days to orbit the Sun, hot Jupiters orbit their stars in less than 10 days. Their close proximity to a star means their temperatures can range from 1,000 to 5,000 degrees Fahrenheit (530 to 2,800 degrees Celsius) or even hotter. By comparison, a hot day on the surface of Mercury (which takes 88 days to orbit the Sun) reaches about 800 degrees Fahrenheit (430 degrees Celsius).

"Though it is impossible to exactly simulate in the laboratory these harsh exoplanet environments, we can come very close," said JPL principal scientist Murthy Gudipati, who leads the group that conducted the new study, published last month in the Astrophysical Journal.

The team started with a simple chemical mixture of mostly hydrogen gas and 0.3 percent carbon monoxide gas. These molecules are extremely common in the universe and in early solar systems, and they could reasonably compose the atmosphere of a hot Jupiter. Then the team heated the mixture to between 620 and 2,240 degrees Fahrenheit (330 and 1,230 Celsius).

The team also exposed the laboratory brew to a high dose of ultraviolet radiation - similar to what a hot Jupiter would experience orbiting so close to its parent star. The UV light proved to be a potent ingredient. It was largely responsible for some of the study's more surprising results about the chemistry that might be taking place in these toasty atmospheres.

Hot Jupiters are large by planet standards, and they radiate more light than cooler planets. Such factors have allowed astronomers to gather more information about their atmospheres than most other types of exoplanets. Those observations reveal that many hot Jupiter atmospheres are opaque at high altitudes. Although clouds might explain the opacity, they become less and less sustainable as the pressure decreases, and the opacity has been observed where the atmospheric pressure is very low.

Scientists have been looking for potential explanations other than clouds, and aerosols - solid particles suspended in the atmosphere - could be one. However, according to the JPL researchers, scientists were previously unaware of how aerosols might develop in hot Jupiter atmospheres. In the new experiment, adding UV light to the hot chemical mix did the trick.

"This result changes the way we interpret those hazy hot Jupiter atmospheres," said Benjamin Fleury, a JPL research scientist and lead author of the study. "Going forward, we want to study the properties of these aerosols. We want to better understand how they form, how they absorb light and how they respond to changes in the environment. All that information can help astronomers understand what they're seeing when they observe these planets."

The study yielded another surprise: The chemical reactions produced significant amounts of carbon dioxide and water. While water vapor has been found in hot Jupiter atmospheres, scientists for the most part expect this precious molecule to form only when there is more oxygen than carbon. The new study shows that water can form when carbon and oxygen are present in equal amounts. (Carbon monoxide contains one carbon atom and one oxygen atom.) And while some carbon dioxide (one carbon and two oxygen atoms) formed without the addition of UV radiation, the reactions accelerated with the addition of simulated starlight.

"These new results are immediately useful for interpreting what we see in hot Jupiter atmospheres," said JPL exoplanet scientist Mark Swain, a study coauthor. "We've assumed that temperature dominates the chemistry in these atmospheres, but this shows we need to look at how radiation plays a role."

With next-generation tools like NASA's James Webb Space Telescope, set to launch in 2021, scientists might produce the first detailed chemical profiles of exoplanet atmospheres, and it's possible that some of those first subjects will be hot Jupiters. These studies will help scientists learn how other solar systems form and how similar or different they are to our own.

For the JPL researchers, the work has just begun. Unlike a typical oven, theirs seals the gas in tightly to prevent leaks or contamination, and it allows the researchers to control the pressure of the gas as the temperature rises. With this hardware, they can now simulate exoplanet atmospheres at even higher temperatures: close to 3,000 degrees Fahrenheit (1,600 degrees Celsius).

"It's been an ongoing challenge figuring out how to design and operate this system successfully, since most standard components such as glass or aluminum melt at these temperatures," said JPL research scientist Bryana Henderson, a coauthor of the study. "We're still learning how to push these boundaries while safely handling these chemical processes in the lab. But at the end of the day, the exciting results that come out of these experiments is worth all the extra effort."

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

“Goldilocks” Stars May Be “Just Right” for Finding Habitable Worlds

5 min read

Scientists looking for signs of life beyond our solar system face major challenges, one of which is that there are hundreds of billions of stars in our galaxy alone to consider. To narrow the search, they must figure out: What kinds of stars are most likely to host habitable planets?

A new study finds a particular class of stars called K stars, which are dimmer than the Sun but brighter than the faintest stars, may be particularly promising targets for searching for signs of life.

Why? First, K stars live a very long time — 17 billion to 70 billion years, compared to 10 billion years for the Sun — giving plenty of time for life to evolve. Also, K stars have less extreme activity in their youth than the universe’s dimmest stars, called M stars or “red dwarfs.”

M stars do offer some advantages for in the search for habitable planets. They are the most common star type in the galaxy, comprising about 75 percent of all the stars in the universe. They are also frugal with their fuel, and could shine on for over a trillion years. One example of an M star, TRAPPIST-1, is known to host seven Earth-size rocky planets.

But the turbulent youth of M stars presents problems for potential life. Stellar flares – explosive releases of magnetic energy – are much more frequent and energetic from young M stars than young Sun-like stars. M stars are also much brighter when they are young, for up to a billion years after they form, with energy that could boil off oceans on any planets that might someday be in the habitable zone.

“I like to think that K stars are in a ‘sweet spot’ between Sun-analog stars and M stars,” said Giada Arney of NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

Arney wanted to find out what biosignatures, or signs of life, might look like on a hypothetical planet orbiting a K star. Her analysis is published in the Astrophysical Journal Letters.

Scientists consider the simultaneous presence of oxygen and methane in a planet’s atmosphere to be a strong biosignature because these gases like to react with each other, destroying each other. So, if you see them present in an atmosphere together, that implies something is producing them both quickly, quite possibly life, according to Arney.

However, because planets around other stars (exoplanets) are so remote, there needs to be significant amounts of oxygen and methane in an exoplanet’s atmosphere for it to be seen by observatories at Earth. Arney’s analysis found that the oxygen-methane biosignature is likely to be stronger around a K star than a Sun-like star.

Arney used a computer model that simulates the chemistry and temperature of a planetary atmosphere, and how that atmosphere responds to different host stars. These synthetic atmospheres were then run through a model that simulates the planet’s spectrum to show what it might look like to future telescopes.

“When you put the planet around a K star, the oxygen does not destroy the methane as rapidly, so more of it can build up in the atmosphere,” said Arney. “This is because the K star’s ultraviolet light does not generate highly reactive oxygen gases that destroy methane as readily as a Sun-like star.”

This stronger oxygen-methane signal has also been predicted for planets around M stars, but their high activity levels might make M stars unable to host habitable worlds. K stars can offer the advantage of a higher probability of simultaneous oxygen-methane detection compared to Sun-like stars without the disadvantages that come along with an M star host.

Additionally, exoplanets around K stars will be easier to see than those around Sun-like stars simply because K stars are dimmer. “The Sun is 10 billion times brighter than an Earthlike planet around it, so that’s a lot of light you have to suppress if you want to see an orbiting planet. A K star might be ‘only’ a billion times brighter than an Earth around it,” said Arney.

Arney’s research also includes discussion of which of the nearby K stars may be the best targets for future observations. Since we don’t have the ability to travel to planets around other stars due to their enormous distances from us, we are limited to analyzing the light from these planets to search for a signal that life might be present. By separating this light into its component colors, or spectrum, scientists can identify the constituents of a planet’s atmosphere, since different compounds emit and absorb distinct colors of light.

“I find that certain nearby K stars like 61 Cyg A/B, Epsilon Indi, Groombridge 1618, and HD 156026 may be particularly good targets for future biosignature searches,” said Arney.

Bill SteigerwaldGoddard Space Flight Center, Greenbelt, Md.william.a.steigerwald@nasa.gov

Weird Worlds? Yes — by the Trillion

4 min read

Pat Brennan

A trip down the list of exoplanets found so far is a wild ride. These planets beyond our solar system, whether orbiting other stars or floating freely between them, can make the planets closer to home look tame by comparison. “Hot Jupiters” are star-hugging, infernal worlds. “Super Earths” are super mysterious. Frozen planets, gas giants that make Jupiter look puny, or small, rocky planets in Earth’s size range but in tight orbits around red dwarf stars – the catalog keeps growing, and soon, that growth will become exponential.

The more than 3,900 exoplanets confirmed so far are really a tiny sampling of what could amount to trillions in our galaxy. And they likely will be joined by tens of thousands more that are expected to be discovered by NASA’s TESS space telescope (the Transiting Exoplanet Survey Satellite).

Astronomers who analyze data from the last exoplanet survey, by NASA’s Kepler space telescope, can already paint a demographic portrait of what TESS will likely find.

According to NASA’s Exoplanet Archive, of the 3,924 exoplanets confirmed so far, 1,665 can be classed as “Neptune-like” – gaseous worlds around the size of Neptune. The rest of the breakdown:

More variety is hidden within these broad categories. Hot Jupiters, for instance, were among the first planet types found – gas giants like Jupiter, yes, but orbiting so close to their stars that their temperatures soar into the thousands of degrees (Fahrenheit or Celsius). These large planets make such tight orbits that they cause a pronounced “wobble” in their stars, their gravity tugging them first this way, then that. That made them easier to detect in the early days of planet hunting.

Or consider the rogue planets: worlds hurtling alone through the galaxy, with no companion star. Many of these worlds could have been ejected from their original solar system, amid the gravitational jostling during the early phases of formation. The final “kick” could have come from another planet or even from the star itself.

The galaxy also seems to be home to a great many oddly sized planets, including those super Earths. Are they super-sized, rocky worlds, like scaled-up versions of planets in Earth’s size range? Or are they low-density worlds with puffy atmospheres? Further investigation is needed.

As if that weren’t enough, scientists also have noted what seems to be a strange gap in planet sizes. It’s been dubbed the Fulton gap, after Benjamin Fulton, lead author on a paper describing it. The Kepler data show that planets of a certain size-range are rare – those between 1.5 and 2 times the size of Earth. It’s possible that this represents a critical size in planet formation: Planets that reach this size quickly attract a thick atmosphere of hydrogen and helium gas and balloon up into gaseous planets, while planets smaller than this limit are not large enough to hold such an atmosphere and remain primarily rocky. On the other hand, the smaller planets that orbit close to their stars could be the cores of Neptune-like worlds that had their atmospheres stripped away.

Explaining the Fulton gap will require a far better understanding of how solar systems form.

As is often the case in science, the more we learn about the kaleidoscope of exoplanets, the more questions they provoke – and the more mysterious our universe becomes.

Pat Brennan is a science writer for NASA's Exoplanet Exploration Program. He joined JPL in 2015 after a 30-year career as a newspaper journalist.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

What Did Kepler Teach Us? Celebrating the Space Telescope, 10 Years after Launch

5 min read

NASA Science Editorial Team

NASA's Kepler space telescope, launched March 6, 2009, was developed to search for planets around other stars and quantify their abundance in our galaxy. But over more than nine years of operations, through the initial four-year "prime" and subsequent K2 missions, Kepler contributed to many other areas of astronomicalresearch.

Kepler operated like a giant light bucket, collecting photons from stars, galaxies and other celestial objects. Its field of view was approximately 11 degrees across, roughly the size on the sky blocked out by an outstretched hand. By acquiring repeated images of a given field, astronomers use the space telescope's data to precisely measure changes in brightness on timescales from minutes to months and longer. The results, called "light curves," show different patterns according to the type of object being observed.

Spinning objects — whether stars or asteroids — tend to change brightness in a periodic manner as they rotate. This also provides information about surface features. Binary star systems are another source of periodic variability. In cases where a star's orbit is highly elliptical, its surface is stretched by the companion star's gravity. The stretching not only causes stellar tidal distortions, but can also cause oscillations in the stars. These effects combine to generate light variations resembling the blips on an electrocardiogram – leading to the moniker "heartbeat stars."

In eclipsing binary systems, regular dips in the light curves occur when one star passes in front of the other, blocking some of the latter's light. Likewise, this happens with transiting planets, but the amount of light that is blocked is even smaller. Once detected, eclipses or transits yield information on the size of the stellar or planetary companion as well as its orbital period.

Pulsating stars are another source of regular variation among stars. Sound waves propagating in their interiors cause the surface to oscillate as a gong would when hit with a mallet. The frequencies of the oscillations are set by the properties of the stellar interior. They can be used to derive the age of a star and even whether it is burning hydrogen or helium deep in its core. The process of learning about stars from their oscillations is called asteroseismology – an area of research to which Kepler has contributed greatly.

Not all celestial objects display periodic variability. Some Kepler targets, such as young stars or the nuclei of distant galaxies, accrete gas in a random manner that gives rise to chaotic brightness variations. Other stars appear to vary when dust or rocks encircle them, blocking some of the starlight. Such appears to be the case with Boyajian's star, an object that has displayed mysterious dimming events over many years. Dust also occults the youngest stars, which are encircled by disks of remnant material from their formation. Old stars such as white dwarfs may also be orbited by asteroidal material that causes dimming events in their light curves.

Supernovae are another – albeit rare – source of light variations seen by Kepler. In its observations of tens of thousands of galaxies the space telescope recorded more than a dozen sudden brightening events signifying the explosion of a star. Kepler provided our first glimpses of the first few hours of supernova explosions, data that are now helping to constrain the end states of stars' lives.

Despite retirement in January 2020, Kepler will continue to impact the astronomical community with its high precision brightness monitoring data of many types of astronomical objects, from stars with planets to distant galaxies. Undoubtedly, more discoveries await. All images and light curves from Kepler have been made publicly available and are expected to serve the worldwide astronomical community for years to come.

In over nine years of observation, NASA's Kepler space telescope imaged hundreds of thousands of stars, many of which host exoplanets. Those planets whose plane of orbit crosses our line of sight to the host star are seen to eclipse, or "transit" and can be detected by Kepler. Indeed, the telescope has enabled astronomers to detect thousands of planets through this transit method.

The discoveries range from Earth-sized rocky bodies to intermediate-sized "super-Earths" and "mini-Neptunes" to gaseous planets the size of Jupiter. These exoplanets orbit a variety of host stars, from small, red dwarfs to Sun-like stars and hotter. The closer the planet to its parent star, the more stellar radiation it receives. Some planets complete their orbit in as few as a few days; these bodies have very high surface temperatures and are known colloquially as "hot roasters." Rocky planet Kepler-10b, for example, is a scorching rocky planet that orbits much closer to its host star than the Mercury-Sun distance. In contrast, the Earth-sized planet Kepler-186f orbits its red dwarf host at a more comfortable distance where conditions may be amenable to liquid water.

Data from Kepler led to the discovery of multiplanet systems. Such is the case with Kepler-90, a Sun-like star orbited by eight bodies including two gas giants and several super-Earths or mini-Neptunes. Other remarkable discoveries include planets in open star clusters and young associations. Of note, the roughly Neptune-sized body K2-33b made news as the youngest confirmed transiting exoplanet (it orbits a newborn star at 5 to 10 million years of age – very young in astronomical terms).

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert! Kepler’s First Planet Candidate Confirmed, 10 Years Later

3 min read

Planet: Kepler-1658b

Discovered by: Chontos et al. using NASA’s Kepler telescope

Date: February 2019

Key Facts: This newly-confirmed exoplanet is a massive hot Jupiter that whips around its star every 3.85 days. From the surface, the star would appear 60 times larger in diameter than the Sun as seen from Earth.

Details: Despite being the very first planet candidate discovered by NASA’s Kepler space telescope, Kepler-1658b had a rocky road to confirmation. The initial estimate of the planet’s host star was off, so the sizes of both the star and Kepler-1658b were vastly underestimated. It was later marked as a false positive — that is, scientists thought the data did not really point to a planet — when the numbers didn’t quite add up for the effects seen on its star for a body of that size. Kepler-1658b moved from planet candidate to false positive and back until new software was used to refine the data and reclassify it, changing it from a data anomaly to possible planet.

Fortuitously, a team at the University of Hawaii was poised to step in at just the right time. As part of her first year research project, lead author Ashley Chontos, a graduate student with the university’s Institute for Astronomy, went back through Kepler data looking for targets to reanalyze in 2017.

“Our new analysis, which uses stellar sound waves observed in the Kepler data to characterize the star, demonstrated that the star is in fact three times larger than previously thought. This in turn means that the planet is three times larger, revealing that Kepler-1658b is actually a hot Jupiter,” Chontos said. With this refined analysis, everything pointed to it being a real planet. Next came confirmation.

“We alerted Dave Latham (a senior astronomer at the Smithsonian Astrophysical Observatory, and co-author on the paper) and his team collected the necessary spectroscopic data to unambiguously show that Kepler-1658b is a planet,” said Dan Huber, co-author and astronomer at the University of Hawaii. “As one of the pioneers of exoplanet science and a key figure behind the Kepler mission, it was particularly fitting to have Dave be part of this confirmation.”

What’s new: Kepler-1658b is one of the closest known planets orbiting a future version of our Sun, and revealed new constraints on the complex physical interactions that cause planets to spiral into their host stars. “Kepler-1658 is a perfect example of why a better understanding of host stars of exoplanets is so important,” Chontos said. “It also tells us that there are many treasures left to be found in the Kepler data.”

Read the paper: The Curious Case of KOI 4: Confirming Kepler’s First Exoplanet Detection

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert! Kepler’s First Planet Candidate Confirmed, 10 Years Later

3 min read

NASA Science Editorial Team

Planet: Kepler-1658b

Discovered by: Chontos et al. using NASA’s Kepler telescope

Date: February 2019

Key Facts: This newly-confirmed exoplanet is a massive hot Jupiter that whips around its star every 3.85 days. From the surface, the star would appear 60 times larger in diameter than the Sun as seen from Earth.

Details: Despite being the very first planet candidate discovered by NASA’s Kepler space telescope, Kepler-1658b had a rocky road to confirmation. The initial estimate of the planet’s host star was off, so the sizes of both the star and Kepler-1658b were vastly underestimated. It was later marked as a false positive — that is, scientists thought the data did not really point to a planet — when the numbers didn’t quite add up for the effects seen on its star for a body of that size. Kepler-1658b moved from planet candidate to false positive and back until new software was used to refine the data and reclassify it, changing it from a data anomaly to possible planet.

Fortuitously, a team at the University of Hawaii was poised to step in at just the right time. As part of her first year research project, lead author Ashley Chontos, a graduate student with the university’s Institute for Astronomy, went back through Kepler data looking for targets to reanalyze in 2017.

“Our new analysis, which uses stellar sound waves observed in the Kepler data to characterize the star, demonstrated that the star is in fact three times larger than previously thought. This in turn means that the planet is three times larger, revealing that Kepler-1658b is actually a hot Jupiter,” Chontos said. With this refined analysis, everything pointed to it being a real planet. Next came confirmation.

“We alerted Dave Latham (a senior astronomer at the Smithsonian Astrophysical Observatory, and co-author on the paper) and his team collected the necessary spectroscopic data to unambiguously show that Kepler-1658b is a planet,” said Dan Huber, co-author and astronomer at the University of Hawaii. “As one of the pioneers of exoplanet science and a key figure behind the Kepler mission, it was particularly fitting to have Dave be part of this confirmation.”

What’s new: Kepler-1658b is one of the closest known planets orbiting a future version of our Sun, and revealed new constraints on the complex physical interactions that cause planets to spiral into their host stars. "Kepler-1658 is a perfect example of why a better understanding of host stars of exoplanets is so important," Chontos said. "It also tells us that there are many treasures left to be found in the Kepler data."

Read the paper: The Curious Case of KOI 4: Confirming Kepler’s First Exoplanet Detection

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Why Do Some Galactic Unions Lead to Doom?

3 min read

NASA Science Editorial Team

Three images from NASA's Spitzer Space Telescope show pairs of galaxies on the cusp of cosmic consolidations. Though the galaxies appear separate now, gravity is pulling them together, and soon they will combine to form new, merged galaxies. Some merged galaxies will experience billions of years of growth. For others, however, the merger will kick off processes that eventually halt star formation, dooming the galaxies to wither prematurely.

Only a few percent of galaxies in the nearby universe are merging, but galaxy mergers were more common between 6 billion and 10 billion years ago, and these processes profoundly shaped our modern galactic landscape. For more than 10 years, scientists working on the Great Observatories All-sky LIRG Survey, or GOALS, have been using nearby galaxies to study the details of galaxy mergers and to use them as local laboratories for that earlier period in the universe's history. The survey has focused on 200 nearby objects, including many galaxies in various stages of merging. The images at the top show three of those targets, imaged by Spitzer.

In these images, different colors correspond to different wavelengths of infrared light, which are not visible to the human eye. Blue corresponds to 3.6 microns, and green corresponds to 4.5 microns - both strongly emitted by stars. Red corresponds to 8.0 microns, a wavelength mostly emitted by dust.

One of the primary processes thought to be responsible for a sudden halt in star formation inside a merged galaxy is an overfed black hole. At the center of most galaxies lies a supermassive black hole – a powerful beast millions to billions of times more massive than the Sun. During a galactic merger, gas and dust are driven into the center of the galaxy, where they help make young stars and also feed the central black hole.

But this sudden burst of activity can create an unstable environment. Shockwaves or powerful winds produced by the growing black hole can sweep through the galaxy, ejecting large quantities of gas and shutting down star formation. Sufficiently powerful or repetitive outflows can hinder the galaxy's ability to make new stars.

The relationship between mergers, bursts of star formation, and black hole activity is complex, and scientists are still working to understand it fully. One of the newly merged galaxies is the subject of a detailed study with the W.M. Keck Observatory in Hawaii, in which GOALS scientists searched for galactic shockwaves driven by the central active galactic nucleus, an extremely bright object powered by a supermassive black hole feeding on material around it. The lack of shock signatures suggests that the role of active galactic nuclei in shaping galaxy growth during a merger may not be straightforward.

Merging galaxies in the nearby universe appear especially bright to infrared observatories like Spitzer. GOALS studies have also relied on observations of the target galaxies by other space-based observatories, including NASA's Hubble and Chandra space telescopes, the European Space Agency's Herschel satellite, as well as facilities on the ground, including the Keck Observatory, the National Science Foundation's Very Large Array and the Atacama Large Millimeter Array.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena, California. Spacecraft operations are based at Lockheed Martin Space in Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech.

More information about the GOALS survey is available at the following site:

http://goals.ipac.caltech.edu/

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Galactic Wind Provides Clues to Evolution of Galaxies

4 min read

NASA Science Editorial Team

The Cigar Galaxy (also known as M82) is famous for its extraordinary speed in making new stars, with stars being born 10 times faster than in the Milky Way. Now, data from the Stratospheric Observatory for Infrared Astronomy, or SOFIA, have been used to study this galaxy in greater detail, revealing how material that affects the evolution of galaxies may get into intergalactic space.

Researchers found, for the first time, that the galactic wind flowing from the center of the Cigar Galaxy (M82) is aligned along a magnetic field and transports a very large mass of gas and dust - the equivalent mass of 50 million to 60 million Suns.

"The space between galaxies is not empty," said Enrique Lopez-Rodriguez, a Universities Space Research Association (USRA) scientist working on the SOFIA team. "It contains gas and dust - which are the seed materials for stars and galaxies. Now, we have a better understanding of how this matter escaped from inside galaxies over time."

Besides being a classic example of a starburst galaxy, which means it is forming an extraordinary number of new stars compared with most other galaxies, M82 also has strong winds blowing gas and dust into intergalactic space. Astronomers have long theorized that these winds would also drag the galaxy's magnetic field in the same direction, but despite numerous studies, there has been no observational proof of the concept.

Researchers using the airborne observatory SOFIA found definitively that the wind from the Cigar Galaxy not only transports a huge amount of gas and dust into the intergalactic medium, but also drags the magnetic field so it is perpendicular to the galactic disc. In fact, the wind drags the magnetic field more than 2,000 light-years across - close to the width of the wind itself.

"One of the main objectives of this research was to evaluate how efficiently the galactic wind can drag along the magnetic field," said Lopez-Rodriguez. "We did not expect to find the magnetic field to be aligned with the wind over such a large area."

These observations indicate that the powerful winds associated with the starburst phenomenon could be one of the mechanisms responsible for seeding material and injecting a magnetic field into the nearby intergalactic medium. If similar processes took place in the early universe, they would have affected the fundamental evolution of the first galaxies.

The results were published in January 2019 in the Astrophysical Journal Letters.

SOFIA's newest instrument,the High-resolution Airborne Wideband Camera-Plus, or HAWC+, uses far-infrared light to observe celestial dust grains, which align along magnetic field lines. From these results, astronomers can infer the shape and direction of the otherwise invisible magnetic field. Far-infrared light provides key information about magnetic fields because the signal is clean and not contaminated by emission from other physical mechanisms, such as scattered visible light.

"Studying intergalactic magnetic fields - and learning how they evolve - is key to understanding how galaxies evolved over the history of the universe," said Terry Jones, professor emeritus at the University of Minnesota, in Minneapolis, and lead researcher for this study. "With SOFIA's HAWC+ instrument, we now have a new perspective on these magnetic fields."

The HAWC+ instrument was developed and delivered to NASA by a multi-institution team led by the Jet Propulsion Laboratory. JPL scientist and HAWC+ Principal Investigator Darren Dowell, along with JPL scientist Paul Goldsmith, were part of the research team using HAWC+ to study the Cigar Galaxy.

SOFIA, the Stratospheric Observatory for Infrared Astronomy, is a Boeing 747SP jetliner modified to carry a 106-inch diameter telescope. It is a joint project of NASA and the German Aerospace Center, DLR. NASA's Ames Research Center in California's Silicon Valley manages the SOFIA program, science and mission operations in cooperation with the Universities Space Research Association headquartered in Columbia, Maryland, and the German SOFIA Institute (DSI) at the University of Stuttgart. The aircraft is maintained and operated from NASA's Armstrong Flight Research Center Hangar 703, in Palmdale, California.

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A passing star: our Sun’s near miss

4 min read

Pat Brennan

Stars jostling around the galaxy aren’t quite like a cosmic game of pool. But they do have occasional near misses as they speed past each other. Back when spears and stone points were the height of human technology, astronomers say, our solar system had a close encounter of the interstellar kind.

The brief visitor was Scholz’s star, and it might have grazed the outer edge of the solar system’s distant Oort Cloud about 70,000 years ago – carrying its companion, a likely brown dwarf, along for the ride.

It’s unclear whether the near miss was close enough to give objects in the Oort Cloud, our solar system’s halo of dormant comets, a gravitational nudge to fall toward the Sun. But the interstellar trespasser highlights a sometimes-forgotten reality: On long time scales, stars seem to fly around like sparks from a campfire, occasionally coming close enough to disturb each other’s cometary clouds.

Such close passes could have profound implications for exoplanets – planets orbiting other stars – and how they got where they are. At least some of the time, an interloper could become a thief, stripping a star of one or more planets – or vice versa.

Our solar system, too, might have been shaped and sculpted by stellar flybys.

A 2018 study showed that the orbital motions of some of our solar system’s small bodies appear still to bear the imprint of Scholz’s gravitational wake. And some planet-like objects in the Kuiper belt, the collection of rocky and icy bodies past the orbit of Neptune, could have been stolen from another star far earlier – in fact, soon after our Sun was born. Scholz’s flyby could just be the latest in a series.

The discovery of our star-crossed close encounter was almost as random as the event itself.

It started when astronomer Eric Mamajek, deputy program scientist for NASA’s Exoplanet Exploration program, was a professor at the University of Rochester. He took yearly excursions to Santiago, Chile, where he made observations with world-class telescopes.

On one such visit in 2013, a fellow astronomer, Valentin Ivanov, showed him a peculiar result: A newly discovered nearby star with a lengthy catalog designation (later nicknamed for its discoverer, Ralf-Dieter Scholz) seemed almost to be sitting still. Most stars move perceptibly across the sky over the course of a year, as measured in a unit called “arc seconds.” In terms of such “sideways” motion, this one hardly moved at all. Yet the star was only 22 light-years away – quite near to us by galactic standards.

Mamajek knew that could mean only one thing. Either the star was heading straight for us, or it was heading directly away. In this case, the astronomers had obtained measurements of the star’s Doppler shift – the reddening of light if a star is moving away, or a shift toward blue if it’s moving toward us.

“It was screaming away at 80 kilometers per second,” Mamajek recalled. And it didn’t take him long to do the math.

“In less than 15 minutes, we figured out that this star had passed within a light-year of the solar system, 70 or 80 thousand years ago,” he said.

The closest stars to our Sun today are the three in the Alpha Centauri system, about four light-years away. But if there were a star one light-year away, that could very well approach or even intersect with the outermost edge of the Oort Cloud.

Mamajek thinks that Scholz’s star, now known as the star that came closest to our solar system, could eventually lose that title. Extremely precise data from the European Space Agency’s new Gaia space probe will likely reveal more near misses, possibly closer ones. And in any case, another close pass by a star known as GJ 710 is due in about 1.3 million years.

For now, however, Scholz’s keeps its prize.

And might those rock-hammering, spear-shaping early humans have caught a glimpse as the star passed by? Turns out, not terribly likely. Scholz’s star is a red dwarf, the smallest and faintest kind of star we know. Even at its nearest point, about 55,000 astronomical units from our Sun (5.1 trillion miles), Scholz’s star would have been 100 times too dim to be seen with the naked eye.

Still, there’s a chance the visitor made itself known. Red dwarfs are known periodically to emit extremely bright flares.

If the star sent up a flare as it was cruising past our solar system, our cave-dwelling ancestors just might have seen it.

Pat Brennan is a science writer for NASA's Exoplanet Exploration Program. He joined JPL in 2015 after a 30-year career as a newspaper journalist.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Tour 55 Cancri e in 360 Degrees, Get the Travel Poster and More

3 min read

NASA Science Editorial Team

Explore the plethora of planets outside our solar system with new multimedia experiences from NASA's Exoplanet Exploration Program (ExEP). In addition to a new Exoplanet Travel Bureau poster celebrating a molten world called 55 Cancri e, space fans can enjoy a 360-degree visualization of the surface of the same planet, a multimedia journey into the life and death of planetary systems, and a major update to the popular Eyes on Exoplanets app.

Lava Life

Designed in the style of vintage travel posters, ExEP's popular Exoplanet Travel Bureau poster series imagines what it might be like to visit known planets outside our solar system, or exoplanets. Focusing on 55 Cancri e, a planet that may be covered in a lava ocean, the newest poster shows futuristic explorers gliding over the red-hot landscape in a protective bubble.

55 Cancri e is also now part of the Exoplanet Travel Bureau's 360-degree visualization tool, which enables you to take a virtual tour of what the planet's surface might look like, based on the limited data available (no photos of the planet exist). Seen as a massive fiery orb on the horizon, the planet's star is 65 times closer to 55 Cancri e than the Sun is to Earth. On the planet's cooler nightside, silicate vapor in the atmosphere may condense into sparkling clouds that reflect the lava below.

All of the 360-degree visualizations are viewable on desktop computers, mobile devices and through virtual reality headsets that work with smartphones.

Life and Death of a Solar System

How did we get here? How do stars and planets come into being, and what fate awaits planets after their stars die? The interactive web feature "Life and Death of a Planetary System" brings readers on an in-depth journey through the formation, evolution and eventual demise of a solar system. This multichapter story offers insight into how the planet we call home formed and what will happen to it when the Sun dies.

Planet Bonanza

Explore thousands of new worlds, both strange and strangely familiar, with NASA's Eyes on Exoplanets 2.0. Users can fly through the galaxy and virtually visit any of the nearly 4,000 known exoplanets, all visualized in 3-D. Interstellar ports of call include the TRAPPIST-1 system of seven Earth-sized planets, the potentially molten-lava-covered 55 Cancri e, the egg-shaped WASP-12b and Kepler-16b, the first world discovered orbiting two stars.

Among other features, the searchable Eyes on Exoplanets 2.0 lets users compare an exoplanet’s size to that of Earth or Jupiter; determine how long it would take to travel to a given planet by car, jet or light-speed starship; and interact with virtual models of NASA space telescopes, such as Hubble, Spitzer, Kepler and the newly launched Transiting Exoplanet Survey Satellite (TESS).

Eyes on Exoplanets 2.0 is powered by data from NASA's Exoplanet Archive, the official database used by scientists researching exoplanets. Available for use on desktop computers as well as most smartphones and tablets, this next-generation, browser-based version of the popular app requires no software download.

The Exoplanet Travel Bureau was developed by NASA's Exoplanet Exploration Program communications team and program chief scientists. Based at the agency's Jet Propulsion Laboratory in Pasadena, California, which is a division of Caltech, the program leads NASA's search for habitable planets and life beyond our solar system. The program develops technology and mission concepts, maintains exoplanet data archives and conducts ground-based exoplanet science for NASA missions.

News Media Contact

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert: Three New Neptunes?

2 min read

NASA Science Editorial Team

Planets: GJ 143 b, HD 23472 b and c

Discovered by: Trifonov et al. 2019

Date: February 2019

Key Facts: NASA's recently launched TESS space telescope added three new exoplanets to its list of confirmed discoveries, all of them with a "weight" (mass) comparable to Neptune's. GJ 143 b is twice the mass of Neptune. It orbits a "K"-type star, an orange star smaller than our Sun, about 53 light-years away. And a year on this planet – once around its star – is only 35 days long. Two more planets, HD 23472 b and c, are siblings, both orbiting the same parent star (this one about 127 light-years away). Both weigh in at about the mass of Neptune, also orbit a "K" star, and have very short years – 18 days for HD 23472 b, 30 days for c.

What's new: TESS (the Transiting Exoplanet Survey Satellite), launched in April 2018, doubles its list of confirmed exoplanet discoveries with the latest three – although thousands more are expected in the years ahead. TESS looks for the faint shadow of a planet crossing the face of its star, known as the "transit" method of detection.

These planets were later confirmed by ground-based telescopes using a different detection method: watching for wobbles in the star's movement caused by orbiting planets pulling one way, then another. Astronomers looking for the wobbles are measuring the star's "radial velocity." A fourth discovery was announced at the same time, unrelated to TESS but also involving the transit method – this time by ground-based instruments. HATS-70 b, some 4,200 light-years from Earth, tips the scale at roughly 13 times the mass of Jupiter. It might be a brown dwarf, a kind of failed star that, despite its enormity, did not have enough mass to ignite nuclear reactions in its core and become a star in its own right.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Citizen Scientists Find New World with NASA Telescope

NASA Science Editorial Team

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

In Search of Missing Worlds, Hubble Finds a Fast Evaporating Exoplanet

6 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Fishermen would be puzzled if they netted only big and little fish, but few medium-sized fish. Astronomers likewise have been perplexed in conducting a census of star-hugging extrasolar planets. They have found hot Jupiter-sized planets and hot super-Earths (planets no more than 1.5 times Earth's diameter). These planets are scorching hot because they orbit very close to their star. But so-called "hot Neptunes," whose atmospheres are heated to more than 1,700 degrees Fahrenheit, have been much harder to find. In fact, only about a handful of hot Neptunes have been found so far.

In fact, most of the known Neptune-sized exoplanets are merely "warm," because they orbit farther away from their star than those in the region where astronomers would expect to find hot Neptunes. The mysterious hot-Neptune deficit suggests that such alien worlds are rare, or, they were plentiful at one time, but have since disappeared.

A few years ago astronomers using NASA's Hubble Space Telescope found that one of the warmest known Neptunes (GJ 436b) is losing its atmosphere. The planet isn't expected to evaporate away, but hotter Neptunes might not have been so lucky.

Now, astronomers have used Hubble to nab a second "very warm" Neptune (GJ 3470b) that is losing its atmosphere at a rate 100 times faster than that of GJ 436b. Both planets reside about 3.7 million miles from their star. That's one-tenth the distance between our solar system's innermost planet, Mercury, and the Sun.

"I think this is the first case where this is so dramatic in terms of planetary evolution," said lead researcher Vincent Bourrier of the University of Geneva in Sauverny, Switzerland. "It's one of the most extreme examples of a planet undergoing a major mass-loss over its lifetime. This sizable mass loss has major consequences for its evolution, and it impacts our understanding of the origin and fate of the population of exoplanets close to their stars."

As with the previously discovered evaporating planets, the star's intense radiation heats the atmosphere to a point where it escapes the planet's gravitational pull like an untethered hot air balloon. The escaping gas forms a giant cloud around the planet that dissipates into space. One reason why GJ 3470b may be evaporating faster than GJ 436b is that it is not as dense, so it is less able to gravitationally hang on to the heated atmosphere.

What's more, the star hosting GJ 3470b is only 2 billion years old, compared to the 4-billion- to 8-billion-year-old star that planet GJ 436b orbits. The younger star is more energetic, so it bombards the planet with more blistering radiation than GJ 436b receives. Both are red dwarf stars, which are smaller and longer-lived than our Sun.

Uncovering two evaporating warm Neptunes reinforces the idea that the hotter version of these distant worlds may be a class of transitory planet whose ultimate fate is to shrink down to the most common type of known exoplanet, mini-Neptunes—planets with heavy, hydrogen-dominated atmospheres that are larger than Earth but smaller than Neptune. Eventually, these planets may downsize even further to become super-Earths, more massive, rocky versions of Earth.

"The question has been, where have the hot Neptunes gone?" said Bourrier. "If we plot planetary size and distance from the star, there's a desert, a hole, in that distribution. That's been a puzzle. We don't really know how much the evaporation of the atmospheres played in forming this desert. But our Hubble observations, which show a large amount of mass loss from a warm Neptune at the edge of the desert, is a direct confirmation that atmospheric escape plays a major role in forming this desert."

The researchers used Hubble's Space Telescope Imaging Spectrograph to detect the ultraviolet-light signature of hydrogen in a huge cocoon surrounding the planet as it passed in front of its star. The intervening cocoon of hydrogen filters out some of the starlight. These results are interpreted as evidence of the planet's atmosphere bleeding off into space.

The team estimates that the planet has lost as much as 35 percent of its material over its lifetime, because it was probably losing mass at a faster rate when its red-dwarf star was younger and emitting even more radiation. If the planet continues to rapidly lose material, it will shrink down to a mini-Neptune in a few billion years.

Hydrogen probably isn't the only element evaporating away: it may be a tracer for other material streaming off into space. The researchers plan to use Hubble to hunt for elements heavier than hydrogen and helium that have hitched a ride with the hydrogen gas to escape the planet. "We think that the hydrogen gas could be dragging heavy elements such as carbon, which reside deeper in the atmosphere, upward and out into space," Bourrier said.

The observations are part of the Panchromatic Comparative Exoplanet Treasury (PanCET) survey, a Hubble program to look at 20 exoplanets, mostly hot Jupiters, in the first large-scale ultraviolet, visible and infrared comparative study of distant worlds.

Observing the evaporation of these two warm Neptunes is encouraging, but team members know they need to study more of them to confirm predictions. Unfortunately, there may be no other planets of this class residing close enough to Earth to observe. The problem is that hydrogen gas cannot be detected in warm Neptunes farther away than 150 light-years from Earth because it is obscured by interstellar gas. GJ 3470b resides 97 light-years away.

However, helium is another tracer for material escaping a warm Neptune's atmosphere. Astronomers could use Hubble and the upcoming NASA James Webb Space Telescope to search in infrared light for helium, because it is not blocked by interstellar material in space.

"Looking for helium could expand our survey range," Bourrier said. "Webb will have incredible sensitivity, so we would be able to detect helium escaping from smaller planets, such as mini-Neptunes."

The researcher's paper will appear in the Dec. 13 issue of Astronomy and Astrophysics.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

Science paper by V. Bourrier et al.:
https://stsci-opo.org/STScI-01EVSQWZFRGN8NQ69QXCYQT66Q.pdf

For NASA's Hubble website, visit: www.nasa.gov/hubble

Contacts:

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

Vincent BourrierUniversity of Geneva, Sauverny, Switzerland011-41-22-379-2449vincent.bourrier@unige.ch

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Growth Spurt for a Young Star

2 min read

NASA Science Editorial Team

› Full image and caption

› Full image and caption

An adolescent star in the midst of a dramatic growth phase has been observed with the help of two NASA space telescopes. The youngster belongs to a class of stars that gain mass when matter swirling around the star falls onto its surface. The in-falling matter causes the star to appear about 100 times brighter. Astronomers have found only 25 stars in this class, and only about half of those have been observed during an outburst.

The new findings shed light on some long-standing mysteries surrounding the evolution of young stars, including how they acquire all of their mass. This rarely observed outbursting behavior could be common but might typically be hidden from our view by thick clouds of dust.

The newfound star, called Gaia 17bpi, was first spotted by the European Space Agency's Gaia satellite, but NASA's asteroid-hunting Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) satellite serendipitously observed the star's brightening at the same time that Gaia did. Additional searches in NEOWISE's data archives and the archives of NASA's infrared-sensing Spitzer Space Telescope showed that these spacecraft had detected the flare-up in infrared light more than one year earlier.

You can read the full story from the Caltech news office here. Caltech manages the Jet Propulsion Laboratory in Pasadena, California, for NASA. The research is detailed in a new study titled "Gaia 17bpi: An FU Ori Type Outburst."

JPL manages and operates the NEOWISE mission for NASA's Planetary Defense Coordination Office within the Science Mission Directorate in Washington. JPL also manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena, California. Data are archived at the Infrared Science Archive housed at IPAC at Caltech.

Search for Life

Stars

Universe

Black Holes

A Trip to the Outback – and to Earth’s Early Life

2 min read

NASA Science Editorial Team

by Nick Siegler, chief technologist, NASA's Exoplanet Exploration Program

This past July I joined a group of geologists, geochemists, microbiologists, and fellow astronomers on a tour of some of the best-preserved evidence for early life.

Entitled the Astrobiology Grand Tour, it was a trip led by Dr. Martin Van Kranendonk, a structural geologist from the University of New South Wales, who had spent more than 25 years surveying Australia’s Pilbara region. Along with his graduate students he had organized a 10-day excursion deep into the outback of Western Australia to visit some of astrobiology’s most renowned sites.

The trip would entail long, hot days of hiking through unmaintained trails on loose surface rocks covered by barb-like bushes called spinifex. As I was to find out, nature was not going to give up its secrets easily. And there were no special privileges allocated to astrophysicists from New Jersey.

The state of Western Australia, almost four times the size of the American state of Texas but with less than a tenth of the population (2.6 million), is the site of many of astrobiology’s most heralded sites. For more than 3 billion years, it has been one of the most stable geologic regions in the world.

It has been ideal for geological preservation due to its arid conditions, lack of tectonic movement, and remoteness. The rock records have in many places survived and are now able to tell their stories (to those who know how to listen).

Our trip began with what felt like a pilgrimage. We left Western Australia’s largest city Perth and headed north for Shark Bay. It felt a bit like a pilgrimage because the next morning we visited one of modern astrobiology’s highlights – the living stromatolites of Shark Bay.

Stromatolite literally means “layered rock.” It’s not the rocks that are alive but rather the community of microbial mats living on top. They are some of the Earth’s earliest ecosystems.

Read the full story on Marc Kaufman's "Many Worlds" blog

Bringing Hubble’s Science into Focus

10 min read

NASA Science Editorial Team

On May 20, 1990, you could hear a pin drop as a room full of scientists waited breathlessly for the initial images from the first major optical telescope in space. As a few bright points of light set against the black canvas of deep space materialized, instead of awe, the room filled with dread. Although better than any ground-based telescope could manage, the image was far less clear than anyone had anticipated.

It was possible that the Hubble Space Telescope was out of focus. This theory, however, proved incorrect. After the requisite adjustments were made, a fateful image of galaxy M100 returned looking as if it was forgotten in the pocket of a pair of jeans and thrown in the wash — mottled, blurred and hazy. It was at this moment that the Hubble team knew their telescope was in trouble.

Scientists and engineers at NASA and its partner institutions spent the next three years orchestrating a solution. Twenty-five years ago, a group of astronauts ascended in the space shuttle to accomplish a feat of unprecedented proportions: to fix Hubble, in space, while orbiting Earth at over 17,500 miles per hour. These seven astronauts would be implementing a repair and upgrade hundreds of scientists and engineers conceived, designed and tested on Earth at multiple locations including NASA’s Johnson Space Center, Goddard Space Flight Center and Jet Propulsion Laboratory.

The Hubble we know and love today is the most productive space telescope ever launched. The data it has provided the world has prompted unparalleled discoveries, and it continues, after 28 years of science, to tell us more about our universe every day. Much of this incredible track record can be attributed to Hubble’s remarkable longevity. So, how has Hubble survived for so long, over a decade longer than originally intended?

The answer to Hubble’s persistent history of excellence and science lies with a wide and diverse group of dedicated individuals committed to making a telescope designed with the capability to be upgraded and repaired — also known as “servicing” — once it was already in space.

“The reason I came to NASA was really to be innovative,” said Frank Cepollina, former Associate Director for the Satellite Servicing Capabilities Project and a man famed for championing satellite servicing as a concept, then seeing it through to fruition. “We were in a first-time business — the first time this stuff had ever been done, so there was a lot of learning and testing and creating.”

Cepollina, affectionately known by his colleagues as “Cepi,” helped conceptualize the first plans to fix an orbiting spacecraft in person on a mission called SolarMax, which astronauts successfully repaired in 1984. He earned the nickname “Father of Satellite Servicing” as a result of his efforts. This work informed the design for Hubble, a telescope built from the outset with the intention of astronauts repeatedly visiting to repair and upgrade over time in a series of servicing missions.

“We wanted to design something that could continue to work mission after mission that wouldn’t have to be redesigned and updated for each flight,” Cepi said of developing a space telescope that could be serviced numerous times. “It needed to work with the brand-new transportation vehicle we were developing: the space shuttle orbiter. So that’s really how we started innovating for Hubble.”

Cepi and his team focused on constructing interchangeable, modular elements for the telescope, which would allow astronauts to smoothly and efficiently swap out pieces of hardware as technology improved through the years. Each instrument would be self-contained, with its spidery wiring inside little (and sometimes rather large) boxes, so that all the astronaut crew needed to worry about would be exchanging one box for another. This forward-thinking would prove to be critical to the success of Hubble's five servicing missions.

Hubble was launched and deployed successfully in April 1990, its orbital release a historic action in and of itself. But then the problems began. Not only was Hubble returning blurry images, but it was also having trouble locking onto the right guide stars — the markers that help Hubble stay locked on an object. "The spherical aberration, the issue that caused the blurry images, was really just one of multiple problems," said Larry Dunham, the Chief Systems Engineer for Flight Systems for Hubble who has worked on the telescope from its very inception — over 30 years. "But we were still doing better science in this field than had ever been done before. We just knew it could be even better."

Dunham chaired a group called the Guide Star Acquisition Working Group. He said that his group was concerned with the blurry images problem, but that they remained concentrated on adjusting Hubble's pointing capabilities so that the telescope could continue to produce scientific results. These capabilities were partially inhibited by a flexing of the solar arrays caused by drastic temperature changes during orbit.

"We developed software to counteract erratic movements from our solar arrays," said Dunham. "Our group was responsible for essentially keeping Hubble pointed in the direction we wanted, so we worked to correct what we could."

Simultaneously, a task force of engineers and scientists assembled to diagnose the aberration issue, find a solution and restructure the first servicing mission around fixing the predominant problems.

"When we began getting pictures from the Wide Field Planetary Camera and they looked weird, it just triggered something in me, and I just could not ignore the problem," said Sandra Faber, an astrophysicist who was recruited as a team lead to determine the cause of Hubble's blurry images. "I was living and breathing this problem every day... I couldn't sleep, actually. I remember I would go to bed at 1 or 2 in the morning, very uncharacteristic of me. I would just lie in bed and these thoughts would revolve in my mind... what could be wrong, and a task list for tomorrow."

Faber and her team worked incessantly to understand the problem with certainty. They constructed hypotheses, made models and tested their theories until they arrived at the solution: the mirror had been incorrectly ground, resulting in an imperfection less than the width of a human hair.

"It was the most complicated emotional moment of my life, because it was so good and so bad at the same time," said Faber, lamenting the interplay of triumph in solving the problem and simultaneous dismay at the problem itself. "We were optimistic about it, though. At a minimum, we could credibly argue as scientists that the telescope could do a lot of very good work while the Hubble repair mission was designed and implemented."

As astronauts Richard Covey, Kenneth Bowersox, Kathryn Thornton, Story Musgrave, Claude Nicollier, Jeff Hoffman and Tom Akers captured Hubble in orbit and moved it into the shuttle bay for repair, the world watched a historic event unfold.

"The American public had never seen a mission like this. You go up, you grab the telescope, and for a week, you're watching these astronauts going out in spacesuits, doing five spacewalks, taking hardware out and putting hardware in, and it was just fascinating," said Dunham. "The spacewalks all started after 10 p.m., and people were staying up into the night watching it on TV. That was just inspiring."

Hubble's servicing mission was imperative for many reasons outside of merely restoring its capabilities. The implications of failure stretched far into the future, as NASA was gearing up to begin building a permanent, orbiting laboratory, now known as the International Space Station.

“Everybody knew it was important,” said Thornton, who engaged in multiple spacewalks to repair the telescope during the mission. “Hubble is a national treasure. We were planning at the time to build the space station by hand. If we couldn’t fix Hubble, it was going to be hard to build the space station by the same method.”

Thornton maintains, however, that the astronauts themselves were largely shielded from the pressure of the mission. “In the end, we just did our jobs,” said Thornton. “We trained extensively, memorized procedures, imagined doing it up there. We took each task one at a time, and I would say it went very much according to plan.”

Necessity is the mother of invention, and the pioneering nature of Hubble’s servicing missions warranted the ingenuity of new procedures and new tools made for highly specific tasks. Specialized power tools helped astronauts use the right amount of torque in microgravity, and layers of protective hard plastic covered screws that needed to be removed, keeping them from floating off into space or falling into the spacecraft.

“We [NASA] did a lot of designing of tools specifically for Hubble,” said Dunham. “Those tools are being used now in all kinds of other places in other ways. Our hardware has evolved over time because we’ve learned from the astronauts what works best for them. We had to design all those things from scratch. I think that knowledge has been able to be used a lot of different places.”

Hubble was the birthplace for many of these new procedures, and changed our idea as a nation of what it means to have a presence in space. “We really expanded our human capability to go up there and repair things, doing things that we thought may not have been possible,” said Thornton. “With each mission, I think we expanded our knowledge of servicing in space. Each mission was more complex than the one before.”

“The whole concept of astronauts treating space as a workplace, where they can go for a week or longer and work... I think we developed that concept on Hubble, and we learned a lot from that,” said Dunham. “That’s the kind of expertise they’ll need for those missions that will travel to the Moon and to Mars.”

Hubble has swept us into a new era of understanding our universe. The advancements and knowledge we have gained from its data and images are unparalleled, and our continuously developing capabilities in servicing have allowed Hubble to remain in orbit for more than a generation. Some people have been able to center their entire careers on Hubble, and the telescope’s vast swaths of data are now influencing the next generation of scientists, engineers and explorers.

“My oldest daughter was 11 years old when we did that first servicing mission,” said Thornton. “She went on to get her doctorate in physics and astronomy using Hubble data, and now she is a professor.”

After 25 years of servicing innovation and 28 years in orbit, Hubble’s vitality, color, vision and scientific prowess remain unmatched. As NASA pursues its mission to uncover further mysteries of the universe, Hubble will endure as the cornerstone of astronomical discovery and human determination.

To learn more about the Hubble Space Telescope, SM1, later servicing missions, images captured by Hubble and more, visit nasa.gov/hubble.

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

How Will TESS Look for Exoplanets?

2 min read

NASA Science Editorial Team

NASA's latest space telescope, the Transiting Exoplanet Survey Satellite (TESS), launched in April 2018. This week, planet hunters worldwide received all the data from the first two months of its planet search. This view, from four cameras on TESS, shows just one region of Earth’s southern sky.

The data in the images from TESS will soon lead to discoveries of planets beyond our solar system – exoplanets. (We’re at 3,848 so far!)

But first, all that data (about 27 gigabytes a day) needs to be processed. And where do space telescopes like TESS get their data cleaned up? At the Star Wash, of course!

TESS sends about 10 billion pixels of data to Earth at a time. A supercomputer at NASA Ames in Silicon Valley processes the raw data, turning those pixels into measures of a star’s brightness.

And that brightness? THAT’S HOW WE FIND PLANETS! A dip in a star’s brightness can reveal an orbiting exoplanet in transit.

TESS will spend a year studying our southern sky, then will turn and survey our northern sky for another year. Eventually, the space telescope will observe 85 percent of Earth’s sky, including 200,000 of the brightest and closest stars to Earth.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Goodnight Kepler: Final Commands for Space Telescope

2 min read

NASA Science Editorial Team

On the evening of Thursday, Nov. 15, 2018, NASA's Kepler space telescope received its final set of commands to disconnect communications with Earth. The "goodnight" commands finalize the spacecraft's transition into retirement, which began on Oct. 30 with NASA's announcement that Kepler had run out of fuel and could no longer conduct science.

Coincidentally, Kepler's "goodnight" falls on the same date as the 388-year anniversary of the death of its namesake, German astronomer Johannes Kepler, who discovered the laws of planetary motion and passed away on Nov. 15, 1630.

The Kepler space telescope has had a profound impact on our understanding of the number of worlds that exist beyond our solar system. Through its survey, we've discovered there are more planets than stars in our galaxy. As a farewell to the spacecraft, we asked some of people closest to Kepler to reflect on what Kepler has meant to them and its finding of "more planets than stars."

The final commands were sent over NASA's Deep Space Network from Kepler's operations center at the Laboratory for Atmospheric and Space Physics, or LASP, at the University of Colorado in Boulder. LASP runs the spacecraft's operations on behalf of NASA and Ball Aerospace & Technologies Corporation in Boulder, Colorado.

Kepler's team disabled the safety modes that could inadvertently turn systems back on, and severed communications by shutting down the transmitters. Because the spacecraft is slowly spinning, the Kepler team had to carefully time the commands so that instructions would reach the spacecraft during periods of viable communication. The team will monitor the spacecraft to ensure that the commands were successful. The spacecraft is now drifting in a safe orbit around the Sun, 94 million miles away from Earth.

The data Kepler collected over the course of more than nine years in operation will be mined for exciting discoveries for many years to come.

NASA's Ames Research Center in California's Silicon Valley manages the Kepler and K2 missions for NASA's Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from LASP.

For more information, visit the Kepler mission website.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Rocky? Habitable? Sizing up a galaxy of planets

5 min read

NASA Science Editorial Team

By Pat Brennan, NASA's Exoplanet Exploration Program

The planets so far discovered across the Milky Way are a motley, teeming multitude: hot Jupiters, gas giants, small, rocky worlds and mysterious planets larger than Earth and smaller than Neptune. As we prepare to add many thousands more to the thousands found already, the search goes on for evidence of life – and for a world something like our own.

And as our space telescopes and other instruments grow ever more sensitive, we're beginning to zero in.

The discoveries so far inspire excitement and curiosity among scientists and the public. We've found rocky planets in Earth's size range, at the right distance from their parent stars to harbor liquid water. While these characteristics don't guarantee a habitable world – we can't quite tell yet if these planets really do possess atmospheres or oceans – they can help point us in the right direction.

Future space telescopes will be able to analyze the light from some of these planets, searching for water or a mixture of gases that resembles our own atmosphere. We will gain a better understanding of temperatures on the surface. As we continue checking off items on the habitability list, we'll draw closer and closer to finding a world bearing recognizable signs of life.

Among the most critical factors in the shaping and development of a habitable planet is the nature of its parent star. The star's mass, size and age determine the distance and extent of its "habitable zone" – the region around a star where the temperature potentially allows for liquid water to pool on a planet's surface.

The European Space Agency's Gaia satellite, launched in 2013, is becoming one of history's greatest star mappers. It relies on a suite of high-precision instruments to measure star brightness, distance and composition. The ambitious goal is to create a three-dimensional map of our Milky Way galaxy. The chart so far includes the positions of about 1.7 billion stars, with distances for about 1.3 billion.

That has prompted a reassessment of star sizes to learn whether some might be larger, smaller, dimmer or brighter than scientists had thought.

It turns out that many of the stars were found to be brighter – and larger – than previous surveys estimated. For the team managing the explosion of planet finds from NASA's Kepler space telescope, beginning in 2009, that also means a revision of sizes for the planets in orbit around them.

If a star is brighter than we thought, it's often larger than we thought as well. The planet in orbit around it, measured proportionally by the transit method, must also be larger.

That means some of the planets thought to be of a size and temperature similar to Earth's are really bigger – and usually, hotter.

"Gaia has improved distances and has improved assessments of how bright a star is, and how big a planet is," said Eric Mamajek, the deputy program chief scientist for NASA's Exoplanet Exploration Program. "The whole issue has always been, how well do we understand the star? This is just another chapter of that ongoing story."

The latest scientific data from the Gaia space probe also is prompting a reassessment of the most promising "habitable zone" planets found by observatories around the world, as well as space-based instruments like NASA's Kepler. As scientists iron out both observations and definitions of what we consider a potentially habitable world, better data is bringing us closer to finding such a planet and – maybe just as important – finding our own planet's place among them.

Of the 3,700 exoplanets – planets around other stars – confirmed by scientists so far, about 2,600 were found by the Kepler space telescope. Kepler hunts for the tiny eclipse, or dip in starlight, as a planet crosses the face of its star.

The most recent analysis of Kepler's discoveries shows that 20 to 50 percent of the stars in the sky are likely to have small, potentially rocky planets in their habitable zones. Our initial estimate of near Earth-sized, habitable-zone planets from the Kepler spacecraft as of June 19, 2017, was 30. Preliminary analysis of newer data, on both those exoplanets and their host stars, shows that the number is likely smaller – possibly between 2 and 12.

Much more data are needed, including a better understanding of how a planet's size relates to its composition.

"We're still trying to figure out how big a planet can be and still be rocky," said Jessie Dotson, an astrophysicist at NASA's Ames Research Center in California's Silicon Valley. She is also the project scientist for Kepler's current, extended mission, known as K2.

At first glance, the latest analysis might seem disappointing: fewer rocky, potentially habitable worlds among the thousands of exoplanets found so far. But that doesn't change one of the most astonishing conclusions after more than 20 years of observation: Planets in the habitable zone are common.

More and better data on these far distant planets means a more accurate demographic portrait of a universe of planets – and a more nuanced understanding of their composition, possible atmospheres and life-bearing potential.

That should put us on more solid ground for the coming torrent of exoplanet discoveries from TESS (the Transiting Exoplanet Survey Satellite), and future telescopes as well. It brings us one step closer in our search for a promising planet among a galaxy of stars.

"This is the exciting part of science," Dotson said. "So often, we're really portrayed as, 'Now we know this story.' But I have a theory: Scientists love it when we don't know something. It's the hunt that's so exciting."

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.626-808-2469calla.e.cofield@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery Alert! A New Super-Earth in the Neighborhood (Six Light-Years Away)

NASA Science Editorial Team

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Meet the Kepler mission team

34 min read

NASA Science Editorial Team

Student Intern

Hometown: Campina Grande, Brazil

"Back in Brazil, when I first heard about NASA's Kepler Mission, the first thing that came into my mind was, 'These people built and operate a space telescope with the goal to find Earth-like planets dozens or hundreds of light years away. They themselves are out of this world!' Working for Kepler was an absolutely amazing experience. The mission and its quest for habitable worlds are so fascinating that every day at work felt like there was going to be a pink box of donuts waiting for you. And that was what actually happened. The feeling and privilege of being surrounded by the outstanding NASA teams of scientists, managers and engineers simply cannot be put into words. Go Kepler!"

Instrument Scientist

Hometown: Pittsburgh, Pennsylvania

I was in graduate school studying star formation in 1995 when 51 Pegasi b, the first exoplanet around a Sun-like star, was found. I remember being very skeptical of this Jupiter-size planet orbiting its star every four days. Little did I know then that I would spend much of my career studying exoplanets and helping the Kepler mission find even more bizarre and amazing planets. In 1998, I started working with Kepler's principal investigator, Bill Borucki, on the Vulcan project. Vulcan was a small, 10 centimeter-diameter telescope designed to look for planets like 51 Peg b that happen to pass in front of – or transit— their star as seen from Earth. At the time this approach was not widely accepted in the astronomy community and Vulcan was a proof-of-concept for the much more ambitious Kepler mission. I was part of a small team (three of us!) working on incorporating our Vulcan experience into the design of Kepler's data processing pipeline to help convince NASA that Kepler would work. After NASA agreed, our team grew significantly as we began the detailed work of designing and building a spacecraft and data analysis pipeline that could monitor over 100,000 stars searching for the tiny transit signals of Earth-size planets. My role shifted to uncovering the quirks of the instrument and understanding how they would affect our search for planets. As instrument scientist I helped oversee the testing and characterization of the photometer and helped develop the models and algorithms needed to calibrate Kepler's science data and distinguish between transit signals from exoplanets and the often much larger artifacts from the instrument. While I enjoy burying my head in the minute details of the data, perhaps the most satisfying part of my time with Kepler is when I step back and see how Kepler's results have fundamentally changed not just the field of astronomy, but humanity's understanding of our place in the universe. We now know that there are not just a handful of oddball exoplanets out there, but that there are more planets than stars, including planetary systems with many that are potentially habitable. I am proud to be a part of the Kepler team.

Co-investigator for Data Analysis

Hometown: Merritt Island, Florida

"Nothing compares to when you get the spacecraft up there and it opens its eyes and sees for the very first time. I was actually going to work (in May 2009), en route, when I got word the data was ready. I got to work at 6 a.m., ready to sit down with my coffee, looking at the data. I couldn't quite bring myself to do it, I was so anxious. I actually washed the coffee pot – 12 people (in the office), but the coffee pot rarely got washed. I took an extra 10 minutes to calm my nerves, to give it an extra scrub. Then I started pulling data across, looking at light curves. The brightness variations of stars were phenomenal – everything we imagined they could be. It was very easy right off the bat to see eclipsing binaries, lots of variable stars and transiting exoplanets. A colleague turned to me. He had this encyclopedia of variable stars. He said, 'Jon, I don't see anything like that in the encyclopedia.' That was what Kepler was like. It showed us stars in a whole new light, in ways we'd never seen or appreciated before. Right out of the box, we knew Kepler would be a success."

Project Scientist

Home town: Oakdale, Pennsylvania

"Kepler and K2 have changed the course of human thought. They have provided an inflection point not only in science but also in the very nature of our existence. These missions have provided paradigm-changing results in stellar astrophysics, new views of cosmology, and their greatest finding, the discovery of a multitude of exoplanets including potentially habitable worlds scattered throughout the galaxy. Bringing together not just scientists but all people, these two missions, assembled here on planet Earth, give us pause to reflect upon ourselves and upon our existence in the Universe. As in the Copernican Revolution, when we learned we were no longer the center of the universe, we now know that we are unlikely to be alone, unlikely to be the only life-bearing rock orbiting the distant stars. Yet for now, Earth is our only home. All of us are important and all our lives are precious. Here there is no room for hate, fear, and bigotry. Perhaps now we can finally dispense with the futile and ignorant belief in war as a political tool and choose instead to go forward together and become emissaries to all life everywhere."

Support Scientist

Home town: Newark, New Jersey

"One of my favorite memories of the Kepler mission was our trip to an asteroseismology conference in Aarhus, Denmark, in June 2010. We were excited to present and hear the first Kepler astrophysics results, and we spent a few days as a science team in Ebeltoft. Four of us – Mike Haas, Doug Caldwell, Steve Bryson, and myself – decided to go on a pilgrimage to Tycho's observatory on the island of Hven in the North Sea, where much of the data analyzed by our namesake Kepler was generated. We got there 10 minutes before closing at 4 p.m. and were crestfallen. Then, Steve Bryson noticed that the young man running the museum was reading the CERN web page, and thought he might be interested in astrophysics as well. He was very excited that we were from the NASA Kepler program. He gave us the keys to the underground observatory and said, 'Just drop the keys off on your way out.' So the four of us went over to the observatory and looked with reverence at Tycho's equipment, things that looked like giant protractors and sextants kept underground for the stability of the measurements – just like the Kepler spacecraft, for which thermal control of the instrument is a key part of doing the precise measurements of the shadows of planets around other stars. I felt great admiration for the people who had come before us in astronomy who did their work without computers or telescopes, but with a great passion for revealing the past and foretelling the future, and felt great gratitude to the taxpayers of the U.S. and our European friends who support our participation in this great adventure.

Data Processing Lead

Hometown: Sonoma, California

"I started in 2007 as a student worker for Dr. Natalie Batalha, while working on my (master's degree) in physics at (San Jose State University), doing light-curve modeling of eclipsing binary stars on Vulcan (photometer) data. In 2009, I was hired on full-time in the Science Operations Center (SOC) as an operations engineer. Work as an operations engineer consists of processing the science data through its lifecycle. The process began with running pipelines to help the science office choose which stars to observe during a (data collection period). Then we'd export those tables and send them off to be uplinked to the spacecraft for science observations. After three months of collecting science data on the spacecraft, that data set would be delivered to the SOC for data accounting, (importing the data) into the computing cluster, processing, and export. The processing and export results get pushed to the science team, and then delivered to the MAST (Mikulski Archive for Space Telescopes) and the NExScI (NASA Exoplanet Science Institute) Exoplanet Archive for the science community. Getting to use the NAS supercomputer to process the big multi-quarter data sets was pretty exciting! It was always fun to go to team meetings to hear the science results before everybody else: when we found the planet going around two stars, or finding the heartbeat stars (binary stars that seem to pulse more strongly as they approach each other). It is hard to choose a favorite science discovery, but I would say that Kepler 186f had a big impact on the team. Looking back, I think this has been a challenging job, but sometimes there would be fun times – like back earlier on, we used to go gather back in a conference room to watch episodes of original Star Trek. I remember watching 'The Trouble with Tribbles' and eating snacks and thinking this was an awesome place to work."

Support Scientist

Hometown: San Rafael, California

"The project evolved over time. We started out (with) a huge software pipeline that we used to analyze data. I was taking responsibility for converting pixel data into light curves. It's mostly about knowing which pixels you want (and) exactly how light is spread out by the system. We needed to test data before we flew. We made simulations of everything from how pixel values appeared to the spacecraft through communications coding, (to the) ground and all the organizations it would flow through. It was absolutely critical; we revealed all kinds of problems doing that. Once (Kepler) launched, I was commissioned with the responsibility of actually measuring how light spread out. It was exciting because it was very high pressure. It fed directly into what we got from the spacecraft. We couldn't do all the pixels; if I selected the wrong pixels, that's it. I got very involved in validations of discoveries. My specialty was making sure they weren't polluted by background objects, by analysis of pixels. One thing I can brag about is being second author on two papers that validated discoveries: first 800, then 1,400 planets, all in one shot. Both of them hold the record. No other single paper validated that many planets at once. One day I came home and my wife, Hanna, asked how work was. I said, 'Fine, we found about four more planets today.' Like that was normal. Then I paused, and realized what I just said. Wow, it's amazing what you get used to. What Kepler was doing: Is this rare or normal? The answer we came up with was, wow, this is really normal. That's what makes it history."

Support Scientist

Hometown: Sunnyvale, California

"Back in 2009 I was in graduate school getting ready to write my thesis. I was working on some photometry projects, monitoring the whims and outbursts of young stars (where 'young' in astronomy means a few million years old). I had used the Canadian space telescope MOST and was soon to use the French space telescope CoRoT. But what was this Kepler telescope that had just launched? Could I use it to observe young stars? It turned out that the answer, at least initially, was no. Kepler was dedicated to a particular patch of sky, and there were no young stars there. I instead became heavily involved with the analysis of young star data from CoRoT. But in late 2012, a computer failure brought the telescope to its knees. Some nine months later, a major problem (loss of a reaction wheel) would strike Kepler too. But there was a ray of hope: unlike the CoRoT mission, which was unsalvageable, Kepler was still able to carry out science. The telescope had simply lost its ability to point stably. Kepler's engineering teams came up with a radical idea: re-orient the spacecraft such (that) it was in rough equilibrium thanks to the Sun's light impinging on its solar panels. Kepler would no longer be able to stare at the same patch of space that it had spent four years on, but it could look to entirely new areas. And in those new areas...were young stars! In early 2014, Kepler was reborn as the K2 Mission. I applied for a postdoctoral fellowship position at the NASA Ames Research Center headquarters to Kepler. Some months later I moved to the Bay Area of California to work with this fabled telescope. It’s now been nearly four years, and it’s one of the best moves I ever made. I’ve had the privilege to get the first look at incredibly high quality and intriguing data on young stars, and with that data we’ve made numerous new discoveries. We have found orbiting blobs of dust around them -- potentially related to the initial seeds of exoplanets. We’ve observed gas funneling onto the young stars in huge bursts. And we’ve identified the youngest known planets orbiting these objects.”

Support Scientist

Hometown: Cambridge, United Kingdom

“Kepler has been such a paradigm shift for people like me. I remember using it for my pre-master’s project. It’s such a constant, such an assumed thing. I’m in a really privileged position to be in the first generation of astronomers able to use it as readily – from the beginning of my career it’s been available. I’m incredibly grateful for it. We use it so much every day; so much relies on it. It’s seamlessly part of the astronomical landscape. I cannot imagine what astronomy was like 20 years ago without Kepler.”

Lead Scientific Programmer

Home town: San Mateo, California

“I joined the Kepler team 1.5 years before the (2009) launch as a senior scientific programmer in the Kepler Science Operations Center (SOC). The SOC was responsible for developing, testing, validating, operating and maintaining the Kepler Science processing pipeline. The pipeline consists of a set of software modules; when run in sequence the modules produced photometric light curves for roughly 160,000 target stars in each observing quarter, searched the light curves for signatures of transiting planets, and generated planet models and vetting diagnostics to help distinguish between legitimate planet candidates and false positive detections. I have a Ph.D. in electrical engineering in the area of signal processing, and had already been involved with NASA programs and planetary missions for over 20 years when I joined the Kepler team. Working in the SOC was a fabulous professional opportunity. Detecting the signatures of transiting planets, in particular small planets orbiting in the habitable zone of their host stars, seemed like the ultimate signal processing problem to me. And so it was!!! The Kepler mission received a great deal of visibility, and the results revolutionized the exoplanet field. Significant contributions were also made in astrophysics and asteroseismology. After a few years in the SOC, I became the lead scientific programmer and assumed a greater responsibility for the work of the group. My workmates were experienced, bright and highly skilled; they were also great fun to work with. I made friendships in the SOC that will last a lifetime. Developing the Kepler pipeline, and identifying the signatures of thousands of potential exoplanets, was greatly challenging and highly rewarding. I am thankful that I had the opportunity to become involved with the Kepler mission, and I am proud of my contributions to Kepler science.”

Safety and Mission Assurance

Home town: Sunnyvale, California

Kepler provided an opportunity to hear about planet observations first. I found it very exciting over the years seeing the photometer get designed, manufactured, assembled, tested, launched, and witness first light as the cover was released that began science data collection. This experience was very cool. The team had moved into mission operations with a new excitement of finding plants. It was incredible to sit in the team meeting and to hear the data has identified planets. It was a privileged to hear about the exciting new discovery before the public as a team member. I am proud to have been able to be part of the team knowing all that Kepler had contributed to science.

Support Scientist

Home town: Dublin, Ireland

From 2010- 2016, I worked on Kepler in the science office. I had a bunch of jobs, from helping to monitor spacecraft health, assessing the quality of the data analysis, to making catalogs of planets. My most important job was to find "not-planets." In other words, there were a bunch of signals in the data that looked like planets, but were actually due to other things, like eclipsing binaries, variable stars, and even high energy particles flying through space and hitting the detector (this happened way more often than you would expect). We had to figure out which signals were planets and which were other stuff.

When K2 was getting started, I had to figure out where to point the spacecraft for the first campaign. I had a lot of fun working with spacecraft orbits and attitudes with loads of vectors and cross products. As Bart Simpson would say, "I'd finally found a practical use for geometry!" To help me figure out all the orientations I made a little Lego model of the spacecraft -- I still have it on my desk -- and I'd spend half an hour lining it up just right on my desk, with coffee cups strategically placed around the office to represent the Sun, the Earth, and any other solar system planets I had to worry about. Once I had the Lego lined up so all the vectors were pointing in the right place I'd go check that my code was giving me the right answers.

Of course, everytime I did this someone would walk into the office, pick up the Lego, turn it around in their hands a few times and ask: "What are you doing with this?" At the end of it all, me and my little Lego model got to point a space telescope millions of light years away in space.

My 6-year-old self would have been seriously impressed.

Support Scientist

Home town: Waukesha, Wisconsin

I was in the Kepler Science Office for seven years. I created exoplanet catalogs and made all the data and planet catalogs accessible (and understandable) to the larger astronomical community.

Kepler will always be the backdrop against the memories I have of starting my family. While I worked on the Kepler team to figure out what the data meant, I was also figuring out how to be a wife and mother. My husband and I both started at Kepler the summer after we got married. My son was born the following year. I gave a presentation on heartbeat stars at the Kepler science conference two weeks later, proudly showing a picture of the newest member of the Kepler team. At the Christmas party, the manager of the Kepler science office, who adores babies, carried my newborn baby boy around in one hand and a plate of food in the other. My daughter arrived right after we lost the second reaction wheel and Kepler became K2. I came back from maternity leave and was suddenly working on a new mission. As my kids grew, they loved visiting my work. They would run through the hallways, draw on the white boards, and come home with mission stickers co-workers found in their offices.

The great thing about Kepler is that it is the first time we were able to look at stars for such a long time at such high precision. As a result, we had a few puzzles to figure out in the data, signals we had never seen before. The one I remember were these periodic events that not only decreased in flux (a drop in starlight) like a transit, but then immediately got brighter. Some looked a bit like the signal you get from an echocardiogram, so they got the nickname “heartbeat” stars. After a lot of long hours of reading papers on related topics, I found a theoretical paper from 20 years earlier that predicted these exact brightness variations from two stars tugging on each other as they danced around each other in an eccentric orbit. Times like these when you go from bewilderment to understanding is the reason you go into astronomy. It was a lot of fun finding these unusual systems in the Kepler data that were believed to be possible, but were difficult to find.

Lead Operations Engineer

Home town: Seattle, Washington

My journey with the stars began when I was a child. In 1986, my family drove out to find a patch of dark sky one evening to catch a glimpse of Halley's Comet. I remember several dozen people out there, with their faces turned up to the sky to witness the event. This comet brought people from many cultures together, to talk and listen to one another, and watch the sky for the wonderful sight.

My journey with Kepler started when I was a master's student in the physics department at San Jose State University. I was taking astrophysics from Dr. Natalie Batalha, who was a co-investigator on Kepler at that time. I started as an intern under Dr. Batalha, studying the Kepler Input Catalog (KIC) to assess the accuracy of the stellar properties: mass and radii. One day in late 2008, Dr. Batalha came into my cubicle and said the Science Operations Center (SOC) needed a test engineer to work on release testing. She had already told them that I would be a great addition to the team and I soon joined the SOC in their preparations to release the pipeline software before launch. After a short stint writing up release test procedures, I jumped into SOC operations, becoming lead operator as the team grew. Working in Kepler SOC operations was a good balance of both excitement and tedium. I worked closely with the SOC pipeline developers to coordinate releases and data re-processing efforts, as well as work with the developer who would fix our latest bug. Even though Kepler was looking at the same patch of sky, near Cygnus, every monthly or quarterly data set had the potential to be just different enough to find a corner case in the code. I also enjoyed working with the Kepler Science Office and getting to know various personalities in each group. Working on the Kepler Mission was an adventure in both science and society.

Like Halley's Comet, Kepler also brought together people from all walks of life, to talk together and wonder about the sky and about our place in the universe. The Kepler mission gathered an amazing group of engineers, developers, scientists, and professionals to work on the mission. The staff on Kepler were (and are) dedicated and enthusiastic about the mission -- about finding the first Earth-like planet in the habitable zone around a Sun-like star. They were (and are!) excited about the science, the software, the challenges, and the wonder that the stars bring down to our Earth.

Kepler brought together children and adults to talk about the stars, planets, and what makes life possible.

Scientific Programmer

Home town: San Ramon, California

When I joined the Kepler Science Operations Center (SOC) in June 2004, it was a small team - Jon Jenkins and Doug Caldwell from SETI Institute, and a few software engineers from Orbital Sciences. The SOC team was temporarily located on the second floor, while the permanent location on the top floor of the building – our "penthouse" - was undergoing major renovations. The team was working diligently and preparing for the Preliminary Design Review. My very first task was to help perform Monte Carlo simulations to estimate the number of false alarms due to eclipsing binaries for three possible positions of the center of the field of view (FOV) of Kepler. Little did I know that it was just the beginning of a learning experience that was to last until 2010. My job was to protype, verify, and validate pipeline signal processing algorithms, document algorithms in design notes, and write software detailed design documents as the SOC team prepared for the Critical Design Review in 2006. After that review, the team grew quite rapidly and it was a joy to work with such a talented and dedicated team of scientific programmers and software engineers. I was in Cape Canaveral with my family to witness the launch of Kepler on March 7, 2009, along with the entire SOC team. It was an exciting time being part of the Kepler commissioning team, waiting for the science data download, and processing the Kepler attitude correction within four hours.

Participating Scientist

Home town: Vienna, Austria

I joined the Kepler science office in 2011, initially as a NASA postdoctoral program fellow and later as a participating scientist. The majority of my work focused on understanding the properties of stars Kepler observed. Since the transit method only measures properties of planets relative to stars, this information is in many cases critical to accurately measure the sizes of planets Kepler detected. I was responsible for generating the Kepler Stellar Properties Catalog, and later also generated the Ecliptic Planet Input Catalog (EPIC) which served as the basis for selecting targets for the K2 mission.

My main research interest with Kepler data is asteroseismology, the study of oscillations, or vibrations, in stars. Similar to how musical instruments vibrate in different tones due to changes in size and composition, sound waves in stars can be used to understand their fundamental properties and interiors. Kepler data revolutionized the field of asteroseismology (arguably on a similar or even larger scale than exoplanets!), and allowed us to peer deeper into the interior of stars than ever before. Particularly exciting studies were those in which we were able to detect stellar oscillations and transiting planets for the same star, which allowed us to characterize both the star and planets using only Kepler data.

My most vivid memories working with the Kepler team were moments of discovery. I still remember the day when Tom Barclay came running down the hallway after spotting the transits of Kepler-186f (the first confirmed Earth-sized planet in the habitable zone of a star), or when Chris Burke came knocking on my door after discovering Kepler-444 (a system of 5 planets smaller than Earth, that asteroseismology revealed to be almost as old as our universe). Advancing our knowledge of our place in the universe in moments like these are the reason why many of us pursue astronomy as a career, and Kepler has allowed so many in the astronomy community to be part of incredibly exciting discoveries that felt like we are contributing a small part to making history.

Software Engineer

Home town: Mukilteo, Washington

I've spent most of my career working at the interface between brilliant scientists and software engineering. It was a great honor to work on the Kepler mission. I helped work on the spacecraft pointing logic, creating tools to help scientists make fast analyses of data, and overall database design. The Kepler team was a great group of talented and enthusiastic software engineers and scientific computing specialists. I'll always remember seeing the spacecraft's rocket launch, the first data from the instruments, and the steady stream of planetary discoveries.

Archive Scientist

Home town: Feeding Hills, Massachusetts

I decided to become an astronomer in junior high school when two important moments aligned at just the right age: the original Star Wars trilogy was re-released in theatres, and the first exoplanet around a Sun-like star was discovered. Both of these events happened in the mid- and late-1990s, when I was in junior and senior high school. I got completely lost within the realm of alien exoplanetology, first in the science-fiction creations and later when astronomers actually discovered more exoplanets. I wanted to know: What were their surfaces like? Were there ice worlds, or desert worlds? Water worlds?

Since then, Kepler has discovered thousands of exoplanet candidates. One of my favorite memories was the announcement of Kepler-16b: the first "Tatooine" world found in real life. It was the perfect synergy of science fiction and science fact. Here was a binary star system that had an extrasolar planet orbiting around both stars, not unlike the planet Luke grew up on in the movies! Not only did it show that planets can indeed form around circumbinary disks and survive, but it perfectly aligned with my favorite sci-fi franchise.

After obtaining my Ph.D. in astronomy, I now have the privilege of working at the Mikulski Archive for Space Telescopes (MAST) in Baltimore. We are the final resting

place for all the phenomenal data collected by Kepler and K2. My job entails making sure these data products are discoverable and available to the worldwide astronomical community for decades to come. In addition to my own research using Kepler and K2 data, I enjoy seeing what the rest of the community is able to do with the data products, even after the mission has formally ended. I know that I have a small, indirect role in every discovery made as one of the stewards of Kepler and K2 data products.

Co-investigator, Education and Public Outreach (EPO)

Home town: Berkeley, California

When David Koch, Kepler deputy principal investigator, invited Edna DeVore (SETI Institute) and I to help prepare the Education and Public Outreach (EPO) element for the second to last proposal in 1998, we had no clue what a momentous mission it would soon become. We also had no idea about the numerous previous proposals and perseverance from the principal investigator, Bill Borucki, in getting the mission ultimately approved. But once things got rolling in 2001 Edna and I were surprised and honored that Dave and Bill were supportive and cognizant of the need for education and public outreach. They made us co-investigators and we were invited to the science team meetings from the very beginning.

The concept of the mission was novel and bold, yet relatively easy to explain to the public. And the public was keenly interested in possibilities for discovery of exoplanets. It married the excitement of science fiction with the excitement of science! In our meetings, we learned all about essential issues – and sometimes excruciating details – and were thus better poised to produce enriching outreach products, including: classroom activities, school curricula, a planet art contest, computer simulations, table-top models (including LEGO and KNEX versions), a traveling museum exhibit, public presentations, planetarium shows, videos, StarDate radio programs, and handouts (lithographs, fact sheets, bookmarks).

The Lawrence Hall of Science at the University of California is extremely proud of its contribution of educational products and resources to the NASA Kepler Mission, which can be found on the Planetarium Activities website.

Operations Software Lead, MOC Flight Director

Home town: Boulder, Colorado

I joined the Kepler team at LASP (Laboratory for Atmospheric & Space Physics at University of Colorado, Boulder) around the mission critical design review, a couple of years before launch. My role was to help stand up the mission operations center (MOC) at LASP, specifically with respect to getting all of the software in place that we would need to conduct mission operations. This involved configuring much of our standard mission ops software to work for the Kepler spacecraft and also writing new software for Kepler's unique operational needs. Some of the new and interesting development hurdles that our team had to overcome were due to the fact that Kepler was LASP's first deep space mission. Much of our software tools and our operational processes had to be modified to work with the Deep Space Network (DSN), as well as the many quirky things that come up in operations when dealing with a significant light-time delay. The speed of light never seemed too slow to me before Kepler came along.

One of my most memorable software tasks was developing the software that we used to convert the raw data (as received by the DSN) into the correctly formatted data sets that the Science Operations Center (SOC) would need to be able to find planets. This was a non-trivial design that had to be constructed in a way that could perform data receipt, assembly, accounting, and delivery fast enough that we could determine any missing data and be capable of re-transmitting it if needed. It was the very first component of the science processing pipeline. I take pride in knowing that every single planet that Kepler ever found was in one of those bytes that my software was integral in processing. Working on the software taught me enough about the mission itself, that I later transitioned to working as LASP flight director, overseeing the day-to-day mission operations.

I have many fond memories of working night shifts with our student operators in the MOC, dimly illuminated by lava lamps. Working on the Kepler mission will always remain one of the brightest accomplishments of my professional career, and I will forever appreciate all the wonderful, talented people who worked on it with me.

Contracting Officer

Home town: Mountain View, California

I became involved in Kepler/K2 back in 2015, when I started administering the contract with Ball Aerospace to operate the Kepler spacecraft. My favorite memory was sitting in Charlie Sobeck's office (project manager at the time) while he used a model of the spacecraft to explain how the NASA, Ball Aerospace, and LASP (Laboratory for Atmospheric and Space Physics) engineers and scientists figured out a way to continue using the spacecraft with only two remaining reaction wheels. Having the opportunity to work with people with that level of ingenuity, pursuing discoveries and knowledge, is what I enjoy working at NASA.

I also enjoyed all the monthly management review meetings. The project team provides updates on new Kepler/K2 scientific publications (and referenced publications) as well as the ever-increasing number of publications as people continued to make sense of the data! The mission demonstrated its power and scope, eventually including citizen scientists to go through K2 data and find new exoplanets. Kepler had tremendous impact on the world of astronomy, on future generations and on our fundamental understanding of the universe.

Flight Director, LASP

Home town: Buena Vista, Colorado

Toward the end of the mission, the light-time delay between sending a command and receiving confirmation was long enough that we had to keep reminding ourselves…

it's Kepler, just wait.

Of course, there were times when waiting changed from being patient to instead…

I think something is wrong

. But most times it was as if Kepler just enjoyed playing. Waiting until you started to have those little moments of panic, then it would let you off the hook with good news.

One of the wonderful things about working on any spacecraft mission are the friends and acquaintances you make along the way. Kepler was no different. I will forever be grateful for the friendships Kepler created, and the opportunity to meet and work with such wonderfully smart and talented people. Being part of a mission that has literally re-written science books on the abundance of planets around stars has been a highlight of my career here at LASP (Laboratory for Atmospheric and Space Physics). When I mention my work on Kepler to the general public I'm always amazed how many people recognize and know the Kepler/K2 mission, some following the mission for a long time. Kepler was truly an inspiring mission. Viva la Kepler!

Student Operator

Home town: Boulder, Colorado

I discovered LASP (Laboratory for Atmospheric and Space Physics) at the University of Colorado, Boulder, and Kepler through an information session for undergraduates interested in working with operations. I arrived looking for free pizza and left looking for a spot on the operations team – largely thanks to the possibility of working on a mission, such as Kepler.

Working directly with the Kepler spacecraft was an unprecedented experience, especially for a college student. I will never forget arriving for shifts at 2 a.m. or waiting for commands and telemetry, moving at the speed of light to travel millions of miles. I will never forget the experience of being a small part of such an impactful mission. Go Kepler!

Software Engineer

Home town: Santa Clara, California

In September 2009, I accepted a software engineer position at the Kepler Science Operations Center (SOC). In my role, I analyze raw data from the Kepler spacecraft for up to 170,000 stars, with the goal of finding habitable planets. I was responsible for running tests on the software developed for Kepler that controls how the data is partitioned and distributed across the computing cluster. I run small data sets through pipeline software on a daily basis as a regression test, allowing my team to detect problems introduced by changes to the code or parameters. I also work closely with developers and scientists to troubleshoot problems, or to experiment with changes to the algorithms, prior to releasing the changes to the full clusters and Pleiades supercomputer to process multi-quarter data sets.

Working for Kepler has been a fascinating experience and I will always cherish my time working with NASA scientists and engineers on this humanitarian mission. I plan on bringing the same energy and enthusiasm to my next team.

Flight Controller, Lead Planner

Home town: Boulder, Colorado

The Kepler/K2 mission has been a tremendously successful mission from both science and engineering perspectives. I am proud to have worked with all the great minds involved on the project. I started off my professional career with the launch of Kepler and am thrilled to have been a part of decommissioning, acting as the on-console flight controller for both major events. During this time, I participated as a flight controller supporting real-time flight operations and also acted as the lead planner in the final years of K2. We supported many late nights and long contacts amongst great colleagues making for an exceptional experience. My participation in this mission was both exciting and rewarding in many ways. Kepler has been a highlight in my career!

Student

Home town: Winthrop, Washington

The Kepler mission was my introduction to astronomy research. I was an undergraduate when I started my first project with K2 data, which focused on removing systematic noise introduced by the motion of the spacecraft. As I worked closely with other young astronomers in the community, I was amazed by how significant the impact of our research felt despite our early career stage. We were part of a large community of scientists excited by the wealth of data from the mission, and we were driven to extract the highest possible volume of science from these observations and build on the work of our colleagues. Our research was encouraged and supported by the Kepler team and other astronomers. I love the collaborative environment that evolved around Kepler/K2 and the open science it has encouraged, and I am grateful to be involved.

Contracting Officer

Home town: Mountain View, California

In 2007 I joined the team to manage the Kepler contracts and naturally began playing on the Kepler-based “Space Cadets” softball team. Besides softball there were many notable Kepler memories including unique contract negotiations, observing the spacecraft build progress in the clean room, launch, “first light,” on-orbit operations, and thousands of planet discoveries – many of which could eventually become habitable! One of my favorite highlights was watching Kepler launch on the Delta II rocket from Cape Canaveral with the team and my family! I will always remember the excitement standing next to Bill Borucki, Kepler’s pioneer and principal investigator, as his brainchild successfully lifted off and made its way into orbit. The pride among the team was palpable! In 2018, I transitioned to deputy director of the NASA Ames Multi-Mission Operations Center (MMOC) and worked with the Kepler team through decommissioning of science operations.

Astronomer

Home town: Clarks Summit, Pennsylvania

I joined the Center for Astrophysics/Harvard & Smithsonian (CfA) in 2008. Beforehand, I conducted observational work with Kuiper Belt objects. When I started at the CfA, it was an exciting time for exoplanets with the launch of Kepler on the horizon. I was interested in getting involved and worked with Dave Latham’s group. I am primarily interested in the confirmation and classification of exoplanets. I owe my start in exoplanet research to the Kepler mission and worked on Kepler/K2, multiple ground-based surveys, and more recently TESS. Thanks Kepler!

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Superflares From Young Red Dwarf Stars Imperil Planets

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

The word "HAZMAT" describes substances that pose a risk to the environment, or even to life itself. Imagine the term being applied to entire planets, where violent flares from the host star may make worlds uninhabitable by affecting their atmospheres.

NASA's Hubble Space Telescope is observing such stars through a large program called HAZMAT — Habitable Zones and M dwarf Activity across Time.

"M dwarf" is the astronomical term for a red dwarf star — the smallest, most abundant and longest-lived type of star in our galaxy. The HAZMAT program is an ultraviolet survey of red dwarfs at three different ages: young, intermediate, and old.

Stellar flares from red dwarfs are particularly bright in ultraviolet wavelengths, compared with Sun-like stars. Hubble's ultraviolet sensitivity makes the telescope very valuable for observing these flares. The flares are believed to be powered by intense magnetic fields that get tangled by the roiling motions of the stellar atmosphere. When the tangling gets too intense, the fields break and reconnect, unleashing tremendous amounts of energy.

The team has found that the flares from the youngest red dwarfs they surveyed — just about 40 million years old — are 100 to 1,000 times more energetic than when the stars are older. This younger age is when terrestrial planets are forming around their stars.

Approximately three-quarters of the stars in our galaxy are red dwarfs. Most of the galaxy's "habitable-zone" planets — planets orbiting their stars at a distance where temperatures are moderate enough for liquid water to exist on their surface — likely orbit red dwarfs. In fact, the nearest star to our Sun, a red dwarf named Proxima Centauri, has an Earth-size planet in its habitable zone.

However, young red dwarfs are active stars, producing ultraviolet flares that blast out so much energy that they could influence atmospheric chemistry and possibly strip off the atmospheres of these fledgling planets.

"The goal of the HAZMAT program is to help understand the habitability of planets around low-mass stars," explained Arizona State University's Evgenya Shkolnik, the program's principal investigator. "These low-mass stars are critically important in understanding planetary atmospheres."

The results of the first part of this Hubble program are being published in The Astrophysical Journal. This study examines the flare frequency of 12 young red dwarfs. "Getting these data on the young stars has been especially important, because the difference in their flare activity is quite large as compared to older stars," said Arizona State University's Parke Loyd, the first author on this paper.

The observing program detected one of the most intense stellar flares ever observed in ultraviolet light. Dubbed the "Hazflare," this event was more energetic than the most powerful flare from our Sun ever recorded.

"With the Sun, we have a hundred years of good observations," Loyd said. "And in that time, we've seen one, maybe two, flares that have an energy approaching that of the Hazflare. In a little less than a day's worth of Hubble observations of these young stars, we caught the Hazflare, which means that we're looking at superflares happening every day or even a few times a day."

Could super-flares of such frequency and intensity bathe young planets in so much ultraviolet radiation that they forever doom chances of habitability? According to Loyd, "Flares like we observed have the capacity to strip away the atmosphere from a planet. But that doesn't necessarily mean doom and gloom for life on the planet. It just might be different life than we imagine. Or there might be other processes that could replenish the atmosphere of the planet. It's certainly a harsh environment, but I would hesitate to say that it is a sterile environment."

The next part of the HAZMAT study will be to study intermediate-aged red dwarfs that are 650 million years old. Then the oldest red dwarfs will be analyzed and compared with the young and intermediate stars to understand the evolution of the ultraviolet radiation environment of low-mass planets around these low-mass stars.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

Contacts:

Ann Jenkins / Ray Villard Space Telescope Science Institute, Baltimore, Maryland 410-338-4488 / 410-338-4514 jenkins@stsci.edu / villard@stsci.edu

Evgenya Shkolnik Arizona State University, Tempe, Arizona 808-292-9088 shkolnik@asu.edu

Parke Loyd Arizona State University, Tempe, Arizona parke@asu.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers Find First Evidence of Possible Moon Outside Our Solar System

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Using NASA’s Hubble and Kepler space telescopes, astronomers have uncovered tantalizing evidence of what could be the first discovery of a moon orbiting a planet outside our solar system.

This moon candidate, which is 8,000 light-years from Earth in the Cygnus constellation, orbits a gas-giant planet that, in turn, orbits a star called Kepler-1625. Researchers caution that the moon hypothesis is tentative and must be confirmed by follow-up Hubble observations.

“This intriguing finding shows how NASA’s missions work together to uncover incredible mysteries in our cosmos,” said Thomas Zurbuchen, associate administrator of NASA’s Science Mission Directorate at Headquarters, Washington. “If confirmed, this finding could completely shake up our understanding of how moons are formed and what they can be made of.”

Since moons outside our solar system – known as exomoons – cannot be imaged directly, their presence is inferred when they pass in front of a star, momentarily dimming its light. Such an event is called a transit, and has been used to detect many of the exoplanets cataloged to date.

However, exomoons are harder to detect than exoplanets because they are smaller than their companion planet, and so their transit signal is weaker when plotted on a light curve that measures the duration of the planet crossing and the amount of momentary dimming. Exomoons also shift position with each transit because the moon is orbiting the planet.

In search of exomoons, Alex Teachey and David Kipping, astronomers at Columbia University in New York, analyzed data from 284 Kepler-discovered planets that were in comparatively wide orbits, longer than 30 days, around their host star. The researchers found one instance in planet Kepler-1625b, of a transit signature with intriguing anomalies, suggesting the presence of a moon.

“We saw little deviations and wobbles in the light curve that caught our attention,” Kipping said.

Based upon their findings, the team spent 40 hours making observations with Hubble to study the planet intensively – also using the transit method – obtaining more precise data on the dips of light. Scientists monitored the planet before and during its 19-hour transit across the face of the star. After the transit ended, Hubble detected a second, and much smaller, decrease in the star’s brightness approximately 3.5 hours later. This small decrease is consistent with a gravitationally-bound moon trailing the planet, much like a dog following after its owner. Unfortunately, the scheduled Hubble observations ended before the complete transit of the candidate moon could be measured and its existence confirmed.

In addition to this dip in light, Hubble provided supporting evidence for the moon hypothesis by finding the planet transit occurring more than an hour earlier than predicted. This is consistent with a planet and moon orbiting a common center of gravity that would cause the planet to wobble from its predicted location, much the way Earth wobbles as our Moon orbits it.

The researchers note the planetary wobble could be caused by the gravitational pull of a hypothetical second planet in the system, rather than a moon. While Kepler has not detected a second planet in the system, it could be that the planet is there, but not detectable using Kepler’s techniques.

“A companion moon is the simplest and most natural explanation for the second dip in the light curve and the orbit-timing deviation,” Kipping explained. “It was definitely a shocking moment to see that Hubble light curve, my heart started beating a little faster as I kept looking at that signature. But we knew our job was to keep a level head and essentially assume it was bogus, testing every conceivable way in which the data could be tricking us.”

In a paper published in the journal Science Advances, the scientists report the candidate moon is unusually large – potentially comparable to Neptune. Such large moons do not exist in our own solar system. The researchers say this may yield new insights into the development of planetary systems and may cause experts to revisit theories of how moons form around planets.

The moon candidate is estimated to be only 1.5 percent the mass of its companion planet, and the planet is estimated to be several times the mass of Jupiter. This mass-ratio is similar to the one between Earth and the Moon. In the case of the Earth-Moon system and the Pluto-Charon system, the moons are thought to be created through dust leftover after rocky planetary collisions. However, Kepler-1625b and its possible satellite are gaseous and not rocky, so the moon may have formed through a different process.

Researchers note that if this is indeed a moon, both it and its host planet lie within their star’s habitable zone, where moderate temperatures allow for the existence of liquid water on any solid planetary surface. However, both bodies are considered to be gaseous and, therefore, unsuitable for life as we know it.

Future searches for exomoons, in general, will target Jupiter-size planets that are farther from their star than Earth is from the Sun. The ideal candidate planets hosting moons are in wide orbits, with long and infrequent transit times. In this search, a moon would have been among the easiest to detect because of its large size. Currently, there are just a handful of such planets in the Kepler database. Whether future observations confirm the existence of the Kepler-1625b moon, NASA’s James Webb Space Telescope will be used to find candidate moons around other planets, with much greater detail than Kepler.

“We can expect to see really tiny moons with Webb,” Teachey said.

Contacts:

Claire AndreoliNASA's Goddard Space Flight Center, Greenbelt, Maryland301-286-1940claire.andreoli@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore410-338-4514villard@stsci.edu

Alison HawkesAmes Research Center, California’s Silicon Valley650-604-0281alison.j.hawkesbak@nasa.gov

In May 2024, a geomagnetic storm hit Earth, sending auroras across the planet’s skies in a once-in-a-generation light display. These dazzling sights are possible because of the interaction of coronal mass ejections – explosions of plasma and magnetic field from the Sun – with Earth’s magnetic field, which protects us from the radiation the Sun […]

Hubble Space Telescope

Exoplanets

Stars Stories

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

How do you find – and confirm – a planet? 10 things about the search for exoplanets

6 min read

NASA Science Editorial Team

So you think you found an exoplanet – a planet around another star? It's not as simple as pointing a telescope upward and looking for a planet that waves back. Scientists must gather many observations and carefully analyze their data before they can be even somewhat sure that they've discovered new worlds. Here are 10 things to know about finding and confirming exoplanets.

The vast majority of planets around other stars have been found through the transit method so far. This technique involves monitoring the amount of light that a star gives off over time, and looking for dips in brightness that may indicate an orbiting planet passing in front of the star.

NASA has two specialized exoplanet-hunting telescopes scanning the sky for new planets right now -- Kepler and the Transiting Exoplanet Survey Satellite (TESS) -- and they both work this way. Other methods of finding exoplanets include radial velocity (looking for a "wobble" in a star's position caused by a planet's gravity), direct imaging (blocking the light of the star to see the planet) and microlensing (watching for events where a star passes in front of another star, and the gravity of the first star acts as a lens).

Here's more about finding exoplanets.

To find a planet, scientists need to get data from telescopes, whether those telescopes are in space or on the ground. But telescopes don't capture photos of planets with nametags. Instead, telescopes designed for the transit method show us how brightly thousands of stars are shining over time. TESS, which launched in April and just began collecting science data, beams its stellar observations back to Earth through NASA's Deep Space Network, and then scientists get to work.

Researchers combing through TESS data are looking for those transit events that could indicate planets around other stars. If the star's light lessens by the same amount on a regular basis -- for example, every 10 days -- this may indicate a planet with an orbital period (or "year") of 10 days. The standard requirement for planet candidates from TESS is at least two transits -- that is, two equal dips in brightness from the same star.

Not all dips in a star's brightness are caused by transiting planets. There may be another object -- such as a companion star, a group of asteroids, a cloud of dust or a failed star called a brown dwarf, that makes a regular trip around the target star. There could also be something funky going on with the telescope's behavior, how it delivered the data, or other "artifacts" in data that just aren't planets. Scientists must rule out all non-planet options to the best of their ability before moving forward.

Finding the same planet candidate using two different techniques is a strong sign that the planet exists, and is the standard for "confirming" a planet. That's why a vast network of ground-based telescopes will be looking for the same planet candidates that TESS discovers. It is also possible that TESS will spot a planet candidate already detected by another telescope in the past. With these combined observations, the planet could then be confirmed. The first planet TESS discovered, Pi Mensae c, orbits a star previously observed with the radial-velocity method on the ground. Scientists compared the TESS data and the radial-velocity data from that star to confirm the presence of planet "c."

Scientists using the radial-velocity detection method see a star's wobble caused by a planet's gravity, and can rule out other kinds of objects such as companion stars. Radial-velocity detection also allows scientists to calculate the mass of the planet.

Other space telescopes may also be used to help confirm exoplanets, characterize them and even discover additional planets around the same stars. If the planet is detected by the same method, but by two different telescopes, and has received enough scrutiny that the scientists are more than 99 percent sure it's a planet, it is said to be "validated" instead of "confirmed."

After thoroughly analyzing the data, and running tests to make sure that their result still looks like the signature of a planet, scientists write a formal paper describing their findings. Using the transit method, they can also report the size of the planet. The planet's radius is related to how much light it blocks from the star, as well as the size of the star itself. The scientists then submit the study to a journal.

Scientific journals have a rigorous peer review process. This means scientific experts not involved in the study review it and make sure the findings look sound. The peer-reviewers may have questions or suggestions for the scientists. When everyone agrees on a version of the study, it gets published.

When the study is published, scientists can officially say they have found a new planet. This may still not be the end of the story, however. For example, the TRAPPIST telescope in Chile first thought they had discovered three Earth-size planets in the TRAPPIST-1 system. When NASA's Spitzer Space Telescope and other ground-based telescopes followed up, they found that one of the original reported planets (the original TRAPPIST-1d) did not exist, but they discovered five others --bringing the total up to seven wondrous rocky worlds.

Confirmed planets get added to the official NASA catalog. So far, Kepler has sent back the biggest bounty of confirmed exoplanets of any telescope -- more than 2,600 to date. TESS, which just began its planet search, is expected to discover many thousands more. Ground-based follow-up will help determine if these planets are gaseous or rocky, and possibly more about their atmospheres. The forthcoming James Webb Space Telescope will be able to take a deeper look at the atmospheres of the most interesting TESS discoveries.

Scientists sometimes even uncover planets with the help of people like you: exoplanet K2-138 was discovered through citizen scientists in Kepler's K2 mission data. Based on surveys so far, scientists calculate that almost every star in the Milky Way should have at least one planet. That makes billions more, waiting to be found! Stay up to date with the latest discoveries using this exoplanet counter.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

10 Steps to Confirm a Planet Around Another Star

7 min read

NASA Science Editorial Team

So you think you found an exoplanet -- a planet around another star? It's not as simple as pointing a telescope upward and looking for a planet that waves back. Scientists must gather many observations and carefully analyze their data before they can be even somewhat sure that they've discovered new worlds. Here are 10 things to know about finding and confirming exoplanets.

The vast majority of planets around other stars have been found through the transit method so far. This technique involves monitoring the amount of light that a star gives off over time, and looking for dips in brightness that may indicate an orbiting planet passing in front of the star.

NASA has two specialized exoplanet-hunting telescopes scanning the sky for new planets right now -- Kepler and the Transiting Exoplanet Survey Satellite (TESS) -- and they both work this way. Other methods of finding exoplanets include radial velocity (looking for a "wobble" in a star's position caused by a planet's gravity), direct imaging (blocking the light of the star to see the planet) and microlensing (watching for events where a star passes in front of another star, and the gravity of the first star acts as a lens).

Here's more about finding exoplanets.

To find a planet, scientists need to get data from telescopes, whether those telescopes are in space or on the ground. But telescopes don't capture photos of planets with nametags. Instead, telescopes designed for the transit method show us how brightly thousands of stars are shining over time. TESS, which launched in April and just began collecting science data, beams its stellar observations back to Earth through NASA's Deep Space Network, and then scientists get to work.

Researchers combing through TESS data are looking for those transit events that could indicate planets around other stars. If the star's light lessens by the same amount on a regular basis -- for example, every 10 days -- this may indicate a planet with an orbital period (or "year") of 10 days. The standard requirement for planet candidates from TESS is at least two transits -- that is, two equal dips in brightness from the same star.

Not all dips in a star's brightness are caused by transiting planets. There may be another object -- such as a companion star, a group of asteroids, a cloud of dust or a failed star called a brown dwarf, that makes a regular trip around the target star. There could also be something funky going on with the telescope's behavior, how it delivered the data, or other "artifacts" in data that just aren't planets. Scientists must rule out all non-planet options to the best of their ability before moving forward.

Finding the same planet candidate using two different techniques is a strong sign that the planet exists, and is the standard for "confirming" a planet. That's why a vast network of ground-based telescopes will be looking for the same planet candidates that TESS discovers. It is also possible that TESS will spot a planet candidate already detected by another telescope in the past. With these combined observations, the planet could then be confirmed. The first planet TESS discovered, Pi Mensae c, orbits a star previously observed with the radial-velocity method on the ground. Scientists compared the TESS data and the radial-velocity data from that star to confirm the presence of planet "c."

Scientists using the radial-velocity detection method see a star's wobble caused by a planet's gravity, and can rule out other kinds of objects such as companion stars. Radial-velocity detection also allows scientists to calculate the mass of the planet.

Other space telescopes may also be used to help confirm exoplanets, characterize them and even discover additional planets around the same stars. If the planet is detected by the same method, but by two different telescopes, and has received enough scrutiny that the scientists are more than 99 percent sure it’s a planet, it is said to be “validated” instead of “confirmed.”

After thoroughly analyzing the data, and running tests to make sure that their result still looks like the signature of a planet, scientists write a formal paper describing their findings. Using the transit method, they can also report the size of the planet. The planet’s radius is related to how much light it blocks from the star, as well as the size of the star itself. The scientists then submit the study to a journal.

Scientific journals have a rigorous peer review process. This means scientific experts not involved in the study review it and make sure the findings look sound. The peer-reviewers may have questions or suggestions for the scientists. When everyone agrees on a version of the study, it gets published.

When the study is published, scientists can officially say they have found a new planet. This may still not be the end of the story, however. For example, the TRAPPIST telescope in Chile first thought they had discovered three Earth-size planets in the TRAPPIST-1 system. When NASA’s Spitzer Space Telescope and other ground-based telescopes followed up, they found that one of the original reported planets (the original TRAPPIST-1d) did not exist, but they discovered five others --bringing the total up to seven wondrous rocky worlds.

Confirmed planets get added to the official NASA catalog. So far, Kepler has sent back the biggest bounty of confirmed exoplanets of any telescope -- more than 2,600 to date. TESS, which just began its planet search, is expected to discover many thousands more. Ground-based follow-up will help determine if these planets are gaseous or rocky, and possibly more about their atmospheres. The forthcoming James Webb Space Telescope will be able to take a deeper look at the atmospheres of the most interesting TESS discoveries.

Scientists sometimes even uncover planets with the help of people like you: exoplanet K2-138 was discovered through citizen scientists in Kepler’s K2 mission data. Based on surveys so far, scientists calculate that almost every star in the Milky Way should have at least one planet. That makes billions more, waiting to be found! Stay up to date with the latest discoveries using this exoplanet counter.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Sun

Facts About Earth

Asteroids, Comets & Meteors

Kuiper Belt

NASA Is Taking a New Look at Searching for Life Beyond Earth

6 min read

Since the beginning of civilization, humanity has wondered whether we are alone in the universe. As NASA has explored our solar system and beyond, it has developed increasingly sophisticated tools to address this fundamental question. Within our solar system, NASA's missions have searched for signs of both ancient and current life, especially on Mars and soon, Jupiter's moon Europa. Beyond our solar system, missions, such as Kepler and TESS, are revealing thousands of planets orbiting other stars.

The explosion of knowledge of planets orbiting other stars, called exoplanets, and the results of decades of research on signatures of life – what scientists call biosignatures – have encouraged NASA to address, in a scientifically rigorous way, whether humanity is alone. Beyond searching for evidence of just microbial life, NASA now is exploring ways to search for life advanced enough to create technology.

Technosignatures are signs or signals, which if observed, would allow us to infer the existence of technological life elsewhere in the universe. The best known technosignature are radio signals, but there are many others that have not been explored fully.

In April 2018, new interest arose in Congress for NASA to begin supporting the scientific search for technosignatures as part of the agency's search for life. As part of that effort, the agency is hosting the NASA Technosignatures Workshop in Houston on Sept. 26-28, 2018, with the purpose of assessing the current state of the field, the most promising avenues of research in technosignatures and where investments could be made to advance the science. A major goal is to identify how NASA could best support this endeavor through partnerships with private and philanthropic organizations.

To view the workshop online, visit:
http://www.ustream.tv/channel/asteroid-initiative-idea-synthesis—3

On Thursday, Sept. 27 at 1 p.m. EDT, several of the workshop's speakers will be answering questions in a Reddit AMA.

What are Technosignatures?

The term technosignatures has a broader meaning than the historically used "search for extraterrestrial intelligence," or SETI, which has generally been limited to communication signals. Technosignatures like radio or laser emissions, signs of massive structures or an atmosphere full of pollutants could imply intelligence.

In recent decades, the private and philanthropic sectors have carried out this research. They have used such methods as searching for patterns in low-band radio frequencies using radio telescopes. Indeed, humanity's own radio and television broadcasts have been drifting into space for a number of years. NASA's SETI program was ended in 1993 after Congress, operating under a budget deficit and decreased political support, cancelled funding for a high-resolution microwave survey of the skies. Since then, NASA's efforts have been directed towards furthering our fundamental understanding of life itself, its origins and the habitability of other bodies in our solar system and galaxy.

History of the Search for Technological Life

Efforts to detect technologically advanced life predates the space age as early 20th century radio pioneers first foresaw the possibility of interplanetary communication. Theoretical work postulating the possibility of carrying signals on radio and microwave bands across vast distances in the galaxy with little interference led to first “listening” experiments in the 1960s.

Thanks to NASA’s Kepler mission’s discovery of thousands of planets beyond our solar system,including some with key similarities to Earth, it’s now possible to not just imagine the science fiction of finding life on other worlds, but to one day scientifically prove life exists beyond our solar system.

As NASA’s 2015 Astrobiology Strategy states: “Complex life may evolve into cognitive systems that can employ technology in ways that may be observable. Nobody knows the probability, but we know that it is not zero.” As we consider the environments of other planets, “technosignatures” could be included in the possible interpretations of data we get from other worlds.

Debate about the probability of finding signals of advanced life varies widely. In 1961, astronomer Frank Drake created a formula estimating the number of potential intelligent civilizations in the galaxy, called the Drake equation, and calculated an answer of 10,000. Most of the variables in the equation continue to be rough estimates, subject to uncertainties. Another famous speculation on the subject called the Fermi paradox, posited by Italian physicist Enrico Fermi, asserted that if another intelligent life form was indeed out there, we would have met it by now.

NASA’s SETI work began with a 1971 proposal by biomedical researcher John Billingham at NASA’s Ames Research Center for a 1,000-dish array of 100-meter telescopes that could pick up television and radio signals from other stars. “Project Cyclops” was not funded, but in 1976, Ames established a SETI branch to continue research in this area. NASA’s Jet Propulsion Laboratory (JPL) also began SETI work.

In 1988, NASA Headquarters in Washington formally endorsed the SETI program leading to development of the High Resolution Microwave Survey. Announced on Columbus Day in 1992 – 500 years after Columbus landed in North America – this 10-year, $100 million project included a targeted search of stars led by Ames using the 300-meter radio telescope in Arecibo, Puerto Rico, and an all-sky survey led by JPL using its Deep Space Network dish. The program lasted only a year before political opposition eliminated the project and effectively ended NASA’s research efforts in SETI.

Why Start Looking at Technosignatures Now?

Fueled by the discovery that our galaxy is teeming with planets, interest in detecting signs of technologically-advanced life is again bubbling up. Kepler’s discovery in 2015 of irregular fluctuations in brightness in what came to be known as Tabby’s Star led to speculation of an alien megastructure, though scientists have since concluded that a dust cloud is the likely cause. However, Tabby’s Star has demonstrated the potential usefulness of looking for anomalies in data collected from space, as signs of technologically-advanced life may appear as aberrations from the norm.

Scientists caution that we will need more than an unexplained signal to definitively prove the existence of technological life. For example, there can be a lot of radio frequency interference from Earth-based sources.

NASA will continue assessing promising current efforts of research in technosignatures and investigating where investments could be made to advance the science. Although we have yet to find signs of extraterrestrial life, NASA is amplifying exploring the solar system and beyond to help humanity answer whether we are alone in the universe.

From studying water on Mars, probing promising “oceans worlds” such as Europa or Saturn’s moon Enceladus, to looking for biosignatures in the atmospheres of exoplanets, NASA’s science missions are working together with a goal to find unmistakable signs of life beyond Earth. And perhaps that life could indeed be more technologically advanced than our own.

Fascinating.

Universe

Galaxies consist of stars, planets, and vast clouds of gas and dust, all bound together by gravity. The largest contain…

Overview Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way.…

Black Holes Black holes are among the most mysterious cosmic objects, much studied but not fully understood. These objects aren’t…

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Shares First Science Image in Hunt to Find New Worlds

5 min read

NASA’s newest planet hunter, the Transiting Exoplanet Survey Satellite (TESS), is now providing valuable data to help scientists discover and study exciting new exoplanets, or planets beyond our solar system. Part of the data from TESS’ initial science orbit includes a detailed picture of the southern sky taken with all four of the spacecraft’s wide-field cameras. This “first light” science image captures a wealth of stars and other objects, including systems previously known to have exoplanets.

“In a sea of stars brimming with new worlds, TESS is casting a wide net and will haul in a bounty of promising planets for further study,” said Paul Hertz, astrophysics division director at NASA Headquarters in Washington. “This first light science image shows the capabilities of TESS’ cameras, and shows that the mission will realize its incredible potential in our search for another Earth.”

TESS acquired the image using all four cameras during a 30-minute period on Tuesday, Aug. 7. The black lines in the image are gaps between the camera detectors. The images include parts of a dozen constellations, from Capricornus to Pictor, and both the Large and Small Magellanic Clouds, the galaxies nearest to our own. The small bright dot above the Small Magellanic Cloud is a globular cluster — a spherical collection of hundreds of thousands of stars — called NGC 104, also known as 47 Tucanae because of its location in the southern constellation Tucana, the Toucan. Two stars, Beta Gruis and R Doradus, are so bright they saturate an entire column of pixels on the detectors of TESS’s second and fourth cameras, creating long spikes of light.

“This swath of the sky’s southern hemisphere includes more than a dozen stars we know have transiting planets based on previous studies from ground observatories,” said George Ricker, TESS principal investigator at the Massachusetts Institute of Technology’s (MIT) Kavli Institute for Astrophysics and Space Research in Cambridge.

TESS’s cameras, designed and built by MIT’s Lincoln Laboratory in Lexington, Massachusetts, and the MIT Kavli Institute, monitor large swaths of the sky to look for transits. Transits occur when a planet passes in front of its star as viewed from the satellite’s perspective, causing a regular dip in the star’s brightness.

TESS will spend two years monitoring 26 such sectors for 27 days each, covering 85 percent of the sky. During its first year of operations, the satellite will study the 13 sectors making up the southern sky. Then TESS will turn to the 13 sectors of the northern sky to carry out a second year-long survey.

MIT coordinates with Northrop Grumman in Falls Church, Virginia, to schedule science observations. TESS transmits images every 13.7 days, each time it swings closest to Earth. NASA’s Deep Space Network receives and forwards the data to the TESS Payload Operations Center at MIT for initial evaluation and analysis. Full data processing and analysis takes place within the Science Processing and Operations Center pipeline at NASA’s Ames Research Center in Silicon Valley, California, which provides calibrated images and refined light curves that scientists can analyze to find promising exoplanet transit candidates.

TESS builds on the legacy of NASA’s Kepler spacecraft, which also uses transits to find exoplanets. TESS’s target stars are 30 to 300 light-years away and about 30 to 100 times brighter than Kepler’s targets, which are 300 to 3,000 light-years away. The brightness of TESS’ targets make them ideal candidates for follow-up study with spectroscopy, the study of how matter and light interact.

The James Webb Space Telescope and other space and ground observatories will use spectroscopy to learn more about the planets TESS finds, including their atmospheric compositions, masses and densities.

TESS has also started observations requested through the TESS Guest Investigator Program, which allows the broader scientific community to conduct research using the satellite.

“We were very pleased with the number of guest investigator proposals we received, and we competitively selected programs for a wide range of science investigations, from studying distant active galaxies to asteroids in our own solar system,” said Padi Boyd, TESS project scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “And of course, lots of exciting exoplanet and star proposals as well. The science community are chomping at the bit to see the amazing data that TESS will produce and the exciting science discoveries for exoplanets and beyond.”

TESS launched from NASA’s Kennedy Space Center in Cape Canaveral, Florida, on April 18 aboard a SpaceX Falcon 9 rocket and used a flyby of the Moon on May 17 to head toward its science orbit. TESS started collecting scientific data on July 25 after a period of extensive checks of its instruments.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT’s Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory in Lexington, Massachusetts; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

First Light! TESS Shares First Science Image in Hunt to Find New Worlds

5 min read

Jeanette Kazmierczak

NASA's newest planet hunter, the Transiting Exoplanet Survey Satellite (TESS), is now providing valuable data to help scientists discover and study exciting new exoplanets, or planets beyond our solar system. Part of the data from TESS' initial science orbit include a detailed picture of the southern sky taken with all four of the spacecraft's wide-field cameras. This "first light" science image captures a wealth of stars and other objects, including systems previously known to have exoplanets.

"In a sea of stars brimming with new worlds, TESS is casting a wide net and will haul in a bounty of promising planets for further study," said Paul Hertz, astrophysics division director at NASA Headquarters in Washington. "This first light science image shows the capabilities of TESS' cameras, and shows that the mission will realize its incredible potential in our search for another Earth."

TESS acquired the image using all four cameras during a 30-minute period on Tuesday, Aug. 7. The black lines in the image are gaps between the camera detectors. The images include parts of a dozen constellations, from Capricornus to Pictor, and both the Large and Small Magellanic Clouds, the galaxies nearest to our own. The small bright dot above the Small Magellanic Cloud is a globular cluster — a spherical collection of hundreds of thousands of stars — called NGC 104, also known as 47 Tucanae because of its location in the southern constellation Toucana, the Toucan. Two stars, Beta Gruis and R Doradus, are so bright they saturate an entire column of pixels on the detectors of TESS's second and fourth cameras, creating long spikes of light.

"This swath of the sky's southern hemisphere includes more than a dozen stars we know have transiting planets based on previous studies from ground observatories," said George Ricker, TESS principal investigator at the Massachusetts Institute of Technology's (MIT) Kavli Institute for Astrophysics and Space Research in Cambridge.

TESS's cameras, designed and built by MIT's Lincoln Laboratory in Lexington, Massachusetts, and the MIT Kavli Institute, monitor large swaths of the sky to look for transits. Transits occur when a planet passes in front of its star as viewed from the satellite's perspective, causing a regular dip in the star's brightness.

TESS will spend two years monitoring 26 such sectors for 27 days each, covering 85 percent of the sky. During its first year of operations, the satellite will study the 13 sectors making up the southern sky. Then TESS will turn to the 13 sectors of the northern sky to carry out a second year-long survey.

MIT coordinates with Northrop Grumman in Falls Church, Virginia, to schedule science observations. TESS transmits images every 13.7 days, each time it swings closest to Earth. NASA's Deep Space Network receives and forwards the data to the TESS Payload Operations Center at MIT for initial evaluation and analysis. Full data processing and analysis takes place within the Science Processing and Operations Center pipeline at NASA's Ames Research Center in Silicon Valley, California, which provides calibrated images and refined light curves that scientists can analyze to find promising exoplanet transit candidates.

TESS builds on the legacy of NASA's Kepler spacecraft, which also uses transits to find exoplanets. TESS's target stars are 30 to 300 light-years away and about 30 to 100 times brighter than Kepler's targets, which are 300 to 3,000 light-years away. The brightness of TESS' targets make them ideal candidates for follow-up study with spectroscopy, the study of how matter and light interact.

The James Webb Space Telescope and other space and ground observatories will use spectroscopy to learn more about the planets TESS finds, including their atmospheric compositions, masses and densities.

TESS has also started observations requested through the TESS Guest Investigator Program, which allows the broader scientific community to conduct research using the satellite.

"We were very pleased with the number of guest investigator proposals we received, and we competitively selected programs for a wide range of science investigations, from studying distant active galaxies to asteroids in our own solar system," said Padi Boyd, TESS project scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "And of course, lots of exciting exoplanet and star proposals as well. The science community are chomping at the bit to see the amazing data that TESS will produce and the exciting science discoveries for exoplanets and beyond."

TESS launched from NASA's Kennedy Space Center in Cape Canaveral, Florida, on April 18 aboard a SpaceX Falcon 9 rocket and used a flyby of the Moon on May 17 to head toward its science orbit. TESS started collecting scientific data on July 25 after a period of extensive checks of its instruments.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA's Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT's Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA's Ames Research Center in California's Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT's Lincoln Laboratory in Lexington, Massachusetts; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Other Skies, Other Suns: the Search for Exoplanet Atmospheres

8 min read

NASA Science Editorial Team

By Pat Brennan, NASA's Exoplanet Exploration Program

We see their shadows but they dance just out of reach: thousands of planets lost in the glare of their parent stars.

Sifting these planets for signs of life will mean capturing light from their atmospheres, splitting it into a rainbow spectrum, then searching those color bands for traces of familiar skies. The big prize: a readout from a small, rocky world showing something like oxygen, methane and carbon dioxide. An atmosphere that reminds us of home; a solid case for life beyond Earth.

We're at the bare beginning of our ability to probe these otherworldly skies and search for life signs – what the scientists doing the hunting call "biosignatures." Our instruments so far are somewhat crude. We can break down the light from big, hot planets, roasting gas giants hundreds of light-years away, and read some of their atmospheric properties. Smaller planets are beginning to be analyzed as well. In the years ahead, far more sensitive instruments sent into space could measure light from Earth-sized worlds to inventory their atmospheres, perhaps finding evidence of a living, breathing planet.

But to set the stage for these future discoveries, much work must be done on Earth and in our own solar system. NASA scientists are creating computer models of exotic, exoplanet atmospheres, based in part on our understanding of Earth's atmosphere, and of worlds closer to home: Mars, Venus, Jupiter and Saturn, and even the cold, smoggy skies of Saturn's moon, Titan.

Along the way, we're learning more about our home planet as well as others sprinkled across the galaxy; the scientists who study Earth and these far-off exoplanets are learning to work together.

"It's an exciting time to be involved with exoplanets," said Tiffany Kataria, an exoplanet research scientist at NASA's Jet Propulsion Laboratory in Pasadena, California. "I was glad to enter the field when I did."

Kataria creates computer models to better understand the atmospheres of large, gas giants. She says early results are revealing some of the structure and components of these atmospheres, such as helium in the scorching skies of a "hot Jupiter" called WASP-107b.

Both instruments and modeling are improving rapidly. Technological progress on space and ground-based telescopes, by one recent estimate, could bring detection of a habitable exoplanet atmosphere by 2030.

But even as the vision of their telescopes grows sharper, exoplanet scientists have come to realize that environment – and history – matter.

Finding evidence of life on other worlds will require knowing what we're looking for; that, in turn, means understanding not only how planet Earth formed but where it came from, the nature of its planetary neighbors, and how the Sun and other stars determine properties of the planets they rule.

"Now is the time for those of us with solar system backgrounds to use our expertise studying the solar system and apply it to studying exoplanets," said Victoria Meadows, a University of

Washington professor who is also principal investigator for the NASA Astrobiology Institute's Virtual Planetary Laboratory.

Meadows and her fellow researchers are opening a wide aperture on exoplanet studies, going well beyond modeling otherworldly analogs of Earth.

"We take it one step further: the solar system as an analog for (other) planetary systems," she said.

Take Venus. The hellish, roiling atmosphere might once have been benign, maybe even habitable.

"Venus is a negative example for us," she said. "The process that caused Venus to lose habitability was a runaway greenhouse."

Venus's fate as a barbecued planet – with a high-pressure atmosphere, clouds of sulfuric acid and a surface hot enough to melt lead – might have lessons for us about other terrestrial planets far beyond our solar system.

Among them are the seven Earth-sized planets orbiting a small, red-dwarf star called TRAPPIST-1. The tightly packed system 40 light-years away offers a "wonderful experiment," she said, on the effects such stars have on planets in close orbit around them.

Red dwarfs, or "M-dwarfs," flare with powerful bursts of radiation early in their lives.

"Do they have atmospheres?" Meadows asks of the TRAPPIST-1 planets. "Did anything survive that process? Are they (carbon dioxide) dominated, like Venus, or oxygen dominated?"

Venus – an early favorite of Meadows', who studied the planet as a post-doctoral researcher – likely lost an ocean to evaporation early in its history.

"Look at Venus, what happened to this world," she said. "If it did lose an ocean, what happened to it? This is the kind of question we should be asking about TRAPPIST-1 and Venus."

To lay further groundwork in the search for life, exoplanet scientists must peer through time as well as space. What might Earth have looked like to distant observers when it was, say, a quarter of its present age – only about one billion years old?

Life likely was present on the infant Earth, but did not rely on oxygen, which was not yet a significant part of its atmosphere.

And exoplanet scientists must try to understand not only the familiar – Earth and its solar system siblings – but the wildly unfamiliar as well.

"The more precise our measurements get, the harder it is getting for our models to fit," said Laura Kreidberg, an exoplanet researcher at Harvard University's Center for Astrophysics.

There's no reason to think the atmospheres of exoplanets will be any less complicated than Earth's, she says. Many are likely to be cloaked in thick haze, like Saturn's moon, Titan. Some might be heavy with oxygen but possess no life at all.

A few could be so spectacularly hot they harbor clouds of vaporized rock.

While the study of exoplanets has revealed that worlds in Earth's size range are common in the galaxy, their atmospheres could be very different.

"In many cases, exoplanets look like nothing we've ever seen before," Kreidberg said. "Different temperatures, different mass, different rotation rate. A lot of them are tidally locked, irradiated continuously on one side rather than rotating."

Kreidberg is co-author of a recent paper detailing a surprising observation for a type of planet known as an “ultrahot Jupiter.” They’re gas giants like our Jupiter, but orbiting so close to their stars that their atmospheres are infernos.

Kreidberg and her team used the Hubble and Spitzer space telescopes to examine one of them, WASP-103b.

“One thing that is puzzling about ultrahot planets is the mysterious absence of water,” Kreidberg said. Water appears to be everywhere, including on planets just a bit less massive than these ultrahot Jupiters. Why not on WASP-103b?

The scientists used spectroscopy – fingerprinting various types of molecules in a planet’s atmosphere by the effect they have on light – to check the behavior of water molecules. They found that water acts very differently on the day-side of this broiling planet, the side that is forever locked in place, facing its star.

“It’s so incredibly hot that water is dissociated – it breaks up on the day side,” Kreidberg said.

The water’s hydrogen and oxygen atoms are torn apart from each other, a process previously thought to happen only in the atmospheres of stars.

“The water dissociated on the day side is blown around to the night side by wind,” Kreidberg said. “Then it recombines to form water. It comes back around, and is dissociated again. It’s a really violent life cycle of a water molecule.”

For now, the spectroscopic capabilities of Hubble, while good enough to reveal the bizarre death and rebirth of water molecules on distant hot Jupiters, are too blunt to resolve the atmospheres of small, rocky worlds that might turn out to be something like Earth.

The James Webb Space Telescope, scheduled for launch in 2021, should be sensitive enough to pick apart the spectrum of light from the atmospheres of super Earths or mini Neptunes – planet sizes that are common in the galaxy but strangely absent from our solar system.

The Webb telescope might also be trained on the TRAPPIST-1 planets, potentially reading which molecules are present in their atmospheres.

NASA scientists and engineers are, in the meantime, already hard at work designing future generations of space telescopes that should, at long last, lay bare the skies of other Earths.

And even in the nearer term, the Webb telescope’s discoveries seem sure to transform our understanding of exoplanet atmospheres.

“Everything is going to change completely in the next five years,” Kreidberg said. “I have no idea what to expect – none – which is a really exciting place to be.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New Apps: ‘NASA Selfies’ and TRAPPIST-1 VR

2 min read

NASA Science Editorial Team

The universe is at your fingertips with two new digital products from NASA.

The NASA Selfies app and NASA's Exoplanet Excursions virtual reality app were created to celebrate the 15th anniversary of the launch of NASA's Spitzer Space Telescope. Spitzer's incredible discoveries and amazing images are at the center of these new products.

The new NASA Selfies app lets you generate snapshots of yourself in a virtual spacesuit, posing in front of gorgeous cosmic locations, like the Orion Nebula or the center of the Milky Way galaxy. The simple interface means you just snap a photo of yourself, pick your background, and share on social media.

The app also provides information about the science behind these stunning images. There are currently 30 eye-catching images to choose from, all taken by Spitzer. More images from the agency's other science and human spaceflight missions will be added in the future.

The app is available for iOS and Android.

In NASA's Exoplanet Excursions virtual reality app, VR users are taken on a guided tour of the TRAPPIST-1 planetary system.

TRAPPIST-1 is the only known exoplanet system to host seven roughly Earth-size planets. Spitzer played a major role in detecting these planets and providing information that has helped scientists learn about the planets' likely compositions. The TRAPPIST-1 system is too far away for telescopes to directly observe these planets, but this VR experience features artists' impressions of what the planets might look like. These impressions are based on data from Spitzer and other telescopes that have studied the TRAPPIST-1 system.

Users of the app are navigated around five of the seven planets, surrounded by the blackness of space and the faint lights of distant stars.

The VR app will be available for Oculus and Vive through the Spitzer mission website and will soon be available through the Oculus store. A 360-degree video is also be available on the Spitzer Youtube page that allows viewers to explore the virtual TRAPPIST-1 system on their desktop, smartphone or with a smartphone-based 360-viewer like Google Cardboard.

http://www.spitzer.caltech.edu/vr

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

15 Years in Space for NASA’s Spitzer Space Telescope

7 min read

NASA Science Editorial Team

Initially scheduled for a minimum 2.5-year primary mission, NASA's Spitzer Space Telescope has gone far beyond its expected lifetime – and is still going strong after 15 years.

Launched into a solar orbit on Aug. 25, 2003, Spitzer was the final of NASA's four Great Observatories to reach space. The space telescope has illuminated some of the oldest galaxies in the universe, revealed a new ring around Saturn, and peered through shrouds of dust to study newborn stars and black holes. Spitzer assisted in the discovery of planets beyond our solar system, including the detection of seven Earth-size planets orbiting the star TRAPPIST-1, among other accomplishments.

"In its 15 years of operations, Spitzer has opened our eyes to new ways of viewing the universe," said Paul Hertz, director of the Astrophysics Division at NASA Headquarters in Washington. "Spitzer's discoveries extend from our own planetary backyard, to planets around other stars, to the far reaches of the universe. And by working in collaboration with NASA's other Great Observatories, Spitzer has helped scientists gain a more complete picture of many cosmic phenomena."

Spitzer detects infrared light – most often heat radiation emitted by warm objects. On Earth, infrared light is used in a variety of applications, including night-vision instruments.

With its infrared vision and high sensitivity, Spitzer has contributed to the study of some of the most distant galaxies in the known universe. The light from some of those galaxies traveled for 13.4 billion years to reach Earth. As a result, scientists see these galaxies as they were less than 400 million years after the birth of the universe.

Among this population of ancient galaxies was a surprise for scientists: "big baby" galaxies that were much larger and more mature than scientists thought early-forming galaxies could be. Large, modern galaxies are thought to have formed through the gradual merger of smaller galaxies. But the "big baby" galaxies showed that massive collections of stars came together very early in the universe's history.

Studies of these very distant galaxies relied on data from both Spitzer and the Hubble Space Telescope, another one of NASA's Great Observatories. Each of the four Great Observatories collects light in a different wavelength range. By combining their observations of various objects and regions, scientists can gain a more complete picture of the universe.

"The Great Observatories program was really a brilliant concept," said Michael Werner, Spitzer project scientist at NASA's Jet Propulsion Laboratory in Pasadena, California. "The idea of getting multispectral images or data on astrophysical phenomenon is very compelling, because most heavenly bodies produce radiation across the spectrum. An average galaxy like our own Milky Way, for example, radiates as much infrared light as visible wavelength light. Each part of the spectrum provides new information."

In recent years, scientists have utilized Spitzer to study exoplanets, or planets orbiting stars other than our Sun, although this was not something the telescope's designers anticipated.

With Spitzer's help, researchers have studied planets with surfaces as hot as stars, others thought to be frozen solid, and many in between. Spitzer has studied some of the nearest known exoplanets to Earth, and some of the most distant exoplanets ever discovered.

Spitzer also played a key role in one of the most significant exoplanet discoveries in history: the detection of seven, roughly Earth-size planets orbiting a single star. The TRAPPIST-1 planetary system was unlike any alien solar system ever discovered, with three of its seven planets located in the "habitable zone," where the temperature might be right for liquid water to exist on the planets' surfaces. Their discovery was an enticing step in the search for life elsewhere in the universe.

"The study of extrasolar planets was still in its infancy when Spitzer launched, but in recent years, often more than half of Spitzer's observation time is used for studies of exoplanets or searches for exoplanets," said Lisa Storrie-Lombardi, Spitzer's project manager at JPL. "Spitzer is very good at characterizing exoplanets, even though it wasn't designed to do that."

Some other major discoveries made using the Spitzer space telescope include:

– The largest known ring around Saturn, a wispy, fine structure with 300 times the diameter of Saturn.

– First exoplanet weather map of temperature variations over the surface of a gas exoplanet. Results suggested the presence of fierce winds.

– Asteroid and planetary smashups. Spitzer has found evidence for several rocky collisions in other solar systems, including one thought to involve two large asteroids.

– Recipe for "comet soup." Spitzer observed the aftermath of the collision between NASA's Deep Impact spacecraft and comet Tempel 1, finding that cometary material in our own solar system resembles that around nearby stars.

– The hidden lairs of newborn stars. Spitzer's infrared images have provided unprecedented views into the hidden cradles where young stars grow up, revolutionizing our understanding of stellar birth.

– Buckyballs in space. Buckyballs are soccer-ball-shaped carbon molecules discovered in laboratory research with multiple technological applications on Earth..

– Massive clusters of galaxies. Spitzer has identified many more distant galaxy clusters than were previously known.

– One of the most extensive maps of the Milky Way galaxyever compiled, including the most accurate map of the large bar of stars in the galaxy's center, created using Spitzer data from the Galactic Legacy Mid-Plane Survey Extraordinaire project, or GLIMPSE.

Spitzer has logged over 106,000 hours of observation time. Thousands of scientists around the world have utilized Spitzer data in their studies, and Spitzer data is cited in more than 8,000 published papers.

Spitzer's primary mission ended up lasting 5.5 years, during which time the spacecraft operated in a "cold phase," with a supply of liquid helium cooling three onboard instruments to just above absolute zero. The cooling system reduced excess heat from the instruments themselves that could contaminate their observations. This gave Spitzer very high sensitivity for "cold" objects.

In July 2009, after Spitzer's helium supply ran out, the spacecraft entered a so-called "warm phase." Spitzer's main instrument, called the Infrared Array Camera (IRAC), has four cameras, two of which continue to operate in the warm phase with the same sensitivity they maintained during the cold phase.

Spitzer orbits the Sun in an Earth-trailing orbit (meaning it literally trails behind Earth as the planet orbits the Sun) and has continued to fall farther and farther behind Earth during its lifetime. This now poses a challenge for the spacecraft, because while it is downloading data to Earth, its solar panels do not directly face the Sun. As a result, Spitzer must use battery power during data downloads. The batteries are then recharged between downloads.

"Spitzer is farther away from Earth than we ever thought it would be while still operating," said Sean Carey, manager of the Spitzer Science Center at Caltech in Pasadena, California. "This has posed some real challenges to the engineering team, and they've been extremely creative and resourceful to keep Spitzer operating far beyond its expected lifetime."

In 2016, Spitzer entered an extended mission dubbed "Spitzer Beyond." The spacecraft is currently scheduled to continue operations into November 2019, more than 10 years after entering its warm phase.

In celebration of Spitzer's 15 years in space, NASA has released two new multimedia products: The NASA Selfies app for iOS and Android, and the Exoplanet Excursions VR Experience for Oculus and Vive, as well as a 360-video version for smartphones. Spitzer's incredible discoveries and amazing images are at the center of these new products. The VR app will be available for Oculus and Vive through ‘the Spitzer mission website' and will soon be available through the Oculus store:

http://www.spitzer.caltech.edu/vr

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena, California. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the IPAC at Caltech. Caltech manages JPL for NASA. For more information about Spitzer, visit:

https://spitzer.caltech.edu

https://www.nasa.gov/spitzer

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery alert! Oddball planet could surrender its secrets

2 min read

NASA Science Editorial Team

Planet: Wolf 503b

Discovered by: Merrin Peterson, et al.

Date: June 2018

Key Facts: A newly discovered planet twice as big around as Earth is about 145 light years away -- close enough to offer a prime target for follow-up investigations. The planet orbits a type of star known as an "orange dwarf," and is so close to the star that it completes an entire orbit -- a "year" on Wolf 503b -- in only six Earth days.

What's new: Astronomers who study exoplanets -- planets around other stars -- have found thousands so far in our galaxy. They've also noticed an odd gap, called the Fulton gap, of planet sizes that seem to be very rare. This gap occurs between about 1.5 and 2 times the size of Earth. One possibility is that planets on the lower side of this size range are rocky, while those twice Earth size or bigger are gaseous, like Neptune.

Wolf 503b's star is relatively close to Earth, making it appear brighter than more distant stars (though it is far too dim to see with the naked eye). This means the planet, discovered using the Kepler space telescope, will be easier to investigate with other instruments. Telescopes that can track the star's "wobble" -- how much it is tugged back and forth by the gravity of the orbiting planet -- will reveal the planet's "weight," or mass. Combining that with the planet's diameter will tell us whether Wolf 503b is very dense, like a rocky planet, or less dense, like a planet with a puffy, gaseous atmosphere. That, in turn, could tell us more about the nature of planets close to the Fulton gap.

Its star's brightness also makes Wolf 503b a likely candidate for closer inspection by the James Webb Space Telescope, scheduled for launch in 2021. The Webb telescope will be equipped to probe the chemistry and composition of the planet's atmosphere -- perhaps like Earth's, or Neptune's, or like nothing we've ever seen before.

See details and check the official NASA planet count at the NASA Exoplanet Archive

Paper: "A 2 Earth radius planet orbiting the bright nearby K-dwarf Wolf 503"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Symphony of stars: The science of stellar sound waves

10 min read

NASA Science Editorial Team

By Elizabeth Landau,NASA's Exoplanet Exploration Program

We can’t hear it with our ears, but the stars in the sky are performing a concert, one that never stops. The biggest stars make the lowest, deepest sounds, like tubas and double basses. Small stars have high-pitched voices, like celestial flutes. These virtuosos don’t just play one "note" at a time, either — our own Sun has thousands of different sound waves bouncing around inside it at any given moment.

Understanding these stellar harmonies represents a revolution in astronomy. By "listening" for stellar sound waves with telescopes, scientists can figure out what stars are made of, how old they are, how big they are and how they contribute to the evolution of our Milky Way galaxy as a whole. The technique is called asteroseismology. Just as earthquakes (or Earth’s seismic waves) tell us about the inside of Earth, stellar waves — resulting in vibrations or "star quakes" — reveal the secret inner workings of stars.

NASA’s Kepler space telescope, now retired, was a key player in that revolution, delivering observations of waves in tens of thousands of stars after its 2009 launch. NASA’s Transiting Exoplanet Survey Satellite (TESS), which launched in April 2018, may observe sound waves in up to one million red giants — the massive, evolved stars that represent what our Sun will look like in about 5 billion years. While both Kepler and TESS are most famous for hunting for planets beyond our solar system (exoplanets), they are also powerful, sensitive tools for detecting stellar vibrations. And, the more we know about stars, the more we know about planets that orbit them.

"We are using seismology to provide an exquisite characterization of the host stars — and hence the planets — we’ve discovered," said W]illiam Chaplin, professor of astrophysics at the University of Birmingham, United Kingdom, who leads the Kepler’s asteroseismology effort for Sun-like stars.

Like bubbles rising in a pot of boiling water, sound waves move through a star’s interior because of temperature changes. They begin in the star’s convection zone, which is the upper 30 percent of a star’s volume if it is similar to the Sun. Hot gas moves upward to the star’s surface, where it cools off and falls back down — though far more violently and turbulently than in your kitchen. Convection, this movement of heat rising and falling, creates waves that bounce around in the star in different ways.

A similar process happens on Earth: seismic waves, caused by convection, make plates on the planet’s surface move and bump up against one another, eventually leading to earthquakes. The Moon also has quakes, measured by instruments that NASA’s Apollo astronauts delivered. And NASA’s InSight is delving into the interior of Mars by measuring seismic waves there. But unlike on these planetary bodies, stellar sound waves are generated continuously by turbulence in the near-surface layers of stars.

Convection-driven waves cause the whole star to expand and contract, in effect ringing the star like a bell. So many waves propagate at once that the overall stellar surface jostles around like Jell-O, but so subtly that the motion would not be visible to the eye. In close-up images of our own Sun, we see the effects of waves as localized areas of brightening and dimming. These are distinct from the dark spots we know as sunspots on our Sun. Sunspots form in areas where the Sun’s magnetic field lines weaken the amount of energy brought to the surface, and represent temporarily cooler regions on the surface of the star.

Some waves ripple around the entire circumference of the star, while others dart right through the star’s core. The bigger the star, the longer it takes sound waves to travel in its interior. In the Sun, a typical wave completes one cycle in five minutes. Any given wave lasts a few days in Sun-like stars, but because new waves crop up all the time, stars are always vibrating. Red giants, which are dozens of times as big as the Sun, have lower-frequency waves that can propagate for weeks to months. By studying stars of various ages, scientists learn about what will happen to our own Sun as it gets older.

Because the Sun is the closest star to us, it’s not surprising that scientists first discovered stellar vibrations there. In 1962, a group of scientists led by Caltech physicist Robert Leighton noted "cells" of moving material at the Sun’s surface, associated with variations in surface brightness, while using the 60-foot solar tower at Mount Wilson Observatory near Los Angeles. Follow-up studies in the 1970s revealed that waves of different frequencies accounted for this behavior. By tracking the Sun’s waves, scientists realized in 1977 that our star’s convection zone ran much deeper than predicted. Since then, the field of helioseismology has gained a much better understanding of the Sun’s rotation and interior structure.

Most other stars are so far away that telescopes can only view them as single points of light, and directly seeing detailed surface features is impossible. The actual changes in a star’s overall brightness caused by sound waves are unimaginably small: about four parts in a million. Those subtle variations are the equivalent of turning your cell phone flashlight on and off in a room full of very bright spotlights, such as the ones that form the famous light beam at the Luxor Hotel and Casino in Las Vegas, said Jennifer van Saders, astronomer at the University of Hawaii. From afar, the building would still appear to emit one unchanging light, because the effect of the flickering flashlight is so subtle.

One way of picking out stellar vibrations uses a principle called the Doppler effect – that light coming toward the observer shifts more blue, and light moving away shifts more red. As the surface of the star moves, an instrument called a spectrograph picks up these shifts. A second method is to measure the overall brightness of light coming from the star over time, which is the method used by both Kepler and TESS.

Subtle changes in brightness are hard to discern with ground-based telescopes because Earth’s atmosphere and weather activity get in the way, and because daylight interrupts observations. For continuous listening to the stellar orchestra, astronomers needed space telescopes. The Convection, Rotation and Planetary Transits (CoRoT) satellite, launched in 2006 and led by the French space agency (CNES), and Kepler, launched in 2009, were the pioneers in exploring helioseismology in an expanse of stars in greater detail than ever before.

"Kepler stares at these points of light and it watches them twinkle — not twinkle as they do here on Earth, because that’s the atmosphere causing them to twinkle — but twinkle because they’re actually changing brightness," van Saders said.

In its first four years, Kepler stared at one patch of sky and measured starlight every minute — the longest continuous observations ever of any stars. (In its later K2 mission, the spacecraft changed its field of view about every three months). This unique dataset, together with nearly six years of data from CoRoT, demonstrated that many stars in the galaxy do not have interiors like the Sun — even those only 20 to 30 percent more massive. The low voices of giant stars confirmed predictions about the interior structures of red giants for the first time.

"That’s what Kepler gave us — the ability to really test what’s going on in the interiors for stars that aren’t just the Sun," van Saders said.

Asteroseismology is also useful for measuring how the surface of a star rotates compared to its interior. While studying stellar sound waves, scientists also were surprised to learn that in one type of red giant, the core rotates rapidly while the surface rotates slowly. A 2012 study using Kepler data found three giant stars whose interiors spin 10 times faster than their surfaces. There’s much more work to be done in terms of creating models of the inner and outer portions of stars.

"Kepler really started to tell that story — TESS will do the census," said Tom Barclay, research scientist with the TESS mission at NASA’s Goddard Space Flight Center, Greenbelt, Maryland.

Scientists are still exploring how the Sun’s vibrations compare to stars with different masses and ages, and how that "ringing" will change as the Sun ages into a red giant. "This is one of the things we are trying to figure out, and that Kepler and TESS and other missions can help us understand," said Dan Huber, astronomer at the University of Hawaii, Honolulu.

Many important aspects of a planet — including size, age and whether or not it could support life – can only be determined from what scientists know about its host star.

When a planet passes in front of its star, TESS detects this "transit" by measuring a sharp dip in the brightness of the star as the planet blocks some of its light (very different from the ripple-like quake signatures). The amount of dimming of the star’s light during a transit is related to the size of the planet relative to the size of the star. So, in order to calculate the planet’s diameter, scientists need the diameter of the star — something that they can determine using asteroseismology. Similarly, while a technique called radial velocity allows scientists to calculate a planet’s mass relative to its star’s mass, scientists must calculate the star’s mass to "weigh" the planet. Asteroseismology is a way to determine the mass.

"Knowing the size of the star is very important for actually knowing what the size of the planet is," Huber said.

Stellar vibrations also help scientists determine how old a star is, which will affect the environment of its planets. A young star is more likely to have violent outbursts, and its planets may still be shuffling around in their orbits. An older star has less frequent flare-ups, and its planets may be more stable.

"Getting precise estimates of ages is incredibly difficult, but this is something that asteroseismology is really well suited to," Chaplin said. "The ticking heartbeat of the star allows us to get precise measurements."

The more stars astronomers can examine through seismology, the better they can map where the young and old stars are, and understand which regions of the Milky Way formed first. This is the science of galactic archaeology. By following the trails of vibrations in stars, like an interstellar Indiana Jones would, astronomers can reconstruct how our Milky Way formed.

"Much like digging through the archaeological site of an old city, you can look at what happened in each of those 'rooms' in our galaxy," said Steve Howell, head of the space and astrobiology division at NASA's Ames Research Center in California’s Silicon Valley.

TESS will record the vibrations of up to one million red giants. As it will do a survey of stars across the entire sky, it will in effect be listening in "surround sound." The European Space Agency’s Gaia mission, which recently released positions and distance indicators for more than one billion stars, offers a powerful addition in charting the history of the galaxy. By calculating the ages of stars and determining how long they have been in the red giant phase, and knowing their distances, scientists will get a fuller picture of how the stars of the galaxy came together and how it is evolving.

Scientists will still be using Kepler's data to make discoveries about the Milky Way’s stars for years to come. TESS complements its predecessor’s detailed observations of the celestial orchestra, and continue unlocking mysteries as it listens to more of the grand ensemble of the galaxy.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Planet-Hunting TESS Catches a Comet Before Starting Science

3 min read

Before NASA’s Transiting Exoplanet Survey Satellite (TESS) started science operations on July 25, 2018, the planet hunter sent back a stunning sequence of serendipitous images showing the motion of a comet. Taken over the course of 17 hours on July 25, these TESS images helped demonstrate the satellite’s ability to collect a prolonged set of stable periodic images covering a broad region of the sky — all critical factors in finding transiting planets orbiting nearby stars.

Over the course of these tests, TESS took images of C/2018 N1, a comet discovered by NASA’s Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE) satellite on June 29. The comet, located about 29 million miles (48 million kilometers) from Earth in the southern constellation Piscis Austrinus, is seen to move across the frame from right to left as it orbits the Sun. The comet’s tail, which consists of gases carried away from the comet by an outflow from the Sun called the solar wind, extends to the top of the frame and gradually pivots as the comet glides across the field of view.

In addition to the comet, the images reveal a treasure trove of other astronomical activity. The stars appear to shift between white and black as a result of image processing. The shift also highlights variable stars — which change brightness either as a result of pulsation, rapid rotation, or by eclipsing binary neighbors. Asteroids in our solar system appear as small white dots moving across the field of view. Towards the end of the video, one can see a faint broad arc of light moving across the middle section of the frame from left to right. This is stray light from Mars, which is located outside the frame. The images were taken when Mars was at its brightest near opposition, or its closest distance, to Earth.

These images were taken during a short period near the end of the mission’s commissioning phase, prior to the start of science operations. The movie presents just a small fraction of TESS’s active field of view. The team continues to fine-tune the spacecraft’s performance as it searches for distant worlds.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT’s Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory in Lexington, Massachusetts; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

Media contact: Claire SaraviaNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Water Is Destroyed, Then Reborn in Ultrahot Jupiters

7 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Imagine a place where the weather forecast is always the same: scorching temperatures, relentlessly sunny, and with absolutely zero chance of rain. This hellish scenario exists on the permanent daysides of a type of planet found outside our solar system dubbed an "ultrahot Jupiter." These worlds orbit extremely close to their stars, with one side of the planet permanently facing the star.

What has puzzled scientists is why water vapor appears to be missing from the toasty worlds' atmospheres, when it is abundant in similar but slightly cooler planets. Observations of ultrahot Jupiters by NASA's Spitzer and Hubble space telescopes, combined with computer simulations, have served as a springboard for a new theoretical study that may have solved this mystery.

According to the new study, ultrahot Jupiters do in fact possess the ingredients for water (hydrogen and oxygen atoms). But due to strong irradiation on the planet's daysides, temperatures there get so intense that water molecules are completely torn apart.

"The daysides of these worlds are furnaces that look more like a stellar atmosphere than a planetary atmosphere," said Vivien Parmentier, an astrophysicist at Aix Marseille University in France and lead author of the new study. "In this way, ultrahot Jupiters stretch out what we think planets should look like."

While telescopes like Spitzer and Hubble can gather some information about the daysides of ultrahot Jupiters, the nightsides are difficult for current instruments to probe. The new paper proposes a model for what might be happening on both the illuminated and dark sides of these planets, based largely on observations and analysis of the ultrahot Jupiter known as WASP-121b, and from three recently published studies, coauthored by Parmentier, that focus on the ultrahot Jupiters WASP-103b, WASP-18b and HAT-P-7b, respectively. The new study suggests that fierce winds may blow the sundered water molecules into the planets' nightside hemispheres. On the cooler, dark side of the planet, the atoms can recombine into molecules and condense into clouds, all before drifting back into the dayside to be splintered again.

Water is not the only molecule that may undergo a cycle of chemical reincarnation on these planets, according to the new study. Previous detections of clouds by Hubble at the boundary between day and night, where temperatures mercifully fall, have shown that titanium oxide (popular as a sunscreen) and aluminum oxide (the basis for ruby, the gemstone) could also be molecularly reborn on the ultrahot Jupiters' nightsides. These materials might even form clouds and rain down as liquid metals and fluidic rubies.

Star-planet hybrids

Among the growing catalog of planets outside our solar system -- known as exoplanets -- ultrahot Jupiters have stood out as a distinct class for about a decade. Found in orbits far closer to their host stars than Mercury is to our Sun, the giant planets are tidally locked, meaning the same hemisphere always faces the star, just as the Moon always presents the same side to Earth. As a result, ultrahot Jupiters' daysides broil in a perpetual high noon. Meanwhile, their opposite hemispheres are gripped by endless nights. Dayside temperatures reach between 3,600 and 5,400 degrees

Fahrenheit (2,000 and 3,000 degrees Celsius), ranking ultrahot Jupiters among the hottest exoplanets on record. Nightside temperatures are around 1,800 degrees Fahrenheit cooler (1,000 degrees Celsius), cold enough for water to re-form and, along with other molecules, coalesce into clouds.

Hot Jupiters, cousins to ultrahot Jupiters with dayside temperatures below 3,600 degrees Fahrenheit (2,000 Celsius), were the first widely discovered type of exoplanet, starting back in the mid-1990s. Water has turned out to be common in their atmospheres. One hypothesis for why it appeared absent in ultrahot Jupiters has been that these planets must have formed with very high levels of carbon instead of oxygen. Yet the authors of the new study say this idea could not explain the traces of water also sometimes detected at the dayside-nightside boundary.

To break the logjam, Parmentier and colleagues took a cue from well-established physical models of the atmospheres of stars, as well as "failed stars," known as brown dwarfs, whose properties overlap somewhat with hot and ultrahot Jupiters. Parmentier adapted a brown dwarf model developed by Mark Marley, one of the paper's coauthors and a research scientist at NASA's Ames Research Center in Silicon Valley, California, to the case of ultrahot Jupiters. Treating the atmospheres of ultrahot Jupiters more like blazing stars than conventionally colder planets offered a way to make sense of the Spitzer and Hubble observations.

"With these studies, we are bringing some of the century-old knowledge gained from studying the astrophysics of stars, to the new field of investigating exoplanetary atmospheres," said Parmentier.

Spitzer's observations in infrared light zeroed in on carbon monoxide in the ultrahot Jupiters' atmospheres. The atoms in carbon monoxide form an extremely strong bond that can uniquely withstand the thermal and radiational assault on the daysides of these planets. The brightness of the hardy carbon monoxide revealed that the planets' atmospheres burn hotter higher up than deeper down. Parmentier said verifying this temperature difference was key for vetting Hubble's no-water result, because a uniform atmosphere can also mask the signatures of water molecules.

"These results are just the most recent example of Spitzer being used for exoplanet science -- something that was not part of its original science manifest," said Michael Werner, project scientist for Spitzer at NASA’s Jet Propulsion Laboratory in Pasadena, California. "In addition, it’s always heartening to see what we can discover when scientists combine the power of Hubble and Spitzer, two of NASA’s Great Observatories."

Although the new model adequately described many ultrahot Jupiters on the books, some outliers do remain, suggesting that additional aspects of these worlds' atmospheres still need to be understood. Those exoplanets not fitting the mold could have exotic chemical compositions or unanticipated heat and circulation patterns. Prior studies have argued that there is a more significant amount of water in the dayside atmosphere of WASP-121b than what is apparent from observations, because most of the signal from the water is obscured. The new paper provides an alternative explanation for the smaller-than-expected water signal, but more studies will be required to better understand the nature of these ultrahot atmospheres.

Resolving this dilemma could be a task for NASA’s next-generation James Webb Space Telescope, slated for a 2021 launch. Parmentier and colleagues expect it will be powerful enough to glean new details about the daysides, as well as confirm that the missing dayside water and other molecules of interest have gone to the planets’ nightsides.

"We now know that ultrahot Jupiters exhibit chemical behavior that is different and more complex than their cooler cousins, the hot Jupiters," said Parmentier. "The studies of exoplanet atmospheres is still really in its infancy and we have so much to learn."

The new study is forthcoming in the journal Astronomy and Astrophysics.

NASA's Jet Propulsion Laboratory, Pasadena, California, manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Spacecraft operations are based at Lockheed Martin Space, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

Hubble is a project of international cooperation between NASA and ESA. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages Hubble. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations.

Contact:Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.818-393-1821Calla.e.cofield@jpl.nasa.gov

In May 2024, a geomagnetic storm hit Earth, sending auroras across the planet’s skies in a once-in-a-generation light display. These dazzling sights are possible because of the interaction of coronal mass ejections – explosions of plasma and magnetic field from the Sun – with Earth’s magnetic field, which protects us from the radiation the Sun […]

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Chandra May Have First Evidence of a Young Star Devouring a Planet

5 min read

Scientists may have observed, for the first time, the destruction of a young planet or planets around a nearby star. Observations from NASA's Chandra X-ray Observatory indicate that the parent star is now in the process of devouring the planetary debris. This discovery gives insight into the processes affecting the survival of infant planets.

Since 1937, astronomers have puzzled over the curious variability of a young star named RW Aur A, located about 450 light years from Earth. Every few decades, the star's optical light has faded briefly before brightening again. In recent years, astronomers have observed the star dimming more frequently, and for longer periods.

Using Chandra, a team of scientists may have uncovered what caused the star's most recent dimming event: a collision of two infant planetary bodies, including at least one object large enough to be a planet. As the resulting planetary debris fell into the star, it would generate a thick veil of dust and gas, temporarily obscuring the star's light.

"Computer simulations have long predicted that planets can fall into a young star, but we have never before observed that," says Hans Moritz Guenther, a research scientist in MIT's Kavli Institute for Astrophysics and Space Research who led the study. "If our interpretation of the data is correct, this would be the first time that we directly observe a young star devouring a planet or planets."

The star's previous dimming events may have been caused by similar smash-ups, of either two planetary bodies or large remnants of past collisions that met head-on and broke apart again.

RW Aur A is located in the Taurus-Auriga Dark Clouds, which host stellar nurseries containing thousands of infant stars. Very young stars, unlike our relatively mature sun, are still surrounded by a rotating disk of gas and clumps of material ranging in size from small dust grains to pebbles, and possibly fledgling planets. These disks last for about 5 million to 10 million years.

RW Aur A is estimated to be several million years old, and is still surrounded by a disk of dust and gas. This star and its binary companion star, RW Aur B, are both about the same mass as the sun.

The noticeable dips in the optical brightness of RW Aur A that occurred every few decades each lasted for about a month. Then, in 2011, the behavior changed. The star dimmed again, this time for about six months. The star eventually brightened, only to fade again in mid-2014. In November 2016, the star returned to its full brightness, and then in January 2017 it dimmed again.

Chandra was used to observe the star during an optically bright period in 2013, and then dim periods in 2015 and 2017, when a decrease in X-rays was also observed.

Because the X-rays come from the hot outer atmosphere of the star, changes in the X-ray spectrum – the intensity of X-rays measured at different wavelengths – over these three observations were used to probe the density and composition of the absorbing material around the star.

The team found that the dips in both optical and X-ray light are caused by dense gas obscuring the star's light. The observation in 2017 showed strong emission from iron atoms, indicating that the disk contained at least 10 times more iron than in the 2013 observation during a bright period.

Guenther and colleagues suggest the excess iron was created when two planetesimals, or infant planetary bodies, collided. If one or both planetary bodies are made partly of iron, their smash-up could release a large amount of iron into the star's disk and temporarily obscure its light as the material falls into the star.

A less favored explanation is that small grains or particles such as iron can become trapped in parts of a disk. If the disk's structure changes suddenly, such as when the star's partner star passes close by, the resulting tidal forces might release the trapped particles, creating an excess of iron that can fall into the star.

The scientists hope to make more observations of the star in the future, to see whether the amount of iron surrounding it has changed – a measure that could help researchers determine the size of the iron's source. For example, if about the same amount of iron appears in a year or two that may indicate it comes from a relatively massive source.

"Much effort currently goes into learning about exoplanets and how they form, so it is obviously very important to see how young planets could be destroyed in interactions with their host stars and other young planets, and what factors determine if they survive," Guenther says.

Guenther is the lead author of a paper detailing the group's results, which appears today in the Astronomical Journal. NASA's Marshall Space Flight Center in Huntsville, Alabama, manages the Chandra program for NASA's Science Mission Directorate in Washington. The Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, controls Chandra's science and flight operations.

Read more from NASA's Chandra X-ray Observatory.

For more Chandra images, multimedia and related materials, visit:

https://www.nasa.gov/chandra

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Spacecraft Starts Science Operations

2 min read

NASA’s Transiting Exoplanet Survey Satellite has started its search for planets around nearby stars, officially beginning science operations on July 25, 2018. TESS is expected to transmit its first series of science data back to Earth in August, and thereafter periodically every 13.5 days, once per orbit, as the spacecraft makes it closest approach to Earth. The TESS Science Team will begin searching the data for new planets immediately after the first series arrives.

“I’m thrilled that our new planet hunter mission is ready to start scouring our solar system’s neighborhood for new worlds,” said Paul Hertz, NASA Astrophysics division director at Headquarters, Washington. “Now that we know there are more planets than stars in our universe, I look forward to the strange, fantastic worlds we’re bound to discover.”

TESS is NASA’s latest satellite to search for planets outside our solar system, known as exoplanets. The mission will spend the next two years monitoring the nearest and brightest stars for periodic dips in their light. These events, called transits, suggest that a planet may be passing in front of its star. TESS is expected to find thousands of planets using this method, some of which could potentially support life.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT’s Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory in Lexington, Massachusetts; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

For the latest updates on TESS, visit nasa.gov/tess.

Media contact: Claire SaraviaNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA’s TESS Spacecraft Continues Testing Prior to First Observations

2 min read

After a successful launch on April 18, 2018, NASA’s newest planet hunter, the Transiting Exoplanet Survey Satellite, is currently undergoing a series of commissioning tests before it begins searching for planets. The TESS team has reported that the spacecraft and cameras are in good health, and the spacecraft has successfully reached its final science orbit. The team continues to conduct tests in order to optimize spacecraft performance with a goal of beginning science at the end of July.

Every new mission goes through a commissioning period of testing and adjustments before beginning science operations. This serves to test how the spacecraft and its instruments are performing and determines whether any changes need to be made before the mission starts observations.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT’s Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Northrop Grumman, based in Falls Church, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; MIT’s Lincoln Laboratory in Lexington, Massachusetts; and the Space Telescope Science Institute in Baltimore. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

For the latest updates on TESS, visit nasa.gov/tess.

Media Contact: Claire SaraviaNASA’s Goddard Space Flight Center, Greenbelt, Md.

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

In a surprise finding, astronomers using NASA’s Hubble Space Telescope have discovered that the blowtorch-like…

Discovery alert! Baby pictures of newborn giant planet

2 min read

NASA Science Editorial Team

From European Southern Observatory

Planet: PDS 70b

Discovered by: M. Keppler et al. using ESO’s Very Large Telescope

Date: July 2, 2018

Key Facts: Even astronomers aren’t immune to baby photos. Especially if it’s a photo of a baby planet! Astronomers in Germany captured the first clear images of the young planet PDS 70b in the process of formation around its star, PDS 70. The planet stands out, visible as a bright point to the right of the center of the image. The black circle in the center is a part of the telescope called a coronagraph, which blocks the blinding light of the star. If the Very Large Telescope did not have a coronagraph, the star’s glare would drown out the fainter light of the planet, hiding it from our view. Even though it looks tiny, this planet is a gas giant more massive than Jupiter. It’s also very, very hot– about 1800 degrees (1000 degrees Celsius).

What's new: Where do planets come from? We’re just starting to see planets form in large structures of gas and dust called “protoplanetary disks,” which orbit very young stars. What we’re still learning is how tiny specks of dust and gas come together via gravity to form huge planets. In the image above, the bright ring around the young star is its protoplanetary disk. A star and its planets form out of a cloud of dust and gas. As gravity pulls the cloud closer together, it starts to rotate, eventually flattening into a spinning disk. Eventually, the material in the disk will begin to stick together, somewhat like household dust sticking together to form dust bunnies. These dust bunnies sweep up more material until they eventually become planets. Images of newborn planets, like this one, will help us test our theories of how planets are formed.

See details and check the official ESO release at European Southern Observatory

Papers: "Discovery of a planetary-mass companion within the gap of the transition disk around PDS 70" and “Orbital and atmospheric characterization of the planet within the gap of the PDS 70 transition disk”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Will we know life when we see it? NASA-led group takes stock of the science

4 min read

NASA Science Editorial Team

In the last decade we have discovered thousands of planets outside our solar system and have learned that rocky, temperate worlds are numerous in our galaxy. The next step will involve asking even bigger questions. Could some of these planets host life? And if so, will we be able to recognize life elsewhere if we see it?

A group of leading researchers in astronomy, biology and geology have come together under NASA's Nexus for Exoplanet System Science, or NExSS, to take stock of our knowledge in the search for life on distant planets and to lay the groundwork for moving the related sciences forward.

"We're moving from theorizing about life elsewhere in our galaxy to a robust science that will eventually give us the answer we seek to that profound question: Are we alone?" said Martin Still, then an exoplanet scientist at NASA.

In a set of five review papers published in the scientific journal Astrobiology, NExSS scientists took an inventory of the most promising signs of life, called biosignatures. They considered how to interpret the presence of biosignatures, should we detect them on distant worlds. A primary concern is ensuring the science is strong enough to distinguish a living world from a barren planet masquerading as one.

Mary Parenteau

NASA astrobiologist

The assessment comes as a new generation of space and ground-based telescopes are in development. NASA's James Webb Space Telescope is characterizing the atmospheres of some of the first small, rocky planets. Other observatories— such as the Giant Magellan Telescope and the Extremely Large Telescope, both in Chile— are planning to carry sophisticated instruments capable of detecting the first biosignatures on faraway worlds.

Through their work with NExSS, scientists aim to identify the instruments needed to detect potential life for future NASA flagship missions. The detection of atmospheric signatures of a few potentially habitable planets may possibly come before 2030, although whether the planets are truly habitable or have life will require more in-depth study.

Since we won't be able to visit distant planets and collect samples anytime soon, the light that a telescope observes will be all we have in the search for life outside our solar system. Telescopes can examine the light reflecting off a distant world to show us the kinds of gases in the atmosphere and their "seasonal" variations, as well as colors like green that could indicate life.

These kinds of biosignatures can all be seen on our fertile Earth from space, but the new worlds we examine will differ significantly. For example, many of the promising planets we have found are around cooler stars, which emit light in the infrared spectrum, rather than our sun's high emissions of visible-light.

"What does a living planet look like?" said Mary Parenteau, an astrobiologist and microbiologist at NASA's Ames Research Center in Silicon Valley and a co-author. "We have to be open to the possibility that life may arise in many contexts in a galaxy with so many diverse worlds — perhaps with purple-colored life instead of the familiar green-dominated life forms on Earth, for example. That’s why we are considering a broad range of biosignatures.”

The scientists assert that oxygen — the gas produced by photosynthetic organisms on Earth — remains the most promising biosignature of life elsewhere, but it is not foolproof. Abiotic processes on a planet could also generate oxygen. Conversely, a planet lacking detectable levels of oxygen could still be alive — which was exactly the case of Earth before the global accumulation of oxygen in the atmosphere.

“On early Earth, we wouldn’t be able to see oxygen, despite abundant life,” said Victoria Meadows, an astronomer at the University of Washington in Seattle and lead author of one of the papers. “Oxygen teaches us that seeing, or not seeing, a single biosignature is insufficient evidence for or against life — overall context matters.”

Rather than measuring a single characteristic, the NExSS scientists argue that we should be looking at a suite of traits. A planet must show itself capable of supporting life through its features, and those of its parent star.

The NExSS scientists will create a framework that can quantify how likely it is that a planet has life, based on all the available evidence. With the observation of many planets, scientists may begin to more broadly classify the “living worlds” that show common characteristics of life, versus the “non-living worlds.”

“We won’t have a ‘yes’ or ‘no’ answer to finding life elsewhere,” said Shawn Domagal-Goldman, an astrobiologist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland and a co-author. “What we will have is a high level of confidence that a planet appears alive for reasons that only be explained by the presence of life.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA's Webb Space Telescope to Inspect Atmospheres of Gas Giant Exoplanets

5 min read

In April 2018, NASA launched the Transiting Exoplanet Survey Satellite (TESS). Its main goal is to locate Earth-sized planets and larger "super-Earths" orbiting nearby stars for further study. One of the most powerful tools that will examine the atmospheres of some planets that TESS discovers will be NASA's James Webb Space Telescope. Since observing small exoplanets with thin atmospheres like Earth will be challenging for Webb, astronomers will target easier, gas giant exoplanets first.

Some of Webb's first observations of gas giant exoplanets will be conducted through the Director's Discretionary Early Release Science program. The transiting exoplanet project team at Webb's science operations center is planning to conduct three different types of observations that will provide both new scientific knowledge and a better understanding of the performance of Webb's science instruments.

"We have two main goals. The first is to get transiting exoplanet datasets from Webb to the astronomical community as soon as possible. The second is to do some great science so that astronomers and the public can see how powerful this observatory is," said Jacob Bean of the University of Chicago, a co-principal investigator on the transiting exoplanet project.

"Our team's goal is to provide critical knowledge and insights to the astronomical community that will help to catalyze exoplanet research and make the best use of Webb in the limited time we have available," added Natalie Batalha of NASA Ames Research Center, the project's principal investigator.

Transit – An atmospheric spectrum

When a planet crosses in front of, or transits, its host star, the star's light is filtered through the planet's atmosphere. Molecules within the atmosphere absorb certain wavelengths, or colors, of light. By splitting the star's light into a rainbow spectrum, astronomers can detect those sections of missing light and determine what molecules are in the planet's atmosphere.

For these observations, the project team selected WASP-79b, a Jupiter-sized planet located about 780 light-years from Earth. The team expects to detect and measure the abundances of water, carbon monoxide, and carbon dioxide in WASP-79b. Webb also might detect new molecules not yet seen in exoplanet atmospheres.

Phase curve – A weather map

Planets that orbit very close to their stars tend to become tidally locked. One side of the planet permanently faces the star while the other side faces away, just as one side of the Moon always faces the Earth. When the planet is in front of the star, we see its cooler backside. But as it orbits the star, more and more of the hot day-side comes into view. By observing an entire orbit, astronomers can observe those variations (called a phase curve) and use the data to map the planet's temperature, clouds, and chemistry as a function of longitude.

The team will observe a phase curve of the "hot Jupiter" known as WASP-43b, which orbits its star in less than 20 hours. By looking at different wavelengths of light, they can sample the atmosphere to different depths and obtain a more complete picture of its structure. "We have already seen dramatic and unexpected variations for this planet with Hubble and Spitzer. With Webb we will reveal these variations in significantly greater detail to understand the physical processes that are responsible," said Bean.

Eclipse – A planet's glow

The greatest challenge when observing an exoplanet is that the star's light is much brighter, swamping the faint light of the planet. To get around this problem, one method is to observe a transiting planet when it disappears behind the star, not when it crosses in front of the star. By comparing the two measurements, one taken when both star and planet are visible, and the other when only the star is in view, astronomers can calculate how much light is coming from the planet alone.

This technique works best for very hot planets that glow brightly in infrared light. The team plans to study WASP-18b, a planet that is baked to a temperature of almost 4,800 degrees Fahrenheit (2,900 K). Among other questions, they hope to determine whether the planet's stratosphere exists due to the presence of titanium oxide, vanadium oxide, or some other molecule.

Habitable planets

Ultimately, astronomers want to use Webb to study potentially habitable planets. In particular, Webb will target planets orbiting red dwarf stars since those stars are smaller and dimmer, making it easier to tease out the signal from an orbiting planet. Red dwarfs are also the most common stars in our galaxy.

"TESS should locate more than a dozen planets orbiting in the habitable zones of red dwarfs, a few of which might actually be habitable. We want to learn whether those planets have atmospheres and Webb will be the one to tell us," said Kevin Stevenson of the Space Telescope Science Institute, a co-principal investigator on the project. "The results will go a long way towards answering the question of whether conditions favorable to life are common in our galaxy."

The James Webb Space Telescope will be the world's premier space science observatory. Webb will solve mysteries of our solar system, look beyond to distant worlds around other stars, and probe the mysterious structures and origins of our universe and our place in it. Webb is an international project led by NASA with its partners, the European Space Agency (ESA) and the Canadian Space Agency (CSA).

For more information about Webb, visit www.nasa.gov/webb

By Christine PulliamSpace Telescope Science Institute, Baltimore, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Taking the astronomical road less traveled

4 min read

NASA Science Editorial Team

By Pat Brennan,NASA's Exoplanet Exploration Program

Orbiting planets tug at their stars, pulling them in different directions. Astronomer Peter Plavchan, who studies such stellar wobbles, might be said to have a similar directional influence on the astronomical community. Plavchan says he likes to pull researchers along untried paths – even when it strains against the prevailing current.

Plavchan, who recently joined the faculty at Virginia's George Mason University as an assistant professor, is a leading expert on detecting exoplanets – planets around other stars – using "radial velocity." Sometimes called the RV or wobble method, it's a way of tracking the path of a star through the sky to look for tiny variations in its speed. Light from the star is stretched if it is moving away, compressed if it is moving toward us; an orbiting planet can cause it to do both as it moves from one side of the star to the other.

The size of these wobbles can tell us the mass of an exoplanet, as well as the length of its year: how long it takes to complete one orbit. It's one of the ways that Earth-based telescopes – and perhaps soon, telescopes in space – could help discover a life-bearing world somewhere in our galaxy.

First, I tell them I am a professor. Then, if they ask, I tell them I teach astronomy. People are usually very excited about that. If they persist, I tell them I look for planets around other stars. I try to ease them into what I do. I've done a number of public talks now. People love hearing about exoplanets. They think the stories they see on the news are just amazing. They always want to know more. If they make it past the professional astronomer question, I know I've caught their attention.

My main area of research is radial velocity detection of exoplanets. I conducted research on debris around M-dwarfs [red dwarf stars] in the early 2000s, when some of the first exoplanets were being discovered; exoplanets were a secondary interest.

The astronomical community superseded me in many respects, though in the early 2000s I was also looking for planets around M-dwarfs. I pivoted somewhat toward younger stars after I got my Ph.D. After that, I turned full force to exoplanets, using the RV method in near infrared wavelengths.

My science philosophies include avoiding competition with the large groups focused on the big science questions, such as searching for Earth analogs, researching data from the Kepler space telescope mission, or estimating eta Earth [the number or frequency of exoplanets in Earth's size range]. As part of my science philosophy, I look for novel projects that haven't been explored. I was one of the early researchers to study M-dwarf exoplanets. It's a much more popular topic today.

I'm now the PI [principal investigator] of a NASA probe mission study, an "Earth finder," studying the scientific feasibility of a mission that relies on a technique traditionally used on the ground: the RV method, or the Doppler method. Placing RV instruments in space allows us to avoid some of the challenges that this technique currently encounters on the ground.

As a professor, I work with a lot of undergraduates. I tell them, "I'd love to have you in my research group." Then I tell them, "Learn how to program."

People who know how to make computers do their bidding don't have to rely on others to write their programs for them. You can be a tool user or a tool creator. It's good to have the ability to create tools, especially when the tools you want don't exist.

There is a great deal of mathematics in exoplanet science, certainly a lot of astrophysics. But it's one of the more approachable subjects for students interested in research, including undergraduates.

I also tell students, especially in my undergraduate classes, that the transition from science fiction to science fact happened in their lifetime. The average college student is 18 to 22 years old. The field of exoplanet science is barely 20 years old. I tell them they're alive during a time when a 2,000-year-old question has finally been answered.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Exoplanet in the corner pocket: a recount for thousands of worlds

5 min read

NASA Science Editorial Team

by Pat Brennan,NASA's Exoplanet Exploration Program

First they rolled in one by one, those newly discovered planets, like billiard balls pushed across a table.

Counting them was easy.

Then they came in handfuls. Still quite manageable; as ground-based observatories began to pile up their discoveries of exoplanets – planets around other stars – in the 1990s and early 2000s, astronomers had no trouble keeping a running tally.

But when discoveries of exoplanets began to flow from space-based telescopes, it was like a pool shark making a big, smashing break. The billiard balls raced across the table in bunches. In just a few years, scientists were racking up new planets by the thousands.

And it wasn't just the number, but the types of planets that had to be accounted for. Hot Jupiters, gas giants, rocky, Earth-sized worlds, "super Earths"; hints of potentially frozen, scalding, lava-choked, icy, steamy or watery planets.

NASA's Exoplanet Science Institute, keepers of the NASA Exoplanet Archive, set up automated counters of exoplanet discoveries – running, online dashboards tracking the number and variety. The latest totals: some 3,700 confirmed exoplanets in our galaxy, with thousands more candidate planets that remain unconfirmed.

But now, after piling up two decades worth of exoplanet discoveries, NASA scientists have begun a wholesale reshuffling of their counting methods.

At first, this means a drop in the number of "candidate" planets, with roughly half moving to the "confirmed" category. These planets were already confirmed but were being double counted: The previous number on the counter, 4,496, was labeled "candidates," but critically, it included the combined total of confirmed and unconfirmed exoplanets, and only from NASA's Kepler space telescope observations from 2009 to 2013.

In the new counter, only "unconfirmed" planets are labeled as "candidates." The count also pulls in other NASA mission discoveries, including Kepler's more recent observations and future exoplanet finds.

That means the initial candidate total drops to 2,724.

But the drop in candidates is temporary. Once the next torrent is unleashed – exoplanet discoveries from the just-launched Transiting Exoplanet Survey Satellite (TESS), likely to begin to flow in early 2019 – planetary candidates are expected to soar into the tens of thousands.

"There could be over 10,000 candidates within the first couple of years," said Eric Mamajek, the deputy program chief scientist for NASA's Exoplanet Exploration Program. "Hundreds will be smaller than Neptune – dozens of things smaller than two or three (times Earth's diameter), within the habitable zone of mostly M-dwarfs (red dwarf stars). There are also going to be thousands upon thousands of Jupiters detected around faint stars. All will initially be unconfirmed, but (some) will need further analysis and observation to follow up."

And that could be just the beginning. In a kind of echo of "Moore's law," the rough doubling of computer processing power each year, Mamajek points out that exoplanet discoveries have doubled roughly every two years over the past three decades. The trend should continue over the next 10 years with data from TESS and future missions, such as the Wide Field Infrared Survey Telescope (WFIRST). That should keep the planet counter clicking.

Other changes reveal the evolving nature of exoplanet science. During the first Kepler mission, the space telescope stared at a patch of sky for four years, watching more than 150,000 stars. For many of those stars, the telescope's extremely sensitive detectors picked up tiny dips in starlight – the shadow of an orbiting planet passing in front of its star.

Scientists analyzed these dips and published papers, announcing raft after raft of exoplanet candidates and pushing them into the thousands. Follow-up observations and analytical techniques allowed large numbers of these candidates to be confirmed – to make sure they weren't due to statistical noise or, perhaps, a companion star in a double-star system, masquerading as a planet.

"There's always more work that needs to be done to confirm them," Mamajek said. "They don't come with a big stamp on their head that says, 'planet.'"

Planets from Kepler's later observations also must be confirmed. These came after the failure of stabilizing components on the Kepler spacecraft ended its initial four-year stare. Clever engineers found a way to use the pressure of sunlight to stabilize the spacecraft, though its observation periods are now much shorter, about 80 days apiece.

But Kepler's latest discoveries are confirmed using a different approach. The imaging data goes straight out to the astronomical community, rather than first being filtered through a scientific team. Candidate and confirmed planets are then published by the community at large.

TESS, a mission led by the Massachusetts Institute of Technology and NASA's Goddard Space Flight Center, will combine the two approaches.

"TESS will provide an official list of candidates," said David Ciardi, a research astronomer and the chief scientist for NASA's Exoplanet Science Institute at Caltech. "Then a bunch of candidates, the community will also provide. It is going to be super exciting!"

Precision counting and a bigger pool of astronomers: It's all to make sure that, amid a coming avalanche of exoplanet discoveries, planet counters don't get left behind the eight ball.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Chandra Scouts Nearest Star System for Possible Hazards

5 min read

In humanity's search for life outside our Solar System, one of the best places scientists have considered is Alpha Centauri, a system containing the three nearest stars beyond our Sun.

A new study that has involved monitoring of Alpha Centauri for more than a decade by NASA's Chandra X-ray Observatory provides encouraging news about one key aspect of planetary habitability. It indicates that any planets orbiting the two brightest stars in the Alpha Cen system are likely not being pummeled by large amounts of X-ray radiation from their host stars. X-rays and related Space Weather effects are bad for unprotected life, directly through high radiation doses and indirectly through stripping away planetary atmospheres (a fate thought to have been suffered by Mars in our own Solar System).

Alpha Centauri is a triple star system located just over four light years, or about 25 trillion miles, from Earth. While this is a large distance in terrestrial terms, it is much closer than the next nearest Sun-like stars.

"Because it is relatively close, the Alpha Centauri system is seen by many as the best candidate to explore for signs of life," said Tom Ayres of the University of Colorado Boulder. "The question is, will we find planets in an environment conducive to life as we know it?"

The stars in the Alpha Centauri system include a pair called "A" and "B," (AB for short) which orbit relatively close to each other. Alpha Cen A is a near twin of our Sun in almost every way, including age, while Alpha Cen B is somewhat smaller and dimmer but still quite similar to the Sun. The third member, Alpha Cen C (also known as Proxima), is a much smaller red dwarf star that travels around the AB pair in a much larger orbit that takes it more than 10 thousand times farther from the AB pair than the Earth-Sun distance. Proxima currently holds the title of the nearest star to Earth, although AB is a very close second.

The Chandra data reveal that the prospects for life in terms of current X-ray bombardment are actually better around Alpha Cen A than for the Sun, and Alpha Cen B fares only slightly worse. Proxima, on the other hand, is a type of active red dwarf star known to frequently send out dangerous flares of X-ray radiation, and is likely hostile to life.

"This is very good news for Alpha Cen AB in terms of the ability of possible life on any of their planets to survive radiation bouts from the stars," said Ayres. "Chandra shows us that life should have a fighting chance on planets around either of these stars."

While one remarkable Earth-size planet has been discovered around Proxima, astronomers continue to search, without success, for exoplanets around Alpha Cen A and B. Planet-hunting around these stars has proved more difficult recently due to the orbit of the pair, which has drawn the two bright stars close together on the sky over the past decade.

To help determine whether Alpha Cen's stars are hospitable to life, astronomers have run a long-term campaign in which Chandra has observed the system's two main stars about every six months since 2005. Chandra is the only X-ray observatory capable of resolving AB during its current close orbital approach, to determine which star is doing what.

These long-term measurements have captured the complete ups and downs of the X-ray activity of AB, analogous to the Sun's 11-year sunspot cycle. They show that any planets in the habitable zone for A would receive a lower dose of X-rays, on average, than similar planets around the Sun.

For companion B the X-ray dose for habitable zone planets is higher than for the Sun, but only by a factor of about five.

In comparison planets in the habitable zone around Proxima receive an average dose of X-rays about 500 times larger than the Earth, and 50,000 times larger during a big flare.

Besides illuminating the possible habitability of Alpha Cen's planets, Chandra's X-ray history of AB plays into theoretical explorations of our own Sun's cyclical X-ray activity. Understanding this is a key to cosmic hazards such as Space Weather, which can impact the technology-laden civilization right here on our home world.

Tom Ayres presented these results at the 232rd meeting of the American Astronomical Society meeting in Denver, Colorado, and some of these results were published in January 2018 in the Research Notes of the American Astronomical Society. NASA's Marshall Space Flight Center in Huntsville, Alabama, manages the Chandra program for NASA's Science Mission Directorate in Washington. The Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, controls Chandra's science and flight operations.

Read More from NASA's Chandra X-ray Observatory.

For more Chandra images, multimedia and related materials, visit:

https://www.nasa.gov/chandra

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

10 Ways to BBQ on an Exoplanet

3 min read

NASA Science Editorial Team

There are over 3,700 planets in our galaxy. Spend Memorial Day barbecuing it up on any of these alien worlds.

Hang your steak on a fishing pole and dangle your meat over the boiling pools of lava on this possible magma world. Try two to three minutes on each side to get an ashy feast of deliciousness.

Set your grill to 1800 degrees Fahrenheit (982 degrees Celsius) or hop onto the first exoplanet discovered and get a perfect char on your hot dogs. By the time your dogs are done, it'll be New Year's Eve, because a year on this planet is only four days long.

Super air fry your duck on this Super Earth, as you skydive in the intense gravity of a planet seven times as massive as Earth. Why are you air frying a duck? We don't know. Why are you skydiving on an exoplanet? We're not judging.

I've got steaks, they're multiplying/and I'm looooosing control. Cause the power this planet is supplying/is electrifying!

Sear your tuna to perfection in the lightning strikes that scientists once thought flashed across the stormy skies of this Neptune-like planet.

Tired of all that meat? Try a multi-colored salad with the vibrant plants that could grow under the red sun of this Earth-sized planet. But it could also be a lifeless rock, so BYOB (bring your own barbecue).

Don't take too long to prep your vegetables for the grill! The hottest planet on record will flash-incinerate your veggies in seconds!

Picture this: You are pressure cooking your chicken on a hot gas giant in the shape of an egg. And you're under pressure to cook fast, because this gas giant is being pulled apart by its nearby star.

Evenly cook your ribs in a dual convection oven under the dual stars of this "Tatooine." Kick back and watch your two shadows grow in the fading light of a double sunset.

Order in for a staycation in our own solar system. The smell of rotten eggs rising from the clouds of sulfuric acid and choking carbon dioxide will put you off cooking, so get that meal to go.

Sometimes the best vacations are the ones you take at home. Flip your burgers on the only planet where you can breathe the atmosphere.

Come grill us on Twitter this Memorial Day, and tell us how bad our jokes are!

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

10 Ways to BBQ on an Exoplanet

3 min read

NASA Science Editorial Team

(WARNING: Don't try any of this on Earth—except the last one.)

Hang your steak on a fishing pole and dangle your meat over the boiling pools of lava on this possible magma world. Try two to three minutes on each side to get an ashy feast of deliciousness.

Set your grill to 1800 degrees Fahrenheit (982 degrees Celsius) or hop onto the first exoplanet discovered and get a perfect char on your hot dogs. By the time your dogs are done, it'll be New Year's Eve, because a year on this planet is only four days long.

Super air fry your duck on this Super Earth, as you skydive in the intense gravity of a planet twice as massive as Earth. Why are you air frying a duck? We don't know. Why are you skydiving on an exoplanet? We're not judging.

I've got steaks, they're multiplying/and I'm looooosing control. Cause the power this planet is supplying/is electrifying!

Sear your tuna to perfection in the lightning strikes that could flash across the stormy skies of this Neptune-like planet.

Tired of all that meat? Try a multi-colored salad with the vibrant plants that could grow under the red sun of this Earth-sized planet. But it could also be a lifeless rock, so BYOB (bring your own barbecue).

Don't take too long to prep your vegetables for the grill! The hottest planet on record will flash-incinerate your veggies in seconds!

Picture this: You are pressure cooking your chicken on a hot gas giant in the shape of an egg. And you're under pressure to cook fast, because this gas giant is being pulled apart by its nearby star.

Evenly cook your ribs in a dual convection oven under the dual stars of this "Tatooine." Kick back and watch your two shadows grow in the fading light of a double sunset.

Order in for a staycation in our own solar system. The smell of rotten eggs rising from the clouds of sulfuric acid and choking carbon dioxide will put you off cooking, so get that meal to go.

Sometimes the best vacations are the ones you take at home. Flip your burgers on the only planet where you can breathe the atmosphere.

Grill us on Twitter this Memorial Day and tell us how bad our jokes are.

Sun

Facts About Earth

Asteroids, Comets & Meteors

Kuiper Belt

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Take a virtual trip to a strange new world with NASA

NASA Science Editorial Team

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Giada Arney Attempts to Answer, “Are We Alone?”

7 min read

NASA Science Editorial Team

By Elizabeth Landau,NASA's Jet Propulsion Laboratory

We talked to astrobiologist Giada Arney about her work on finding signs of life among the stars. Arney is a research scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

I’m from the suburbs of Denver, Colorado.

My mom used to do stargazing with me and my sister in our backyard, when I was 4 or 5. I thought that was fun. I remember my mom would tell me and my sister about space stories she heard in the news, like the Voyagers visiting the outer planets, and that sparked my own interest. I also read every children's astronomy book in our local library. But at the time, I didn't necessarily think I wanted to do it as a career. It didn't click that you could do it as a career until later.

Giada Arney

research scientist, NASA's Goddard Space Flight Center

By the time I got to college, at some point I was like, 'This is cool, maybe I could do this for my job.' A lot of my friends were bouncing around between different majors but I knew I wanted to do astronomy.

I think it was a class I took my sophomore year of college, called E.T. Life, at the University of Colorado, that first introduced me to exoplanets. Some of my friends decided to form an astrobiology club, sparked by some of the things we learned in this class.

It was mostly hanging out in the planetarium and eating pizza and talking about astrobiology. But we also did field trips to Yellowstone and a conference in Arizona.

I took a year off between undergrad and grad school, working at an after-school science program for kids at an elementary school. After that year, I went to grad school at the University of Washington.

For my Ph.D. dissertation, I worked with Vikki Meadows, the principal investigator of the NASA Astrobiology Institute's Virtual Planetary Laboratory. The first project I worked on was about Venus, one of the least habitable planets you could imagine.

We observed Venus with the Apache Point Telescope in New Mexico. You can actually see below the cloud deck to the surface of Venus from Earth at certain wavelengths. Most people don’t know this. I made maps of the abundances of different trace gases in the lower atmosphere of Venus for this project. Even though Venus is a hostile environment today, there’s evidence it may once have had oceans of liquid water, so it’s really interesting to think about what happened to Venus and why.

Then, I shifted to working more on using early Earth as an analog for exoplanets, which are planets outside our solar system. I started working on a project called the Pale Orange Dot. Geochemical evidence suggests that between 4 and 2.5 billion years ago, there may have been an intermittent haze in the atmosphere of Earth similar to the haze in the atmosphere of Saturn’s moon Titan. It's a really alien phase of Earth's history – our planet wouldn't have been a pale blue dot, it would have been a pale orange dot.

We thought about questions like: What would our planet look like if you were looking at it as an exoplanet? How you might infer biosignatures – the signs of life – from looking at such an alien planet?

I think so. You would see water vapor features in the atmosphere. You would see tons of methane. Methane can be formed from geological processes, but biological processes tend to outpace geological processes. If you see a planet like Earth, with abundant carbon dioxide and water and methane in the atmosphere, that suggests that the methane is more likely to be produced by biology.

I started off as a NASA postdoctoral fellow, still working on photochemical modeling of planets – in particular, figuring out how we would know if a given gas in a planet's atmosphere is a biosignature or not. In January 2017, I was hired as a civil servant at NASA's Goddard Space Flight Center.

Usually I spend my day at my computer doing simulations and working on documents for LUVOIR (Large UV/Optical/IR Surveyor), a mission concept for characterizing planets. It is one of four concepts being studied for the next Astrophysics Decadal Survey. We want to find out: Are there habitable planets around nearby stars? Are we alone in the universe? If there is life on a nearby planet, and if there are biosignatures, how do we detect them? We want this mission to be able to answer these questions.

When I was studying Venus, I was trying to figure out the quantities of gases in Venus's lower atmosphere. I collected thousands of what scientists call spectra – basically, graphs showing how different molecules in the atmosphere react to various wavelengths of light. My big challenge was to make a computer model that matched the observations, so I could make sense of them and figure out the abundances of molecules. When I finally produced a model that looked like the real thing, that felt really powerful.

I got into Carl Sagan's "Cosmos" when I was in high school. My grad school advisors were also super inspirational: Vikki Meadows and Shawn Domagal-Goldman.

What I do is astrobiology. To do astrobiology, you need to become an expert in one discipline (for me, that's astronomy), but you need to know how to interact with people across a whole range of disciplines. I think a lot of scientists are not used to communicating with people in other fields, but it's a really fun and rewarding experience that makes the science so much richer. Stay curious and think about how your science connects to other areas of study. Planets are so complicated, especially when you throw life into the mix.

If you're a high schooler interested in astrobiology, the important thing is not to become overwhelmed by how much astrobiology encompasses. You don't have to become an expert in astronomy and biology and everything else. Specialize in one area, and make connections to people you can collaborate with who specialize in other things.

I love to travel. Most of my travel lately is work travel, but work has taken me to really cool places like the Australian outback and Tokyo. I always try to do fun things even when I travel for work. I love to try out new things. I recently took up crocheting. I do like to go to the Washington D.C. museums now that I live near them. I loved hiking when I lived in Colorado. I also love gardening.

My favorite space image is probably (Cassini's famous backlit Saturn image, with Earth in the background).

It's so beautiful, and I love that you can see Earth as a pale blue dot peeking between Saturn's rings. These are the kinds of images that remind me why I got into astronomy and planetary science in the first place.

As systems integration team lead for NASA’s Commercial Low Earth Orbit Development Program (CLDP), Hector Chavez helps build a future where NASA and private industry work together to push the boundaries of space exploration. With the rise of commercial providers in the space sector, Chavez’s team works to ensure that these companies can develop end-to-end […]

Senior Resource Analyst Julie Rivera Pérez ensures finances and assets are in place to enable missions’ engineering and science “magic” can happen. As a former intern, she also reaches out to current students to ensure a diverse and inclusive future workforce. Name: Julie Rivera PérezFormal Job Classification: Senior Resources AnalystOrganization: Systems Review Office/Resource Management Office, […]

During an event Thursday, NASA and the National Association for the Advancement of Colored People (NAACP) signed a Space Act Agreement to increase engagement and equity for underrepresented students pursuing science, technology, engineering, and mathematics (STEM) fields and to improve access to agency activities and opportunities. “NASA and the NAACP share a longstanding commitment to […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Stellar dust survey paves way for exoplanet missions

2 min read

NASA Science Editorial Team

Veils of dust wrapped around distant stars could make it difficult for scientists to find potentially habitable planets in those star systems. The Hunt for Observable Signatures of Terrestrial Systems, or HOSTS, survey was tasked with learning more about the effect of dust on the search for new worlds. The goal is to help guide the design of future planet-hunting missions. In a new paper published in the Astrophysical Journal, HOSTS scientists report on the survey's initial findings.

Using the Large Binocular Telescope Interferometer, or LBTI, on Mount Graham in Arizona, the HOSTS survey determines the brightness of warm dust floating in the orbital planes of other stars (called exozodiacal dust). In particular, HOSTS has studied dust in nearby stars' habitable zones, where liquid water could exist on the surface of a planet. The LBTI is five to 10 times more sensitive than the previous telescope capable of detecting exozodiacal dust, the Keck Interferometer Nuller.

Among the findings detailed in the new paper, the HOSTS scientists report that a majority of Sun-like stars in their survey do not possess high levels of dust – good news for future efforts to study potentially-habitable planets around those stars. A final report on the full HOSTS survey results is expected early next year.

More information about the new findings from HOSTS and the search for Earthlike planets beyond our solar system is available in this news release from the University of Arizona.

The LBTI is funded by NASA's Exoplanet Exploration Program office and managed by the agency's Jet Propulsion Laboratory in Pasadena, California. JPL is a division of Caltech, also in Pasadena. Six JPL scientists co-authored the new research paper. The LBTI is an international collaboration among institutions in the U.S., Italy and Germany, and it is managed and headquartered at the University of Arizona in Tucson.

NASA is taking a multifaceted approach to finding and studying planets outside our solar system. On April 18, NASA launched its newest planet-hunting observatory, the Transiting Exoplanet Survey Satellite (TESS), which is expected to find thousands of new exoplanets, mostly around stars smaller than our Sun.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA’s New Planet Hunter Snaps Initial Test Image, Swings by Moon Toward Final Orbit

3 min read

NASA’s next planet hunter, the Transiting Exoplanet Survey Satellite (TESS), is one step closer to searching for new worlds after successfully completing a lunar flyby on May 17. The spacecraft passed about 5,000 miles from the Moon, which provided a gravity assist that helped TESS sail toward its final working orbit.

As part of camera commissioning, the science team snapped a two-second test exposure using one of the four TESS cameras. The image, centered on the southern constellation Centaurus, reveals more than 200,000 stars. The edge of the Coalsack Nebula is in the right upper corner and the bright star Beta Centauri is visible at the lower left edge. TESS is expected to cover more than 400 times as much sky as shown in this image with its four cameras during its initial two-year search for exoplanets. A science-quality image, also referred to as a “first light” image, is expected to be released in June.

TESS will undergo one final thruster burn on May 30 to enter its science orbit around Earth. This highly elliptical orbit will maximize the amount of sky the spacecraft can image, allowing it to continuously monitor large swaths of the sky. TESS is expected to begin science operations in mid-June after reaching this orbit and completing camera calibrations.

Launched from Cape Canaveral Air Force Station in Florida on April 18, TESS is the next step in NASA’s search for planets outside our solar system, known as exoplanets. The mission will observe nearly the entire sky to monitor nearby, bright stars in search of transits — periodic dips in a star’s brightness caused by a planet passing in front of the star. TESS is expected to find thousands of exoplanets. NASA’s upcoming James Webb Space Telescope, scheduled for launch in 2020, will provide important follow-up observations of some of the most promising TESS-discovered exoplanets, allowing scientists to study their atmospheres.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT’s Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Orbital ATK, based in Dulles, Virginia; NASA’s Ames Research Center in California’s Silicon Valley; the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts; and the Space Telescope Science Institute in Baltimore. The TESS science instruments were jointly developed by MIT’s Kavli Institute for Astrophysics and Space Research and MIT’s Lincoln Laboratory. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

By Claire SaraviaNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New Exoplanet Collaboration Hosts Meeting to Explore Molecular Seeds of Life

5 min read

Earth's early days featured a catalog of environmental horrors including vigorous volcanic activity, an atmosphere lacking oxygen and a Sun that blasted our planet with X-ray flares and storms of charged particles more intense than what we see today. All in all, the young Earth doesn't sound as if it was a particularly hospitable place for the development of life. A better understanding of how life acquired and maintained its toehold on Earth will help prepare scientists for assessing conditions around worlds beyond our solar system, also known as exoplanets. It's a fitting topic for the Sellers Exoplanet Environments Collaboration (SEEC), a new interdisciplinary collaboration at NASA's Goddard Space Flight Center in Greenbelt, Maryland, which is exploring how the first molecules needed for life could have developed in such unlikely conditions.

SEEC is hosting its first annual symposium at Goddard April 9–13, which will be available via live webcast. Titled "Environments of Terrestrial Planets Under the Young Sun: Seeds of Biomolecules," the meeting will bring together researchers from eight countries to discuss how our knowledge of the early days of the solar system can be leveraged to study the environments of other worlds.

Researchers will present what is currently known about the conditions on planets like Earth and Mars under the early Sun, including how solar activity, climate and weather could have affected the development of biomolecules, the precursors of RNA and DNA, which are essential to life as we know it. Attendees will deliberate on how to best shape future research on exoplanet environments. Their conclusions will be submitted to journals for review by the scientific community.

Formed in 2017, SEEC's initial goals are to produce high-quality, cross-divisional research at Goddard, promote similar work in the larger scientific community and provide outreach by hosting workshops and facilitating collaboration across disciplines.

"Named after our preeminent astronaut and NASA science champion, the late Piers Sellers, SEEC will reveal valuable insights about the diversity of exoplanet atmospheres and climate," said Colleen Hartman, director of the Sciences and Exploration Directorate at Goddard. "This initiative harnesses Goddard's ability to combine capabilities from all of our science divisions — astrophysics, heliophysics, Earth sciences and solar system. Pooling our talent and resources gives us a significant advantage in our mission to answer the most pressing questions about our universe. With this collaborative approach, we will continue to blaze trails in scientific exploration and discovery."

Avi Mandell, a Goddard astrobiologist and SEEC's director, said these efforts are focused on preparing the tools scientists will need to interpret data from NASA exoplanet missions over the next 10 to 20 years. For example, the James Webb Space Telescope will use spectroscopy, the study of the absorption of light, to discover what molecules are in exoplanet atmospheres by looking at how they absorb light in the infrared.

"Right now, even if we succeeded in measuring a high-quality spectrum of a potentially habitable planet, we would only have the basic building blocks of the tools needed to interpret that spectrum and determine what the data are telling us about the planet," he said. "The long-term goal from all of SEEC's work is to be ready with a set of integrated and well-tested tools, institutional knowledge and collaborative relationships so we can dive into this type of research when the data arrive."

Part of that effort is housed in the Exoplanet Modeling and Analysis Center (EMAC), which is home to community modeling and analysis tools with an accessible web interface. A central hub for codes like this will help improve standardization and efficiency, explained Bill Danchi, a Goddard astrophysicist and deputy director of SEEC.

“EMAC is modeled on the Community Coordinated Modeling Center, which was developed by heliophysicists through NASA and the National Science Foundation,” Danchi said. “Without it, everybody would be spending a lot of time writing their own versions of the same algorithms — reinventing the wheel. With EMAC, users will be able to access tools through a web interface, and users can combine tools and add modules to do their new bit of physics. It’s more efficient. There’s agreement that the code is good, and it’s well tested by users in the community. It will produce numbers that make sense.”

Vladimir Airapetian, a Goddard astrophysicist and a member of the SEEC leadership team, said the goal of the meeting is to hammer out what we have, what we don’t have and what we need to move forward with exoplanet environment studies. The interdisciplinary background of the attendees reflects a crucial aspect of both the symposium and SEEC as a whole.

“Imagine that life is a big elephant in a dark room. You’re just seeing one of the legs, and therefore you call it life,” Airapetian said. “Another guy looks at the trunk and says, this is life. Goddard is the place where trunks and legs unify in three dimensions. That’s the only way to approach it, to bring those people together.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Web Sites, Social Media Honored in 2018 Webby Awards

4 min read

NASA Science Editorial Team

The 2018 Webby Awards have honored NASA's digital communications with one Webby, while three other NASA properties won the People's Voice Awards, given by popular vote, in their categories.

"Thank you to all of our NASA fans for your support in the voting and for your continued engagement with our websites and social media." said Jen Rae Wang, NASA's associate administrator for communications. "Credit for these awards goes to our extraordinary digital media teams throughout the agency and to the NASA employees who recognize the importance of our digital presence and support it. We will continue strive to set a standard of excellence for galaxy-wide communications."

The winners, nominees and honorees this year were:

Solar System Exploration: first Webby Award and second People's Voice Award for science website.

NASA's flagship website: 10th People's Voice Award for government. This is the third consecutive People's Voice Award for the site, which has also won three Webbys.

Exoplanet Exploration: first nomination and first People's Voice Award, in the Weird category.

Jet Propulsion Laboratory social media: People's Voice award for Corporate Communications.

Climate Change website: nominee in the Green category. The site has previously won a Webby Award and People's Voice Award.

NASA's Snapchat account: nominee in the Education and Discovery category.

The Cassini project's Real-Time Grand Finale was honored in the Best Use of Online Media.

NASA Webby Award winners, nominees and honorees, 1997-2018

The Office of Communications has managed NASA.gov, the agency's primary site on the World Wide Web, since 1994, setting a high standard for government online communications. The site has been awarded the Webby for government websites in 2003, 2012 and 2014, while the public has voted it the winner of the People's Voice award 10 times since 2002, most recently last year. The site receives almost 350,000 visits a day, surging when news piques the interest of the public. In 2017, the site anchored NASA's most popular online event ever: coverage of the Aug. 21 solar eclipse. More than 40 million people watched live TV coverage from across the path of totality on NASA.gov, the agency's Facebook page and other platforms. More than 12 million people watched multiple live video feeds of the eclipse from the ground, aircraft and balloons on NASA.gov, and the site saw almost 26 million sessions total, nearly a fifth of the year's total in one day.

NASA's Jet Propulsion Laboratory, which manages the Solar System Exploration, Exoplanet, Climate Change and Cassini sites, has produced many Webby and People's Voice winners over the years. The Climate Change website won the Science Webby in 2011 and 2015, as well as the People's Voice for Science in 2010. In 2013, the Solar System Exploration site won Webbys for both Government and Science, while the Mars Curiosity Rover Social Media Campaign won the Webby and People's Voice for Best Overall Social Presence. Most of NASA's awards have been in the government, science and education categories; the Exoplanet Exploration site's nomination is NASA's first in the Weird category.

NASA’s social media presence comprises more than 525 social media accounts on 18 platforms. Through this presence, NASA seeks to not just share new discoveries and stories about space exploration on social media, but to do so in a way that is understandable and engages the public to interact with our content. The agency’s flagship Twitter account now has more than 29 million followers, the most of any federal government agency and is in the top 100 overall accounts on the platform. NASA's flagship Instagram account has over 31 million followers and is in the top 50 accounts on the platform, in addition to NASA being the popular federal agency on Facebook and Google+. NASA maintains a robust presence sharing behind-the-scenes stories on Snapchat and curates highlights from around the agency on Tumblr, Pinterest, and GIPHY. All told, NASA's social media presence reaches more than 173 million followers across all agency accounts. Thanks in large part to social media, more people are now connecting and engaging with NASA and learning about its missions.

Established in 1996 by the International Academy of Digital Arts and Sciences, the Webby Awards honor excellence on the internet, including websites, advertising and media, online film and video, mobile sites, apps and social media. The Webby in each category is awarded by a judging panel, but members of the public can register with the Webby Awards and vote for the People's Voice Award in each category.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

On August 12-13, 24 students from the West Coast cohort of NASA’s Student Airborne Research Program (SARP) gathered at University of California, Irvine (UCI) to present their final research to a room of mentors, professors, family, and NASA personnel. SARP is an eight-week summer internship for undergraduate students, hosted in two cohorts: SARP West operates […]

Sun

Facts About Earth

Asteroids, Comets & Meteors

Kuiper Belt

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astrophysics CubeSat demonstrates big potential in a small package

4 min read

NASA Science Editorial Team

The ASTERIA satellite, which was deployed into low-Earth orbit in November, is only slightly larger than a box of cereal, but it could be used to help astrophysicists study planets orbiting other stars.

Mission managers at NASA's Jet Propulsion Laboratory in Pasadena, California, recently announced that ASTERIA has accomplished all of its primary mission objectives, demonstrating that the miniaturized technologies on board can operate in space as expected. This marks the success of one of the world's first astrophysics CubeSat missions, and shows that small, low-cost satellites could be used to assist in future studies of the universe beyond the solar system.

"ASTERIA is small but mighty," said Mission Manager Matthew W. Smith of JPL. "Packing the capabilities of a much larger spacecraft into a small footprint was a challenge, but in the end we demonstrated cutting-edge performance for a system this size."

ASTERIA, or the Arcsecond Space Telescope Enabling Research in Astrophysics, weighs only 22 pounds (10 kilograms). It carries a payload for measuring the brightness of stars, which allows researchers to monitor nearby stars for orbiting exoplanets that cause a brief drop in brightness as they block the starlight.

This approach to finding and studying exoplanets is called the transit method. NASA's Kepler Space Telescope has detected more than 2,300 confirmed planets using this method, more than any other planet-hunting observatory. The agency's next large-scale, space-based planet-hunting observatory, the Transiting Exoplanet Survey Satellite (TESS), is anticipated to discover thousands of exoplanets and scheduled to launch from Cape Canaveral Air Force Station in Florida on April 16.

In the future, small satellites like ASTERIA could serve as a low-cost method to identify transiting exoplanets orbiting bright, Sun-like stars. These small satellites could be used to look for planetary transits when larger observatories are not available, and planets of interest could then be studied in more detail by other telescopes. Small satellites like ASTERIA could also be used to study certain star systems that are not within the field of view of larger observatories, and most significantly, focus on star systems that have planets with long orbits that require long observation campaigns.

The ASTERIA team has now demonstrated that the satellite's payload can point directly and steadily at a bright source for an extended period of time, a key requirement for performing the precision photometry necessary to study exoplanets via the transit method.

Holding steady on a faraway star is difficult because there are many things that subtly push and pull on the satellite, such as Earth's atmosphere and magnetic field. ASTERIA's payload achieved a pointing stability of 0.5 arcseconds RMS, which refers to the degree to which the payload wobbles away from its intended target over a 20-minute observation period. The pointing stability was repeated over multiple orbits, with the stars positioned on the same pixels on each orbit.

"That's like being able to hit a quarter with a laser pointer from about a mile away," said Christopher Pong, the attitude and pointing control engineer for ASTERIA at JPL. "The laser beam has to stay inside the edge of the quarter, and then the satellite has to be able to hit that exact same quarter – or star – over multiple orbits around the Earth. So what we've accomplished is both stability and repeatability."

The payload also employed a control system to reduce "noise" in the data created by temperature fluctuations in the satellite, another major hurdle for an instrument attempting to carefully monitor stellar brightness. During observations, the temperature of the controlled section of the detector fluctuates by less than 0.02 Fahrenheit (0.01 Kelvin, or 0.01 degree Celsius).

ASTERIA is a CubeSat, a type of small satellite consisting of "units" that are 10 centimeters cubed, or about 4 inches on each side. ASTERIA is the size of six CubeSat units, making it roughly 10 centimeters by 20 centimeters by 30 centimeters. With its two solar panels unfolded, the satellite is about as long as a skateboard.

The ASTERIA mission utilized commercially available CubeSat hardware where possible, and is contributing to a general knowledge of how those components operate in space.

"We're continuing to characterize CubeSat components that other missions are using or want to use," said Amanda Donner, mission assurance manager for ASTERIA at JPL.

ASTERIA launched to the International Space Station in August 2017. Having been in space for more than 140 days, the satellite is operating on an extended mission through May.

ASTERIA was developed under the Phaeton Program at JPL. Phaeton provides early-career hires, under the guidance of experienced mentors, with the challenges of a flight project. ASTERIA is a collaboration with the Massachusetts Institute of Technology in Cambridge; where Sara Seager is the principal investigator.

In May 2024, a geomagnetic storm hit Earth, sending auroras across the planet’s skies in a once-in-a-generation light display. These dazzling sights are possible because of the interaction of coronal mass ejections – explosions of plasma and magnetic field from the Sun – with Earth’s magnetic field, which protects us from the radiation the Sun […]

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery alert! An Earth that looks like Neptune

2 min read

NASA Science Editorial Team

Planet: Kepler-1655 b

Discovered by: Raphaëlle D. Haywood et al.

Date: April 6, 2018

Key Facts: This new planet, discovered a whopping 750 light-years away, is twice the size of Earth. That usually would make it a "super Earth," but its discoverers believe that it may be a Neptune-like world, shrouded in gas. It orbits a star like the Sun, with a short year that lasts only 12 days.

What's new: This planet is a cool clue that helps answer the question: how big do planets have to be before they're gas giants? Not that big, apparently. Kepler-1655 b (the new planet) is only two times the size of Earth, but it's probably a gas planet like Neptune. That means that planets have to be pretty close to the size of Earth to be rocky worlds– recent studies think planets need to be 1.6 times the size of Earth or smaller to be terrestrial worlds. Our own solar system doesn't have a planet that's between the size of Neptune and Earth– but planets that size are actually the most common planets in the galaxy. These worlds are called "super Earths" or "mini Neptunes." And we're still figuring out if those planets are rocky or gassy. It's a space mystery, waiting to be solved.

See details and check the official NASA planet count at the NASA Exoplanet Archive

Paper: "An accurate mass determination for Kepler-1655b, a moderately-irradiated world with a significant volatile envelope"

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

New Study Shows What Interstellar Visitor ‘Oumuamua Can Teach Us

5 min read

The first interstellar object ever seen in our solar system, named ‘Oumuamua, is giving scientists a fresh perspective on the development of planetary systems. A new study by a team including astrophysicists at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, calculated how this visitor from outside our solar system fits into what we know about how planets, asteroids and comets form.

On Oct. 19, 2017, astronomers working with the NASA-funded Panoramic Survey Telescope and Rapid Response System (Pan-STARRS1) at the University of Hawaii spotted an object zipping through our solar system at a very high speed. Scientists at the Minor Planet Center, funded by NASA’s Near-Earth Object Observations Program, confirmed it was the first object of interstellar origin that we’ve seen. The team dubbed it ‘Oumuamua (pronounced oh-MOO-ah-MOO-ah), which means “a messenger from afar arriving first” in Hawaiian — and it’s already living up to its name.

“This object was likely ejected from a distant star system,” said Elisa Quintana, an astrophysicist at Goddard. “What’s interesting is that just this one object flying by so quickly can help us constrain some of our planet formation models.”

On Sept. 19, ‘Oumuamua sped past the Sun at about 196,000 mph (315,400 km/h), fast enough to escape the Sun’s gravitational pull and break free of the solar system, never to return. Usually, an object traveling at a similar speed would be a comet falling sunward from the outer solar system. Comets are icy objects that range between house-sized to many miles across. But they usually shed gas and dust as they approach the Sun and warm up. ‘Oumuamua didn’t. Some scientists interpreted this to mean that ‘Oumuamua was a dry asteroid.

Planets and planetesimals, smaller objects that include comets and asteroids, condense out of disks of dust, gas and ice around young stars. Smaller objects that form closer to their stars are too hot to have stable surface ice and become asteroids. Those that form farther away use ice as a building block and become comets. The region where asteroids develop is relatively small.

“The total real estate that’s hot enough for that is almost zero,” said lead author Sean Raymond, an astrophysicist at the French National Center for Scientific Research and the University of Bordeaux. “It’s these tiny little circular regions around stars. It’s harder for that stuff to get ejected because it’s more gravitationally bound to the star. It’s hard to imagine how ‘Oumuamua could have gotten kicked out of its system if it started off as an asteroid.”

The distance from a star beyond which water stays ice, even if it’s exposed to sunlight, is called the snow line or ice line. In our own solar system, for example, objects that developed within three times the distance between the Sun and Earth would have been so hot that they lost all their water. That snow line contracted a little as the Sun shrank and cooled over time, but our main belt asteroids are located within or near our snow line — close enough to the Sun that it would be difficult to be ejected.

“If we understand planet formation correctly, ejected material like ‘Oumuamua should be predominantly icy,” said Thomas Barclay, an astrophysicist at Goddard and the University of Maryland, Baltimore County. “If we see populations of these objects that are predominantly rocky, it tells us we’ve got something wrong in our models.”

Scientists suspect most ejected planetesimals come from systems with giant gas planets. The gravitational pull of these massive planets can fling objects out of their system and into interstellar space. Systems with giant planets in unstable orbits are the most efficient at ejecting these smaller bodies because as the giants shift around, they come into contact with more material. Systems that do not form giant planets rarely eject material.

Using simulations from previous research, Raymond and colleagues showed that a small percentage of objects get so close to gas giants as they're ejected that they should be torn into pieces. The researchers believe the strong gravitational stretching that occurs in these scenarios could explain 'Oumuamua's long, thin cigar-like shape.

The researchers calculated the number of interstellar objects we should see, based on estimates that a star system likely ejects a couple of Earth-masses of material during planet formation. They estimated that a few large planetesimals will hold most of that mass but will be outnumbered by smaller fragments like 'Oumuamua. The results were published March 27 in the journal Monthly Notices of the Royal Astronomical Society.

The findings have already been partially confirmed by observations of the object's color. Other studies have also noted that star systems like our own would be more likely to eject comets than asteroids. Future observatories like the National Science Foundation-funded Large Synoptic Survey Telescope could help scientists spot more of these objects and improve our statistical understanding of planet and planetesimal formation — even beyond our solar system.

"Even though this object was flying through our solar system, it does have implications for extrasolar planets and finding other Earths," Quintana said.

By Jeanette KazmierczakNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s next planet-hunting mission: 5 reasons TESS is going to be awesome

4 min read

NASA Science Editorial Team

by Elisa Quintana, astrophysicist,NASA Goddard Space Flight Center

The Transiting Exoplanet Survey Satellite (TESS), scheduled to launch on April 16, is NASA’s next mission to search for exoplanets – planets outside our solar system. It will look for small planets orbiting nearby, bright stars. TESS will rely on the transit method, looking for periodic dips in starlight that could reveal a planet passing in front of its star.

Here’s why TESS is going to be great:

Thanks to the trailblazing of NASA’s Kepler space telescope, scientists now believe there may be at least one planet around every star in the sky. Kepler successfully discovered nearly 2,700 confirmed planets of all sizes and around all types of stars, as part of its census of how common exoplanets were, by observing 5 percent of the sky during it primary and K2 missions. TESS is designed with a larger field of view and will cover more than 85 percent of the night sky in its search of nearby exoplanets.

Most of Kepler’s planets are hundreds of light-years away, close enough to measure their size and orbit, but too distant to search for any signs of life. TESS will observe stars that are nearby, relatively speaking, and 30 to 100 times brighter than those surveyed by Kepler, and therefore far easier to study with follow-up observations. TESS will usher in a new era, finding planets suitable for NASA’s upcoming James Webb Telescope, set to launch in 2020. The Webb telescope will examine light from these distant planets to learn the makeup of their atmospheres and look for signs of life.

Think of the sky as a giant sphere surrounding Earth, with TESS looking out from the inside. TESS will observe each half of that sphere for a year at a time, beginning in the south. In the first year, about 500 known exoplanets will be visible to TESS. In year two, over 3,000 will be in the TESS field of view – most of them Kepler planets, since TESS will be observing Kepler’s field of view.

TESS will collect starlight from over 200,000 stars every two minutes to search for transiting planets. In addition, TESS will also save the full images taken by each 16.8-megapixel camera every 30 minutes. These Full Frame Images (FFIs) will observe over 30 million astrophysical objects and will be available to the public. We now live in a time when anyone can be a planet (or star, or galaxy) hunter.

TESS plans to achieve its primary science goals with a two-year prime mission. But TESS has fuel reserves for more than a decade of operation if the mission is extended. TESS will be in a unique “high-Earth orbit” that has never been used before, and could remain in that orbit for over a hundred years!

Elisa Quintana is an astrophysicist and TESS Mission support scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland. George Ricker of MIT’s Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Orbital ATK, NASA’s Ames Research

Center, the Harvard-Smithsonian Center for Astrophysics and the Space Telescope Science Institute. More than a dozen universities, research institutes and observatories worldwide are participants in the mission.

For more information, please visit science.nasa.gov/mission/tess.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

10 Things: Exoplanets 101

3 min read

NASA Science Editorial Team

We call planets in our solar system, well, planets, but the many planets we’re starting to discover outside of our solar system are called exoplanets. Basically, they’re planets that orbit another star.

Remember the major 2016 announcement that NASA had discovered seven planets 40 light-years away, orbiting a star called TRAPPIST-1? Those are all exoplanets. (Here’s a refresher.)

Just last month, NASA’s Kepler telescope discovered 95 new exoplanets beyond our solar system (on top of the thousands of exoplanets Kepler has discovered so far). The total known planet count beyond our solar system is now more than 3,700. The planets range in size from mostly rocky super-Earths and fluffy mini-Neptunes, to Jupiter-like giants. They include a new planet orbiting a very bright star—the brightest star ever discovered by Kepler to have a transiting planet.

How many more exoplanets are out there waiting to be discovered? TESS will monitor more than 200,000 of the nearest and brightest stars in search of transit events—periodic dips in a star’s brightness caused by planets passing in front—and is expected to find thousands of exoplanets.

NASA’s upcoming James Webb Space Telescope will provide important follow-up observations of some of the most promising TESS-discovered exoplanets. It will also allow scientists to study their atmospheres and, in some special cases, search for signs that these planets could support life.

TESS is scheduled to launch on a SpaceX Falcon 9 rocket from Cape Canaveral Air Force Station nearby NASA’s Kennedy Space Center in Florida, no earlier than April 16, pending range approval.

In 1995, 51 Pegasi b (also called "Dimidium") was the first exoplanet discovered orbiting a star like our Sun. This find confirmed that planets like the ones in our solar system could exist elsewhere in the universe.

A recent statistical estimate places, on average, at least one planet around every star in the galaxy. That means there could be a trillion planets in our galaxy alone, many of them in the range of Earth’s size.

Of course, the NASA's ultimate science goal is to find unmistakable signs of current life. How soon can that happen? It depends on two unknowns: the prevalence of life in the galaxy and a bit of luck. Read more about the search for life.

No need to be an astronaut. Take a trip outside our solar system with help from NASA’s Exoplanet Travel Bureau.

Sun

Facts About Earth

Asteroids, Comets & Meteors

Kuiper Belt

Discovery alert! A weird alien Mercury as big as Earth

2 min read

NASA Science Editorial Team

Planet: K2-229 b

Discovered by: A. Santerne et al. using NASA's Kepler telescope

Date: March 26, 2018

Key Facts: Mercury, the planet closest to the Sun, isn't alone...there are more Mercury-like worlds out there. This new discovery resembles our solar system's innermost planet, but much bigger. K2-229 b is like Mercury on steroids; about the size of Earth, it's four times bigger and five times hotter. It orbits a star like our Sun, but the day side of the planet can get up to temperatures hot enough to vaporize rock– around 3,700 degrees Fahrenheit (2,000 Celsius). Like Mercury, K2-229 b is made mostly of heavy elements, like iron and nickle. These heavy elements can survive being close to the heat of a star. And unlike the Earth which is only 35 percent iron, K2-229 b, like Mercury, is 70 percent iron.

Fun fact: Mercury's name comes from the Roman god Mercury, the herald and messenger in Roman mythology. K2-229 b's name comes from the mission that found it, the Kepler telescope's K2 mission.

What's new: Humanity is just now on the brink of learning more about exoplanets, or the planets beyond our solar system. Everything up until now has been focused on the discovery of these worlds, but now we're beginning to characterize them. This latest find from the Kepler telescope looks like a planet in our solar system...but it's also not like anything we find in our solar system. That means there may be another Earth out there, with a personality all its own.

See details and check the official NASA planet count at the NASA Exoplanet Archive

Paper: "An Earth-sized exoplanet with a Mercury-like composition"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The planet that wasn’t there (Oh, wait, it was)

3 min read

NASA Science Editorial Team

by Pat Brennan

A massive gas giant more weighty than Jupiter, orbiting an orange star some 45 light years away, might be the most important exoplanet you’ve never heard of.

The planet, called Gamma Cephei A b – “Tadmor” for short – achieved its 15 minutes of fame in 1988. At least, among astronomers. It was the first planet to be discovered outside our solar system.

Or it would have been. The discovery was withdrawn by the Canadian team that announced it in 1992, after the data backing it up was determined to be too wobbly for astronomers to be sure the planet was real. Tadmor was added to a growing list of mistaken exoplanet detections that began as far back as the 19th century.

In this case, “wobbly” turns out to be the right word. The astronomers who thought they’d found the first exoplanet had developed a technique that allowed them to track the subtle motions of stars. The amount of “wobble” would reveal the mass of an object orbiting the star, tugging it first this way, then that. The researchers’ major advance was precision measurement – capturing stellar movements as small as 43 feet (13 meters) per second. That kind of precision was needed to pick up the tiny wobbles, back and forth, that a large orbiting planet caused the star to make.

Despite their advance, the research team, Bruce Campbell, Gordon Walker and Stephenson Yang, worried that periodic changes in the star’s magnetic activity might have looked to them like the gravitational tugs of a planet – in other words, that they might have mistaken jitters within the star for a planet in orbit around it.

They bid goodbye to Tadmor.

Riffle forward through the calendar, and stop in 2002. On-again, off-again Tadmor was on again – this time, its presence solidly confirmed. A team of astronomers that included the original discoverers captured strong evidence of the planet. They used four separate data sets from high-precision “wobble” measurements, known as radial velocity, spanning the period from 1981 to 2002.

The radial velocity method today has notched hundreds of exoplanet discoveries. It’s been overshadowed only by the “transit” method, responsible for thousands, that looks for a tiny dip in the light from a star as a planet passes in front of it.

And although the list of confirmed exoplanets was just beginning to grow in the early 2000s, Tadmor already had been eclipsed. A planet called 51 Pegasi b, discovered by Michel Mayor and Didier Queloz, stole most of the spotlight in 1995. It was the first confirmed exoplanet detection to capture worldwide public attention.

Tadmor, of course, continues to orbit its big orange sun, somewhere in the constellation Cepheus, presumably unaware of its near-fame on a small blue planet dozens of light-years away. Time rolls on. Happy 30th anniversary, Tadmor.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

10 Things: All About TRAPPIST-1

4 min read

Elizabeth Landau

The star we today call TRAPPIST-1 was first discovered in 1999 by astronomer John Gizis and colleagues. At that time, the ultra-cool dwarf star got the unwieldy name 2MASS J23062928-0502285, because it was spotted with the Two Micron All-Sky Survey (2MASS).

Then, in May 2016, scientists announced they had found three planet candidates around this star using the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile. Only two of the planets were confirmed, however. In honor of this telescope, scientists began referring to the star as TRAPPIST-1.

Read more: Promising worlds found around nearby ultra-cool dwarf star

NASA's Hubble Space Telescope was used to find that TRAPPIST-1b and c were unlikely to have hydrogen-dominated atmospheres like those we see in gas giants. This strengthens the case that these planets could be rocky and possibly hold onto water. This result was published in July 2016.

Read more: NASA's Hubble Telescope makes first atmospheric study of Earth-sized exoplanets

Astronomers using NASA's Spitzer Space Telescope and ground-based telescopes discovered that the system has seven planets. Three of these planets are in the theoretical "habitable zone," the area around a star where rocky planets are most likely to hold liquid water. This landmark finding was announced on Feb. 22, 2017.

Read more: NASA telescope reveals largest batch of Earth-size habitable zone planets around single star

Researchers determined that the farthest planet from the star, TRAPPIST-1h, orbits its star every 19 days, using NASA's Kepler space telescope. This is still much shorter than the orbit of Mercury, which goes around the Sun every 88 days. But because TRAPPIST-1 is so faint – it outputs only .05 percent the amount of energy of the Sun – planet h receives a lot less heat than Mercury, and may be covered in ice.

Read more: Astronomers confirm orbital details of TRAPPIST-1h

The age of a star is important for understanding whether planets around it could host life. Scientists wrote in an August 2017 study that TRAPPIST-1 is between 5.4 and 9.8 billion years old. This is up to twice as old as our own solar system, which formed some 4.5 billion years ago.

Read more: TRAPPIST-1 is older than our solar system

Throughout 2017, scientists worked on creating sophisticated computer models to simulate the planets based on available information. They used additional data from Spitzer, Kepler and ground-based telescopes to come up with the best-yet estimates for the planets' densities. The results are consistent with all of the TRAPPIST-1 planets being mostly made of rock. This result was published in February 2018.

Read more: New clues to compositions of TRAPPIST-1 planets

Continued observations with Hubble showed that TRAPPIST-1 d, e and f are unlikely to have puffy, hydrogen-dominated atmospheres, as of February 2018. Scientists will need more data to determine how much hydrogen TRAPPIST-1g has.

Read more: Hubble probes atmospheres of exoplanets in TRAPPIST-1 habitable zone

The TRAPPIST-1 planets are so close together that if you could stand on the surface of one, you might see some of the neighboring planets hovering above. This idea was inspirational for the TRAPPIST-1 travel poster.

You can download your own here: TRAPPIST-1 poster

While we can't take photos of the planets themselves, visualization specialists at Caltech/IPAC in Pasadena, California, work with scientists and their data to come up with illustrations of the TRAPPIST-1 system. Read more about Robert Hurt and Tim Pyle here:

Read more: An image is worth a thousand worlds

On Feb. 22 at 1:30 PT, we'll have a Facebook Live talking about illustrating the TRAPPIST-1 planets, how Spitzer works and more. Follow NASA PlanetQuest to learn more this week

Watch Live: https://www.facebook.com/NasaPlanetquest/

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Finds a Large Amount of Water in an Exoplanet’s Atmosphere

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Much like detectives study fingerprints to identify the culprit, scientists used NASA’s Hubble and Spitzer space telescopes to find the “fingerprints” of water in the atmosphere of a hot, bloated, Saturn-mass exoplanet some 700 light-years away. And, they found a lot of water. In fact, the planet, known as WASP-39b, has three times as much water as Saturn does.

Though no planet like this resides in our solar system, WASP-39b can provide new insights into how and where planets form around a star, say researchers. This exoplanet is so unique, it underscores the fact that the more astronomers learn about the complexity of other worlds, the more there is to learn about their origins. This latest observation is a significant step toward characterizing these worlds.

Although the researchers predicted they’d see water, they were surprised by how much water they found in this “hot Saturn.” Because WASP-39b has so much more water than our famously ringed neighbor, it must have formed differently. The amount of water suggests that the planet actually developed far away from the star, where it was bombarded by a lot of icy material. WASP-39b likely had an interesting evolutionary history as it migrated in, taking an epic journey across its planetary system and perhaps obliterating planetary objects in its path.

“We need to look outward so we can understand our own solar system,” explained lead investigator Hannah Wakeford of the Space Telescope Science Institute in Baltimore, Maryland, and the University of Exeter in Devon, United Kingdom. “But exoplanets are showing us that planet formation is more complicated and more confusing than we thought it was. And that’s fantastic!”

Wakeford and her team were able to analyze the atmospheric components of this exoplanet, which is similar in mass to Saturn but profoundly different in many other ways. By dissecting starlight filtering through the planet’s atmosphere into its component colors, the team found clear evidence for water. This water is detected as vapor in the atmosphere.

Using Hubble and Spitzer, the team has captured the most complete spectrum of an exoplanet’s atmosphere possible with present-day technology. “This spectrum is thus far the most beautiful example we have of what a clear exoplanet atmosphere looks like,” said Wakeford.

“WASP-39b shows exoplanets can have much different compositions than those of our solar system,” said co-author David Sing of the University of Exeter in Devon, United Kingdom. “Hopefully this diversity we see in exoplanets will give us clues in figuring out all the different ways a planet can form and evolve.”

Located in the constellation Virgo, WASP-39b whips around a quiet, Sun-like star, called WASP-39, once every four days. The exoplanet is currently positioned more than 20 times closer to its star than Earth is to the Sun. It is tidally locked, meaning it always shows the same face to its star.

Its day-side temperature is a scorching 1,430 degrees Fahrenheit (776.7 degrees Celsius). Powerful winds transport heat from the day-side around the planet, keeping the permanent night-side almost as hot. Although it is called a “hot Saturn,” WASP-39b is not known to have rings. Instead, is has a puffy atmosphere that is free of high-altitude clouds, allowing Wakeford and her team to peer down into its depths.

Looking ahead, Wakeford hopes to use the James Webb Space Telescope — scheduled to launch in 2019 — to get an even more complete spectrum of the exoplanet. Webb will be able to give information about the planet’s atmospheric carbon, which absorbs light at longer, infrared wavelengths than Hubble can see. By understanding the amount of carbon and oxygen in the atmosphere, scientists can learn even more about where and how this planet formed.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA’s Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, Inc., in Washington, D.C.

NASA’s Jet Propulsion Laboratory, Pasadena, California, manages the Spitzer Space Telescope mission for NASA’s Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

Related Links

Contacts:

Ann Jenkins / Ray VillardSpace Telescope Science Institute, Baltimore, Md.410-338-4488 / 410-338-4514jenkins@stsci.edu / villard@stsci.edu

Calla CofieldJet Propulsion Laboratory, Pasadena, Calif.818-354-5011calla.e.cofield@jpl.nasa.gov

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

10 Things: Exoplanets 101

3 min read

NASA Science Editorial Team

We call planets in our solar system, well, planets, but the many planets we're starting to discover outside of our solar system are called exoplanets. Basically, they're planets that orbit another star.

Remember the major 2016 announcement that NASA had discovered seven planets 40 light-years away, orbiting a star called TRAPPIST-1? Those are all exoplanets. (Here's a refresher.)

Just last month, NASA's Kepler telescope discovered 95 new exoplanets beyond our solar system (on top of the thousands of exoplanets Kepler has discovered so far). The total known planet count beyond our solar system is now more than 3,700. The planets range in size from mostly rocky super-Earths and fluffy mini-Neptunes, to Jupiter-like giants. They include a new planet orbiting a very bright star—the brightest star ever discovered by Kepler to have a transiting planet.

How many more exoplanets are out there waiting to be discovered? TESS will monitor more than 200,000 of the nearest and brightest stars in search of transit events—periodic dips in a star's brightness caused by planets passing in front—and is expected to find thousands of exoplanets.

NASA's upcoming James Webb Space Telescope, scheduled for launch in 2019, will provide important follow-up observations of some of the most promising TESS-discovered exoplanets. It will also allow scientists to study their atmospheres and, in some special cases, search for signs that these planets could support life.

TESS is scheduled to launch on a SpaceX Falcon 9 rocket from Cape Canaveral Air Force Station nearby NASA's Kennedy Space Center in Florida, no earlier than April 16, pending range approval.

In 1995, 51 Pegasi b (also called "Dimidium") was the first exoplanet discovered orbiting a star like our Sun. This find confirmed that planets like the ones in our solar system could exist elsewhere in the universe.

A recent statistical estimate places, on average, at least one planet around every star in the galaxy. That means there could be a trillion planets in our galaxy alone, many of them in the range of Earth's size.

Of course, the NASA's ultimate science goal is to find unmistakable signs of current life. How soon can that happen? It depends on two unknowns: the prevalence of life in the galaxy and a bit of luck. Read more about the search for life.

No need to be an astronaut. Take a trip outside our solar system with help from NASA's Exoplanet Travel Bureau.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

10 Things: All About TRAPPIST-1

4 min read

NASA Science Editorial Team

The star we today call TRAPPIST-1 was first discovered in 1999 by astronomer John Gizis and colleagues. At that time, the ultra-cool dwarf star got the unwieldy name 2MASS J23062928-0502285, because it was spotted with the Two Micron All-Sky Survey (2MASS).

Then, in May 2016, scientists announced they had found three planets around this star using the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile. In honor of this telescope, scientists began referring to the star as TRAPPIST-1.

› Read More:
https://www.nasa.gov/feature/promising-worlds-found-around-nearby-ultra-cool-dwarf-star

NASA's Hubble Space Telescope was used to find that TRAPPIST-1b and c were unlikely to have hydrogen-dominated atmospheres like those we see in gas giants. This strengthens the case that these planets could be rocky and possibly hold onto water. This result was published in July 2016.

› Read More: https://www.nasa.gov/press-release/nasa-s-hubble-telescope-makes-first-atmospheric-study-of-earth-sized-exoplanets

Astronomers using NASA's Spitzer Space Telescope and ground-based telescopes discovered that the system has seven planets. Three of these planets are in the theoretical "habitable zone," the area around a star where rocky planets are most likely to hold liquid water. This landmark finding was announced on Feb. 22, 2017.

› Read More: https://exoplanets.nasa.gov/news/1419/nasa-telescope-reveals-largest-batch-of-earth-size-habitable-zone-planets-around-single-star/

Researchers determined that the farthest planet from the star, TRAPPIST-1h, orbits its star every 19 days, using NASA's Kepler space telescope. This is still much shorter than the orbit of Mercury, which goes around the Sun every 88 days. But because TRAPPIST-1 is so faint – it outputs only .05 percent the amount of energy of the Sun – planet h receives a lot less heat than Mercury, and may be covered in ice.

› Read More: https://www.nasa.gov/feature/ames/kepler/astronomers-confirm-orbital-details-of-trappist1-least-understood-planet

The age of a star is important for understanding whether planets around it could host life. Scientists wrote in an August 2017 study that TRAPPIST-1 is between 5.4 and 9.8 billion years old. This is up to twice as old as our own solar system, which formed some 4.5 billion years ago.

› Read More: https://www.nasa.gov/feature/jpl/trappist-1-is-older-than-our-solar-system

Throughout 2017, scientists worked on creating sophisticated computer models to simulate the planets based on available information. They used additional data from Spitzer, Kepler and ground-based telescopes to come up with the best-yet estimates for the planets' densities. The results are consistent with all of the TRAPPIST-1 planets being mostly made of rock. This result was published in February 2018.

› Read More: https://www.jpl.nasa.gov/news/news.php?release=2018-022

Continued observations with Hubble showed that TRAPPIST-1 d, e and f are unlikely to have puffy, hydrogen-dominated atmospheres, as of February 2018. Scientists will need more data to determine how much hydrogen TRAPPIST-1g has.

› Read More: http://hubblesite.org/news_release/news/2018-07

The TRAPPIST-1 planets are so close together that if you could stand on the surface of one, you might see some of the neighboring planets hovering above. This idea was inspirational for the TRAPPIST-1 travel poster.

You can download your own here: https://exoplanets.nasa.gov/trappist1/#Poster

While we can't take photos of the planets themselves, visualization specialists at Caltech/IPAC in Pasadena, California, work with scientists and their data to come up with illustrations of the TRAPPIST-1 system. Read more about Robert Hurt and Tim Pyle here:

› Read More: https://www.jpl.nasa.gov/news/news.php?feature=6868

On Feb. 22 at 1:30 PT, we'll have a Facebook Live talking about illustrating the TRAPPIST-1 planets, how Spitzer works and more. Follow NASA PlanetQuest to learn more this week

› Read More: https://www.facebook.com/NasaPlanetquest/

Sun

Facts About Earth

Asteroids, Comets & Meteors

Kuiper Belt

NASA’s Transiting Exoplanet Survey Satellite Arrives at Kennedy Space Center for Launch

2 min read

NASA’s next planet-hunting mission has arrived in Florida to begin preparations for launch. The Transiting Exoplanet Survey Satellite (TESS) is scheduled to launch on a SpaceX Falcon 9 rocket from Cape Canaveral Air Force Station nearby NASA’s Kennedy Space Center in Florida no earlier than April 16, pending range approval. TESS was delivered Feb. 12 aboard a truck from Orbital ATK in Dulles, Virginia, where it spent 2017 being assembled and tested. Over the next month, the spacecraft will be prepped for launch at Kennedy’s Payload Hazardous Servicing Facility (PHSF).

TESS is the next step in NASA’s search for planets outside our solar system, known as exoplanets. The mission will scan nearly the entire sky to monitor more than 200,000 of the nearest and brightest stars in search of transit events — periodic dips in a star’s brightness caused by planets passing in front of their stars. TESS is expected to find thousands of exoplanets. The upcoming James Webb Space Telescope, scheduled for launch in 2019, will provide important follow-up observations of some of the most promising TESS-discovered exoplanets, allowing scientists to study their atmospheres and, in some special cases, to search for signs that these planets could support life.

TESS is a NASA Astrophysics Explorer mission led and operated by MIT in Cambridge, Massachusetts, and managed by NASA’s Goddard Space Flight Center in Greenbelt, Maryland. Dr. George Ricker of MIT’s Kavli Institute for Astrophysics and Space Research serves as principal investigator for the mission. Additional partners include Orbital ATK, NASA’s Ames Research Center in California’s Silicon Valley, the Harvard-Smithsonian Center for Astrophysics and the Space Telescope Science Institute. More than a dozen universities, research institutes and observatories worldwide are participants in the mission. NASA’s Launch Services Program is responsible for launch management. SpaceX of Hawthorne, California, is the provider of the Falcon 9 launch service.

By Claire SaraviaNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery alert! 95 new planets found with NASA telescope

1 min read

NASA Science Editorial Team

Discovery: 95 new planets!

Discovered by: Andrew Mayo et al. using NASA's Kepler telescope

Date: February 15, 2018

Key Facts: Ninety-five new exoplanets were discovered beyond our solar system! The planets range in size from mostly rocky super-Earths and fluffy mini-Neptunes to Jupiter-like giants. They include a new planet orbiting a very bright star– the brightest star ever discovered by Kepler to have a transiting planet. The new worlds were found using NASA's Kepler telescope, which launched almost a decade ago.

What's new: Planets, in all shapes and sizes! These discoveries aren't just cool– they're also somewhat of a miracle. During its first mission, parts of the Kepler telescope broke in a way that almost left it drifting. Instead, engineers figured out how to get it back on track. Kepler's second mission, called K2, has confirmed over 300 planets since then.

See details and check the official NASA planet count at the NASA Exoplanet Archive

Paper: "275 candidates and 149 validated planets orbiting bright stars in K2 campaigns 0-10"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

New Clues to TRAPPIST-1 Planet Compositions, Atmospheres

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

In the year since NASA announced the seven Earth-sized planets of the TRAPPIST-1 system, scientists have been working hard to better understand these enticing worlds just 40 light-years away. Thanks to data from a combination of space- and ground-based telescopes, we know more about TRAPPIST-1 than any other planetary system besides our solar system.

A new study in the journal Astronomy and Astrophysics, using data from NASA's Spitzer and Kepler space telescopes, offers the best-yet picture of what these planets are made of. They used the telescope observations to calculate the densities more precisely than ever, then used those numbers in complex simulations. Researchers determined that all of the planets are mostly made of rock. Additionally, some have up to 5 percent of their mass in water, which is 250 times more than the oceans on Earth.

The form that water takes on TRAPPIST-1 planets would depend on how much heat they receive from their ultra-cool dwarf star, which is only about 9 percent as massive as our Sun. Planets closest to the star are more likely to host water in the form of atmospheric vapor, while those farther away may have water frozen on their surfaces as ice. TRAPPIST-1e is the rockiest planet of them all, but is still believed to have the potential to host some liquid water.

The question of the planets' atmospheres is also important for understanding whether liquid water could be present on these surfaces -- an essential ingredient for habitability. NASA's Hubble Space Telescope has now surveyed six of the seven TRAPPIST-1 planets, and new results on four of them are published in Nature Astronomy. In the new study, Hubble reveals that at least three of the TRAPPIST-1 planets -- d, e, and f -- do not seem to contain puffy, hydrogen-rich atmospheres like the gas giants of our own solar system. Hydrogen is a greenhouse gas, and would make these close-in planets hot and inhospitable to life.

In 2016, Hubble observations also did not find evidence for hydrogen atmospheres in b and c. These results and the new ones, instead, favor more compact atmospheres like those of Earth, Venus and Mars. Additional observations are needed to determine the hydrogen content of planet g's atmosphere

Both studies help pave the way for NASA’s James Webb Space Telescope, scheduled to launch in 2019. Webb will probe deeper into the planetary atmospheres, searching for heavier gases such as carbon dioxide, methane, water and oxygen. The presence of such elements could offer hints of whether life could be present, or if the planets are habitable.

TRAPPIST-1 is named for the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile, which discovered two of the seven TRAPPIST planets we know of today -- announced in February 2016. NASA's Spitzer Space Telescope, in collaboration with ground-based telescopes, confirmed these planets and uncovered the other five in the system.

For more information about TRAPPIST-1, visit:

https://exoplanets.nasa.gov/trappist1

For more information about Spitzer and Kepler’s findings, visit:

https://www.jpl.nasa.gov/news/news.php?feature=7052

For more information about Hubble’s findings, visit:

http://hubblesite.org/news_release/news/2018-07

Updated on Feb. 13, 2018 at 5:20 p.m. PST to correct the two innermost TRAPPIST-1 planets Hubble has studied. They are TRAPPIST-1b and c.

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

2018-022

In May 2024, a geomagnetic storm hit Earth, sending auroras across the planet’s skies in a once-in-a-generation light display. These dazzling sights are possible because of the interaction of coronal mass ejections – explosions of plasma and magnetic field from the Sun – with Earth’s magnetic field, which protects us from the radiation the Sun […]

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

Happy Valentine’s Day

2 min read

NASA Science Editorial Team

Send your love from outer space! Share or download six out-of-this-world valentines to send to your space-ial someone.

Tell someone they're as unique as the only life-bearing planet we know. Though we've found thousands of planets spinning in the galaxy, we haven't yet found any to match the beauty of the vibrant life on our home planet.

Save card

Keep your valentine close with a tidally-locked planet that always faces its star. Tidally-locked planets are so close to their star, the strength of their star's gravity locks one side of the planet in a sunny day, and the other half in lasting starry night.

Save card

Celebrate your rocking single status with a rogue planet! Rogue planets float freely through the universe, without the gravity of a star or planetary system to hold them in one place. You could say they're dancing among the stars.

Save card

Give these tight-knit worlds to your faves. The Kepler-11 system is made up of six planets closely packed together. If these exoplanets from light-years away were dropped into our solar system, all six would fit between Venus and the Sun. Talk about a close family.

Save card

Celebrate with a Jupiter that's red hot. A hot Jupiter is a kind of gas giant that tightly hugs its star. Its orbit lasts a few days or weeks, equal to one year on Earth.

Save card

Tell someone they're just right for you. A planet in the habitable zone of its star is one that's not too hot and not too cold, but just right for liquid water.

Save card

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Two Telescopes Reveal Clues to TRAPPIST-1 Planet Compositions, Atmospheres

3 min read

NASA Science Editorial Team

In the year since NASA announced the seven Earth-sized planets of the TRAPPIST-1 system, scientists have been working hard to better understand these enticing worlds just 40 light-years away. Thanks to data from a combination of space- and ground-based telescopes, we know more about TRAPPIST-1 than any other planetary system besides our solar system.

A new study in the journal Astronomy and Astrophysics, using data from NASA's Spitzer and Kepler space telescopes, offers the best-yet picture of what these planets are made of. They used the telescope observations to calculate the densities more precisely than ever, then used those numbers in complex simulations. Researchers determined that all of the planets are mostly made of rock. Additionally, some have up to 5 percent of their mass in water, which is 250 times more than the oceans on Earth.

The form that water takes on TRAPPIST-1 planets would depend on how much heat they receive from their ultra-cool dwarf star, which is only about 9 percent as massive as our Sun. Planets closest to the star are more likely to host water in the form of atmospheric vapor, while those farther away may have water frozen on their surfaces as ice. TRAPPIST-1e is the rockiest planet of them all, but is still believed to have the potential to host some liquid water.

The question of the planets' atmospheres is also important for understanding whether liquid water could be present on these surfaces -- an essential ingredient for habitability. NASA's Hubble Space Telescope has now surveyed six of the seven TRAPPIST-1 planets, and new results on four of them are published in Nature Astronomy. In the new study, Hubble reveals that at least three of the TRAPPIST-1 planets -- d, e, and f -- do not seem to contain puffy, hydrogen-rich atmospheres like the gas giants of our own solar system. Hydrogen is a greenhouse gas, and would make these close-in planets hot and inhospitable to life.

In 2016, Hubble observations also did not find evidence for hydrogen atmospheres in c and d. These results and the new ones, instead, favor more compact atmospheres like those of Earth, Venus and Mars. Additional observations are needed to determine the hydrogen content of planet g's atmosphere.

Both studies help pave the way for NASA’s James Webb Space Telescope, scheduled to launch in 2019. Webb will probe deeper into the planetary atmospheres, searching for heavier gases such as carbon dioxide, methane, water and oxygen. The presence of such elements could offer hints of whether life could be present, or if the planets are habitable.

TRAPPIST-1 is named for the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile, which discovered two of the seven TRAPPIST planets we know of today -- announced in February 2016. NASA's Spitzer Space Telescope, in collaboration with ground-based telescopes, confirmed these planets and uncovered the other five in the system.

For more information about TRAPPIST-1, visit:

https://exoplanets.nasa.gov/trappist1

For more information about Spitzer and Kepler’s findings, visit:

https://www.jpl.nasa.gov/news/news.php?feature=7052

For more information about Hubble’s findings, visit:

http://hubblesite.org/news_release/news/2018-07

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery alert! Iron-massive super Earth

1 min read

NASA Science Editorial Team

System: K2-141

Discovered by: Luca Malavolta et al. and Barragán et al. using NASA's Kepler telescope

Date: January 18, 2018

Key Facts: This discovery includes a super Earth five times Earth's mass, that orbits an orange Sun-like star. This planet takes only six hours to orbit its K-type star, a journey that takes Mercury 88 days, making it a hot inferno world! K2-141 b is denser than Earth because of its greater mass and its larger iron core. It also has a Neptune-size companion that takes about eight days to orbit the same star.

What's new: The super Earth K2-141 b is what's known as an ultra-short period planet, a class of planet that takes less than one day to orbit its star. The origin of these planets is still a mystery. Similar short-orbit rocky planets might be lava-ocean worlds, because of their scorching heat from their nearby star. The discovery of the rocky K2-141 b may help explain how these planets form.

See details and check the official NASA planet count at the NASA Exoplanet Archive

Paper: "An ultra-short period rocky super-Earth with a secondary eclipse and a Neptune-like companion around K2-141"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Poised to Topple a Planet-Finding Barrier

4 min read

Optics Experts Measure to Picometer Accuracy — a NASA First

NASA optics experts are well on the way to toppling a barrier that has thwarted scientists from achieving a long-held ambition: building an ultra-stable telescope that locates and images dozens of Earth-like planets beyond the solar system and then scrutinizes their atmospheres for signs of life.

Babak Saif and Lee Feinberg at NASA's Goddard Space Flight Center in Greenbelt, Maryland, have shown for the first time that they can dynamically detect subatomic- or picometer-sized distortions — changes that are far smaller than an atom — across a five-foot segmented telescope mirror and its support structure. Collaborating with Perry Greenfield at the Space Telescope Science Institute in Baltimore, the team now plans to use a next-generation tool and thermal test chamber to further refine their measurements.

The measurement feat is good news to scientists studying future missions for finding and characterizing extrasolar Earth-like planets that potentially could support life.

To find life, these observatories would have to gather and focus enough light to distinguish the planet's light from that of its much brighter parent star and then be able to dissect that light to discern different atmospheric chemical signatures, such as oxygen and methane. This would require a super-stable observatory whose optical components move or distort no more than 12 picometers, a measurement that is about one-tenth the size of a hydrogen atom.

To date, NASA has not built an observatory with such demanding stability requirements.

How Displacements Occur

Displacements and movement occur when materials used to build telescopes shrink or expand due to wildly fluctuating temperatures, such as those experienced when traveling from Earth to the frigidity of space, or when exposed to fierce launch forces more than six-and-a-half times the force of gravity.

Scientists say that even nearly imperceptible, atomic-sized movements would affect a future observatory's ability to gather and focus enough light to image and analyze the planet's light. Consequently, mission planners must design telescopes to picometer accuracies and then test it at the same level across the entire structure, not just between the telescope's reflective mirrors. Movement occurring at any particular position might not accurately reflect what's actually happening in other locations.

"These future missions will require an incredibly stable observatory," said Azita Valinia, deputy Astrophysics Projects Division program manager. "This is one of the highest technology tall poles that future observatories of this caliber must overcome. The team's success has shown that we are steadily whittling away at that particular obstacle."

The Initial Test

To carry out the test, Saif and Feinberg used the High-Speed Interferometer, or HSI — an instrument that the Arizona-based 4D Technology developed to measure nanometer-sized dynamic changes in the James Webb Space Telescope's optical components — including its 18 mirror segments, mounts, and other supporting structures — during thermal, vibration and other types of environmental testing.

Like all interferometers, the instrument splits light and then recombines it to measure tiny changes, including motion. The HSI can quickly measure dynamic changes across the mirror and other structural components, giving scientists insights into what is happening all across the telescope, not just in one particular spot.

Even though the HSI was designed to measure nanometer or molecule-sized distortions — which was the design standard for Webb — the team wanted to see it could use the same instrument, coupled with specially developed algorithms, to detect even smaller changes over the surface of a spare five-foot Webb mirror segment and its support hardware.

The test proved it could, measuring dynamic movement as small as 25 picometers — about twice the desired target, Saif said.

Next Steps

However, Goddard and 4D Technology have designed a new high-speed instrument, called a speckle interferometer, that allows measurements of both reflective and diffuse surfaces at picometer accuracies. 4D Technology has built the instrument and the Goddard team has begun initial characterization of its performance in a new thermal-vacuum test chamber that controls internal temperatures to a frosty 1-millikelvin.

Saif and Feinberg plan to place test items inside the chamber to see if they can achieve the 12-picometer target accuracy.

“I think we’ve made a lot of progress. We’re getting there,” Saif said.

For more Goddard technology news, go to https://www.nasa.gov/wp-content/uploads/2018/02/winter_2018_final_lowrez.pdf?emrc=640796

By Lori KeeseyNASA’s Goddard Space Flight Center

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

No Planets Needed: NASA Study Shows Disk Patterns Can Self-Generate

5 min read

When scientists searching for exoplanets — worlds located beyond our solar system — first spotted patterns in disks of dust and gas around young stars, they thought newly formed planets might be the cause. But a recent NASA study cautions that there may be another explanation — one that doesn't involve planets at all.

Exoplanet hunters watch stars for a few telltale signs that there might be planets in orbit, like changes in the color and brightness of the starlight. For young stars, which are often surrounded by disks of dust and gas, scientists look for patterns in the debris — such as rings, arcs and spirals — that might be caused by an orbiting world.

"We're exploring what we think is the leading alternative contender to the planet hypothesis, which is that the dust and gas in the disk form the patterns when they get hit by ultraviolet light," said Marc Kuchner, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Kuchner presented the findings of the new study on Thursday, Jan. 11, at the American Astronomical Society meeting in Washington. A paper describing the results has been submitted to The Astrophysical Journal.

When high-energy UV starlight hits dust grains, it strips away electrons. Those electrons collide with and heat nearby gas. As the gas warms, its pressure increases and it traps more dust, which in turn heats more gas. The resulting cycle, called the photoelectric instability (PeI), can work in tandem with other forces to create some of the features astronomers have previously associated with planets in debris disks.

Kuchner and his colleagues designed computer simulations to better understand these effects. The research was led by Alexander Richert, a doctoral student at Penn State in University Park, Pennsylvania, and includes Wladimir Lyra, a professor of astronomy at California State University, Northridge and research associate at NASA's Jet Propulstion Laboratory in Pasadena, California. The simulations were run on the Discover supercomputing cluster at the NASA Center for Climate Simulation at Goddard.

In 2013, Lyra and Kuchner suggested that PeI could explain the narrow rings seen in some disks. Their model also predicted that some disks would have arcs, or incomplete rings, which were first directly observed in 2016.

"People very often model these systems with planets, but if you want to know what a disk with a planet looks like, you first have to know what a disk looks like without a planet," Richert said.

Richert is lead author on the new study, which builds on Lyra and Kuchner's previous simulations by including an additional new factor: radiation pressure, a force caused by starlight striking dust grains.

Light exerts a minute physical force on everything it encounters. This radiation pressure propels solar sails and helps direct comet tails so they always point away from the Sun. The same force can push dust into highly eccentric orbits, and even blow some of the smaller grains out of the disk entirely.

The researchers modeled how radiation pressure and PeI work together to affect the movement of dust and gas. They also found that the two forces manifest different patterns depending on the physical properties of the dust and gas.

The 2013 simulations of PeI revealed how dust and gas interact to create rings and arcs, like those observed around the real star HD 141569A. With the inclusion of radiation pressure, the 2017 models show how these two factors can create spirals like those also observed around the same star. While planets can also cause these patterns, the new models show scientists should avoid jumping to conclusions.

“Carl Sagan used to say extraordinary claims require extraordinary evidence,” Lyra said. “I feel we are sometimes too quick to jump to the idea that the structures we see are caused by planets. That is what I consider an extraordinary claim. We need to rule out everything else before we claim that.”

Kuchner and his colleagues said they would continue to factor other parameters into their simulations, like turbulence and different types of dust and gas. They also intend to model how these factors might contribute to pattern formation around different types of stars.

A NASA-funded citizen science project spearheaded by Kuchner, called Disk Detective, aims to discover more stars with debris disks. So far, participants have contributed more than 2.5 million classifications of potential disks. The data has already helped break new ground in this research.

By Jeanette KazmierczakNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Multi-planet System Found Through Crowdsourcing

2 min read

NASA Science Editorial Team

A system of at least five exoplanets has been discovered by citizen scientists through a project called Exoplanet Explorers, part of the online platform Zooniverse, using data from NASA's Kepler space telescope. This is the first multi-planet system discovered entirely through crowdsourcing. A study describing the system has been accepted for publication in The Astronomical Journal.

Thousands of citizen scientists got to work on Kepler data in 2017 when Exoplanet Explorers launched. It was featured on a program called Stargazing Live on the Australia Broadcasting Corporation (ABC). On the final night of the three-day program, researchers announced the discovery of a four-planet system. Since then, they have named it K2-138 and determined that it has a fifth planet -- and perhaps even a sixth, according to the new paper.

Another batch of 2017 Kepler data was recently uploaded to Exoplanet Explorers for citizen scientists to peer through. Astronomers have not yet searched through most of it for planets.

Read more from Caltech

NASA's Ames Research Center manages the Kepler and K2 missions for NASA’s Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

Year in review: Top 5 NASA moments of 2017

4 min read

NASA Science Editorial Team

For New Year’s Eve, we’re sharing the top moments of the past year in NASA’s search for life and planets outside our solar system. Here are a few of the most exciting discoveries of 2017, as we count down to a new year, and new worlds.

This year brought us one of the most exciting discoveries yet: a system of seven worlds that sets a new record for the greatest number of habitable-zone planets found around a single star. All seven of TRAPPIST-1 planets could have liquid water under the right atmospheric conditions, but the chances are highest with the three in the habitable zone. The three planets in the habitable zone are in the area around the parent star where a rocky planet is most likely to have the temperature for liquid water– which is key to life as we know it. But recent findings suggest life would have an uphill battle on a planet close to a red dwarf star like TRAPPIST-1, largely because such stars are extremely active in their early years—shooting off potentially lethal flares and bursts of radiation.

More: NASA telescope reveals largest batch of Earth-size, habitable-zone planets around single star

Our solar system now is tied for most number of planets around a single star, with the recent discovery of an eighth planet circling Kepler-90, a Sun-like star 2,545 light-years from Earth. The newly-discovered Kepler-90 i – a sizzling hot, rocky planet that orbits its star once every 14.4 days – was found in data from NASA’s Kepler Space Telescope, using machine learning from Google. In this case, computers learned to identify the signals caused by planets by finding instances in Kepler data where the telescope recorded changes in starlight caused by planets beyond our solar system, known as exoplanets.

More: See the Kepler-90 system in 3D

The technology to directly image exoplanets is still in early stages, but the results are already spectacular. This new movie shows four planets more massive than Jupiter orbiting their star HR 8799, more than 100 light-years from Earth. The movie is actually a series of images taken over seven years at the W.M. Keck Observatory in Hawaii. Only a small fraction of the planets' full orbits are shown over this time period. The closest-in planet circles the star in around 40 years; the furthest takes more than 400 years.

More: See "Many Worlds"

A delightfully strange discovery of 2017 was made by NASA’s Hubble Space Telescope: a blistering hot planet outside our solar system where it "snows" sunscreen. The problem is the sunscreen (titanium oxide) precipitation only happens on the planet's permanent night side. Any possible visitors to the exoplanet, called Kepler-13A b, would need to bottle up some of that sunscreen, because they won't find it on the sizzling hot, daytime side, which always faces its host star.

More: Hubble observes exoplanet that snows sunscreen

If you like oddball planets, here’s a contender for the weirdest. In 2017, NASA's Hubble Space Telescope observed a pitch-black exoplanet that’s the shape of an egg. WASP-12 b looks as black as fresh asphalt because it eats light rather than reflecting it back into space. The doomed Jupiter-like planet is also being stretched into the shape of an egg by the tidal forces of its extremely close star, which will ultimately destroy it.

More: NASA's Hubble captures blistering pitch-black planet

This year marked the 100th anniversary since the first evidence of planets outside our solar system. But the photographic proof of this astonishing discovery was overlooked and buried in the Mount Wilson Observatory archives, because no one knew exoplanets existed. The data was only rediscovered and published last year.

More: See the first exoplanet evidence

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New Study Finds ‘Winking’ Star May Be Devouring Wrecked Planets

5 min read

A team of U.S. astronomers studying the star RZ Piscium has found evidence suggesting its strange, unpredictable dimming episodes may be caused by vast orbiting clouds of gas and dust, the remains of one or more destroyed planets.

“Our observations show there are massive blobs of dust and gas that occasionally block the star’s light and are probably spiraling into it,” said Kristina Punzi, a doctoral student at the Rochester Institute of Technology (RIT) in New York and lead author of a paper describing the findings. “Although there could be other explanations, we suggest this material may have been produced by the break-up of massive orbiting bodies near the star.”

RZ Piscium is located about 550 light-years away in the constellation Pisces. During its erratic dimming episodes, which can last as long as two days, the star becomes as much as 10 times fainter. It produces far more energy at infrared wavelengths than emitted by stars like our Sun, which indicates the star is surrounded by a disk of warm dust. In fact, about 8 percent of its total luminosity is in the infrared, a level matched by only a few of the thousands of nearby stars studied over the past 40 years. This implies enormous quantities of dust.

These and other observations led some astronomers to conclude that RZ Piscium is a young Sun-like star surrounded by a dense asteroid belt, where frequent collisions grind the rocks to dust.

But the evidence was far from clear. An alternative view suggests the star is instead somewhat older than our Sun and just beginning its transition into the red giant stage. A dusty disk from the star’s youth would have dispersed after a few million years, so astronomers needed another source of dust to account for the star’s infrared glow. Because the aging star is growing larger, it would doom any planets in close orbits, and their destruction could provide the necessary dust.

So which is it, a young star with a debris disk or a planet-smashing stellar senior? According to the research by Punzi and her colleagues, RZ Piscium is a bit of both.

The team investigated the star using the European Space Agency’s (ESA) XMM-Newton satellite, the Shane 3-meter telescope at Lick Observatory in California and the 10-meter Keck I telescope at W. M. Keck Observatory in Hawaii.

Young stars are often prodigious X-ray sources. Thanks to 11 hours of XMM-Newton observations, Punzi’s team shows that RZ Piscium is, too. Its total X-ray output is roughly 1,000 times greater than our Sun’s, essentially clinching the case for stellar youth.

The team’s ground-based observations revealed the star’s surface temperature to be about 9,600 degrees Fahrenheit (5,330 degrees Celsius), only slightly cooler than the Sun’s. They also show the star is enriched in the tell-tale element lithium, which is slowly destroyed by nuclear reactions inside stars.

“The amount of lithium in a star’s surface declines as it ages, so it serves as a clock that allows us to estimate the elapsed time since a star’s birth,” said co-author Joel Kastner, director of RIT’s Laboratory for Multiwavelength Astrophysics. “Our lithium measurement for RZ Piscium is typical for a star of its surface temperature that is about 30 to 50 million years old.”

So while the star is young, it’s actually too old to be surrounded by so much gas and dust. “Most Sun-like stars have lost their planet-forming disks within a few million years of their birth,” said team member Ben Zuckerman, an astronomy professor at the University of California, Los Angeles. “The fact that RZ Piscium hosts so much gas and dust after tens of millions of years means it’s probably destroying, rather than building, planets.”

Ground-based observations also probed the star’s environment, capturing evidence that the dust is accompanied by substantial amounts of gas. Based on the temperature of the dust, around 450 degrees F (230 degrees C), the researchers think most of the debris is orbiting about 30 million miles (50 million kilometers) from the star.

“While we think the bulk of this debris is about as close to the star as the planet Mercury ever gets to our Sun, the measurements also show variable and rapidly moving emission and absorption from hydrogen-rich gas,” said co-author Carl Melis, an associate research scientist at the University of California, San Diego. “Our measurements provide evidence that material is both falling inward toward the star and also flowing outward.”

A paper reporting the findings was published Thurs., Dec. 21, in The Astronomical Journal.

The best explanation that accounts for all of the available data, say the researchers, is that the star is encircled by debris representing the aftermath of a disaster of planetary proportions. It’s possible the star’s tides may be stripping material from a close substellar companion or giant planet, producing intermittent streams of gas and dust, or that the companion is already completely dissolved. Another possibility is that one or more massive gas-rich planets in the system underwent a catastrophic collision in the astronomically recent past.

ESA’s XMM-Newton observatory was launched in December 1999 from Kourou, French Guiana. NASA funded elements of the XMM-Newton instrument package and provides the NASA Guest Observer Facility at Goddard, which supports use of the observatory by U.S. astronomers.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Spanning Disciplines in the Search for Life Beyond Earth

9 min read

Download related briefing materials from Dec. 13's press conference at the 2017 American Geophysical Union meeting.

The search for life beyond Earth is riding a surge of creativity and innovation. Following a gold rush of exoplanet discovery over the past two decades, it is time to tackle the next step: determining which of the known exoplanets are proper candidates for life.

Scientists from NASA and two universities presented new results dedicated to this task in fields spanning astrophysics, Earth science, heliophysics and planetary science — demonstrating how a cross-disciplinary approach is essential to finding life on other worlds — at the fall meeting of the American Geophysical Union on Dec. 13, 2017, in New Orleans, Louisiana.

"The potentially habitable real estate in the universe has greatly expanded," said Giada Arney, an astrobiologist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "We now know of thousands of exoplanets, but what we know about them is limited because we can't yet see them directly."

Currently, scientists mostly rely on indirect methods to identify and study exoplanets; such methods can tell them whether a planet is Earth-like or how close it is to its parent star. But this isn't yet enough to say whether a planet is truly habitable, or suitable for life — for this, scientists must ultimately be able to observe exoplanets directly.

Direct-imaging instrument and mission designs are underway, but in the meantime, Arney explained, scientists are making progress with tools already at their disposal. They are building computational models to simulate what habitable planets might look like and how they would interact with their parent stars. To validate their models, they are looking to planets within our own solar system, as analogs for the exoplanets we may one day discover. This, of course, includes Earth itself — the planet we know best, and the only one we know of yet that is habitable.

"In our quest for life on other worlds, it is important for scientists to consider exoplanets from a holistic sense — that is, from the perspective of multiple disciplines," Arney said. "We need these multi-disciplinary studies to examine exoplanets as the complex worlds shaped by multiple astrophysical, planetary and stellar processes, rather than just distant points in the sky."

When humans start collecting the first direct images of exoplanets, even the closest image will appear as a handful of pixels. What can we learn about planetary life from just a smattering of pixels?

Stephen Kane, an exoplanets expert at the University of California, Riverside, has come up with one way to answer that question using NASA's Earth Polychromatic Imaging Camera aboard the National Oceanic and Atmospheric Administration's Deep Space Climate Observatory, or DSCOVR. Kane explained that he and his colleagues take DSCOVR's high-resolution images — typically used to document Earth's global weather patterns and other climate-related events — and degrade them down to images just a few pixels in size. Kane runs the DSCOVR images through a noise filter that attempts to simulate the interference expected from an exoplanet mission.

"From just a handful of pixels, we try to extract as much information that we know about Earth as we can," Kane said. "If we can do it accurately for Earth, we can do this for planets around other stars."

DSCOVR takes a picture every half hour and it's been in orbit for two years. Its more than 30,000 images are by far the longest continuous record of full-disk observations from space in existence. By observing how the brightness of Earth changes when mostly land is in view compared with mostly water, Kane has been able to reverse-engineer Earth's albedo, obliquity, rotation rate and even seasonal variation — something that has yet to be measured directly for exoplanets — all of which could potentially influence a planet's ability to support life.

Much the way scientists use Earth as a case-study for habitable planets, they also use planets within the solar system — and therefore planets they are more familiar with — as studies for what makes planets uninhabitable.

Kane also studies Earth's sister planet, Venus, where the surface is 850 degrees Fahrenheit and the atmosphere — filled with sulfuric acid — bogs down on the surface with 90 times the pressure of Earth's. Since Earth and Venus are so close in size and yet so different in terms of their prospects for habitability, he is interested in developing methods for distinguishing Earth- and Venus-analogs in other planetary systems, as a way of identifying potentially habitable terrestrial planets.

Kane explained that he works to identify Venus analogs in data from NASA's Kepler by defining the "Venus Zone," where planetary insolation — how much light a given planet receives from its host star — plays a key role in atmospheric erosion and greenhouse gas cycles.

"The fate of Earth and Venus and their atmospheres are tied to each other," Kane said. "By searching for similar planets, we are trying to understand their evolution, and ultimately how often developing planets end up a Venus-like hellscape."

While Kane talked about planets, Goddard space scientist Katherine Garcia-Sage focused on the way planets interact with their host star. Scientists must also consider how the qualities of a host star and a planet's electromagnetic environment — which can shield it from harsh stellar radiation — either hinder or help habitability. Earth's magnetic field, for example, protects the atmosphere from the harsh solar wind, the Sun's constant outpouring of charged solar material, which can strip away atmospheric gases in a process called ionospheric escape.

Garcia-Sage described research on Proxima b, an exoplanet that is four light-years away and known to exist within the habitable zone of its red dwarf star, Proxima Centauri. But just because it's in the habitable zone — the right distance from a star where water could pool on a planet's surface — doesn't necessarily mean it's habitable.

While scientists can't yet tell whether Proxima b is magnetized, they can use computational models to simulate how well an Earth-like magnetic field would protect its atmosphere at the exoplanet's close orbit to Proxima Centauri, which frequently produces violent stellar storms. The effects of such storms on a given planet's space environment are collectively known as space weather.

"We need to understand a planet's space weather environment to understand whether a planet is habitable," Garcia-Sage said. "If the star is too active, it can endanger an atmosphere, which is necessary for providing liquid water. But there's a fine line: There is some indication that radiation from a star can produce building blocks for life."

A red dwarf star — one of the most common types of stars in our galaxy — like Proxima Centauri strips away atmosphere when extreme ultraviolet radiation ionizes atmospheric gases, producing a swath of electrically charged particles that can stream out into space along magnetic field lines.

The scientists calculated how much radiation Proxima Centauri produces on average, based on observations from NASA's Chandra X-ray Observatory. At Proxima b's orbit, the scientists found their Earth-like planet encountered bouts of extreme ultraviolet radiation hundreds of times greater than Earth does from the Sun.

Garcia-Sage and her colleagues designed a computer model to study whether an Earth-like planet — with Earth's atmosphere, magnetic field and gravity — in Proxima b's orbit could hold on to its atmosphere. They examined three factors that drive ionospheric escape: stellar radiation, temperature of the neutral atmosphere, and size of the polar cap, the region over which the escape happens.

The scientists show that with the extreme conditions likely to exist at Proxima b, the planet could lose an amount equivalent to the entirety of Earth's atmosphere in 100 million years — just a fraction of Proxima b's 4 billion years thus far. Even in the best-case scenario, that much mass escapes over 2 billion years, well within the planet's lifetime.

While Garcia-Sage spoke of magnetized planets, David Brain, planetary scientist at the University of Colorado, Boulder, spoke of Mars — a planet without a magnetic field.

"Mars is a great laboratory for thinking about exoplanets," Brain said. "We can use Mars to help constrain our thinking about a variety of rocky exoplanets where we don't have observations yet."

Brain's research uses observations from NASA's Mars Atmosphere and Volatile Evolution, or MAVEN, mission to ask the question: How would Mars have evolved if it were orbiting a different kind of star? The answer provides information for how rocky planets — not unlike our own — could develop differently in different situations.

It is thought that Mars once carried water and an atmosphere that might have made it hospitable to Earth-like life. But Mars lost much of its atmosphere over time through a variety of chemical and physical processes — MAVEN has observed similar atmospheric loss on the planet since its launch in late 2013.

Brain, a MAVEN co-investigator, and his colleagues applied MAVEN's insights to a hypothetical simulation of a Mars-like planet orbiting an M-class star — commonly known as a red dwarf star. In this imaginary situation, the planet would receive about five to 10 times more ultraviolet radiation than the real Mars does, which in turn speeds up atmospheric escape to much higher rates. Their calculations indicate that the planet's atmosphere could lose three to five times as many charged particles and about five to 10 times more neutral particles.

Such a rate of atmospheric loss suggests that orbiting at the edge of the habitable zone of a quiet M-class star, instead of our Sun, could shorten the habitable period for the planet by a factor of about five to 20.

"But I wouldn't give up hope for rocky planets orbiting M dwarfs," Brain said. "We picked a worst-case scenario. Mars is a small planet, and lacks a magnetic field so solar wind can more effectively strip away its atmosphere. We also picked a Mars that isn't geologically active, so there's no internal source of atmosphere. If you changed any one factor, such a planet might be a happier place."

Each one of these studies contributes just one piece to a much larger puzzle — to determine what characteristics we should look for, and need to recognize, in the search for a planet that might support life. Together, such interdisciplinary research lays the groundwork to ensure that, as new missions to observe exoplanets more clearly are developed, we'll be ready to determine if they might just host life.

By Lina Tran, Karen Fox, Elizabeth
Zubritsky, Carol RasmussenNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Holiday Special: Eight Nights of Exoplanet Light

5 min read

NASA Science Editorial Team

For the holidays, we’re bringing you eight examples of light from real planets beyond our solar system. These real images show exoplanets light-years (aka trillions of miles) away from Earth. Exoplanets are far away, and they are millions of times dimmer than the stars they orbit. So, unsurprisingly, taking pictures of them the same way you'd take pictures of, say Jupiter or Venus, is exceedingly hard. But new techniques and rapidly-advancing technology are making it happen.

Four giants twirl around their star in a slow dance over eight years of observation. Each moving dot is a gas giant planet more massive than Jupiter; the innermost planet takes 40 years to orbit its star, and the furthest takes 400 years! The wonder of seeing another star system 129 light-years away hasn’t faded since the images were first taken. The black circle in the center of the image is from a coronagraph, which purposely blocks the light of the young star to reveal the much fainter light from the planets. The HR 8799 system can be found in the constellation Pegasus.

Download image

Read more

One of our best views of an exoplanet moving in its orbit around a distant star. Beta Pictoris b is a massive planet about 63 light-years away, orbiting the second-brightest star in the constellation Pictoris. This gas giant is about 10 times more massive than Jupiter, and passes through a bright ring of dust and debris as it circles its star. A series of images captured between November 2013 to April 2015 shows the exoplanet as it moves through 1.5 years of its 22-year orbital period. The planet is nearly 100,000 times fainter than its star; a device inside the telescope called a coronagraph blocks the light of star Beta Pictoris so the planet is visible.

Download image

Read more

The bright moving spot is 51 Eridani b, the most Jupiter-like exoplanet ever imaged, about 100 light-years from Earth. A series of images taken over three years, beginning December 2014, shows a small fraction of this gas planet’s 41-year orbit around its Sun-like star. 51 Eridani b is still young enough that it glows from the heat of its birth. The striking young Jupiter hints at how our own Jupiter may have formed long ago.

Download image

Read more

A tiny dot begins its long journey around its bright star. Though it’s almost too small to see next to the “eye of Sauron,” Fomalhaut b is a planet almost twice Jupiter's size. It’s also one of the few planets with a name chosen by the public– Dagon, a Semitic deity that’s half man and half fish. The illusion of a giant eye is created by the Hubble Space Telescope; the blue and white streaks are scattered starlight, reflected by its coronagraph. Dagon is only 25 light-years away from Earth, and takes 872 years orbit its star. This video shows its orbit from 2004 to 2012.

Download image

Read more

Hot, clouded with dust, and really, really big. The gas giant HIP 65426b, discovered using the European Southern Observatory's Very Large Telescope, is believed to be between six and 12 times the mass of Jupiter. It has a thickly clouded atmosphere and a searing temperature of 1,800 to 2,500 degrees Fahrenheit (1,000 to 1,400 degrees Celsius), and it orbits a hot, young star. Just how the planet formed is a puzzle. One possibility is that it's really a failed star, its domineering companion – and now its host star – preventing it from gathering sufficient mass. In this image, the starlight is blocked out so the light from its giant companion can be seen.

Read more

Like a baby photo, the brightly colored lights show infant planets in the making. There are 450 light-years between Earth and LkCa15, a young star with a doughnut-shaped protoplanetary disk around it, also known as a birthplace for planets. This composite image of the young star system LkCa15 is the first photo of several planets being formed. Protoplanetary disks form around young stars using the debris left over from the star's formation. Though scientists don't know for certain, it's theorized that planets then form from this spinning disk of gas and dust around the young star. The color in this image has been added afterwards.

Read more

This celestial body is a cherry. Gliese 504 b glows pink with heat, like a dark cherry blossom in space. This giant's star can be seen from Earth, faintly visible in the constellation Virgo, 57 light-years away. Its massive pink companion is probably a brown dwarf, an object too big to be a planet but not massive enough to burn like a star. Like planets, brown dwarfs can have atmospheres, storms, and clouds. Gliese 504 b takes 260 years to orbit its Sun-like star.

Read more

The massive world HD 106906 b is one of the most distantly orbiting planets found around a Sun-like star. More than 20 times the distance than Neptune is from the Sun, this gas giant takes 3,000 years to complete one trip around its star! Its extreme separation from its parent star puzzled astronomers and challenged our idea of how solar systems form. The young world weighs in at 11 times Jupiter's mass, and still burns with the heat of its formation. The image above was taken in thermal infrared light, where the giant planet is brightest, and processed to remove the bright light from its host star, HD 106906 A.

Read more

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery of eight planets makes alien system the first to tie with our solar system

6 min read

NASA Science Editorial Team

Our solar system is tied for most number of planets around a single star, with the 2017 discovery of an eighth planet circling Kepler-90, a Sun-like star 2,545 light-years from Earth. The planet was discovered in data from NASA's Kepler Space Telescope.

Kepler-90i – a sizzling hot, rocky planet that orbits its star once every 14.4 days – was found using machine learning from Google. Machine learning is an approach to artificial intelligence in which computers "learn." In this case, computers learned to identify planets by finding in Kepler data instances where the telescope recorded changes in starlight caused by planets beyond our solar system, known as exoplanets.

Explore the eight Kepler-90 planets with a click or a tap, or make it fullscreen.

The discovery of an eighth planet makes the Kepler-90 system the first to tie our solar system for number of planets. Like our solar system, Kepler-90 has rocky planets close to its Sun-like star, with gas giants orbiting farther away. Kepler-90 is over 2,000 light-years away, and none of its planets are considered good candidates for life.

NASA hosted a Reddit Ask Me Anything on this discovery.

"Just as we expected, there are exciting discoveries lurking in our archived Kepler data, waiting for the right tool or technology to unearth them," said Paul Hertz, director of NASA's Astrophysics Division in Washington. "This finding shows that our data will be a treasure trove available to innovative researchers for years to come."

Andrew Vanderburg

NASA Sagan Postdoctoral Fellow

The discovery came about after researchers Christopher Shallue and Andrew Vanderburg trained a computer to learn how to identify exoplanets in the light readings recorded by Kepler – the miniscule change in brightness captured when a planet passed in front of, or transited, a star. Inspired by the way neurons connect in the human brain, this artificial "neural network" sifted through Kepler data and found weak transit signals from a previously-missed eighth planet orbiting Kepler-90, in the constellation Draco.

Machine learning has previously been used in searches of the Kepler database, and this continuing research demonstrates that neural networks are a promising tool in finding some of the weakest signals of distant worlds.

[Kepler finds Largest batch of Earth-size, habitable zone planets]

Other planetary systems probably hold more promise for life than Kepler-90. About 30 percent larger than Earth, Kepler-90i is so close to its star that its average surface temperature is believed to exceed 800 degrees Fahrenheit, on par with Mercury. Its outermost planet, Kepler-90h, orbits at a similar distance to its star as Earth does to the Sun.

“The Kepler-90 star system is like a mini version of our solar system. You have small planets inside and big planets outside, but everything is scrunched in much closer,” said Vanderburg, a NASA Sagan Postdoctoral Fellow and astronomer at the University of Texas at Austin.

Shallue, a senior software engineer with Google’s research team Google AI, came up with the idea to apply a neural network to Kepler data. He became interested in exoplanet discovery after learning that astronomy, like other branches of science, is rapidly being inundated with data as the technology for data collection from space advances.

[Stand on the surface of another planet with our 360 virtual reality]

“In my spare time, I started Googling for ‘finding exoplanets with large data sets’ and found out about the Kepler mission and the huge data set available,” said Shallue. "Machine learning really shines in situations where there is so much data that humans can't search it for themselves.”

Kepler’s four-year dataset consists of 35,000 possible planetary signals. Automated tests, and sometimes human eyes, are used to verify the most promising signals in the data. However, the weakest signals often are missed using these methods. Shallue and Vanderburg thought there could be more interesting exoplanet discoveries faintly lurking in the data.

First, they trained the neural network to identify transiting exoplanets using a set of 15,000 previously vetted signals from the Kepler exoplanet catalog. In the test set, the neural network correctly identified true planets and false positives 96 percent of the time. Then, with the neural network having "learned" to detect the pattern of a transiting exoplanet, the researchers directed their model to search for weaker signals in 670 star systems that already had multiple known planets. Their assumption was that multiple-planet systems would be the best places to look for more exoplanets.

“We got lots of false positives of planets, but also potentially more real planets,” said Vanderburg. “It’s like sifting through rocks to find jewels. If you have a finer sieve then you will catch more rocks but you might catch more jewels, as well.”

Kepler-90i wasn’t the only jewel this neural network sifted out. In the Kepler-80 system, they found a sixth planet. This one, the Earth-sized Kepler-80g, and four of its neighboring planets form what is called a resonant chain – where planets are locked by their mutual gravity in a rhythmic orbital dance. The result is an extremely stable system, similar to the seven planets in the TRAPPIST-1 system.

Their research paper reporting these findings was published in The Astronomical Journal.

Kepler produced an unprecedented data set for exoplanet hunting. After gazing at one patch of space for four years, the spacecraft operated on an extended mission and was retired in 2018.

“These results demonstrate the enduring value of Kepler’s mission,” said Jessie Dotson, Kepler’s project scientist at NASA’s Ames Research Center in California’s Silicon Valley. “New ways of looking at the data – such as this early-stage research to apply machine learning algorithms – promise to continue to yield significant advances in our understanding of planetary systems around other stars. I’m sure there are more firsts in the data waiting for people to find them.”

Ames managed the Kepler and K2 missions for NASA’s Science Mission Directorate in Washington. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder. This work was performed through the Carl Sagan Postdoctoral Fellowship Program executed by the NASA Exoplanet Science Institute.

For more information on this announcement, visit:

https://www.nasa.gov/mediaresources

For more information about the Kepler mission, visit:

https://www.nasa.gov/kepler

Felicia ChouHeadquarters, Washington202-358-0257felicia.chou@nasa.gov

Alison HawkesAmes Research Center, California’s Silicon Valley650-604-0281alison.j.hawkesbak@nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Mars Mission Sheds Light on Habitability of Distant Planets

5 min read

Related Story: Spanning Disciplines in the Search for Life Beyond Earth

Following a gold rush of exoplanet discovery, the next step in the search for life is determining which of the known exoplanets are proper candidates for life — and for this, a cross-disciplinary approach is essential.

How long might a rocky, Mars-like planet be habitable if it were orbiting a red dwarf star? It's a complex question but one that NASA's Mars Atmosphere and Volatile Evolution mission can help answer.

"The MAVEN mission tells us that Mars lost substantial amounts of its atmosphere over time, changing the planet's habitability," said David Brain, a MAVEN co-investigator and a professor at the Laboratory for Atmospheric and Space Physics at the University of Colorado Boulder. "We can use Mars, a planet that we know a lot about, as a laboratory for studying rocky planets outside our solar system, which we don't know much about yet."

At the fall meeting of the American Geophysical Union on Dec. 13, 2017, in New Orleans, Louisiana, Brain described how insights from the MAVEN mission could be applied to the habitability of rocky planets orbiting other stars.

MAVEN carries a suite of instruments that have been measuring Mars' atmospheric loss since November 2014. The studies indicate that Mars has lost the majority of its atmosphere to space over time through a combination of chemical and physical processes. The spacecraft's instruments were chosen to determine how much each process contributes to the total escape.

In the past three years, the Sun has gone through periods of higher and lower solar activity, and Mars also has experienced solar storms, solar flares and coronal mass ejections. These varying conditions have given MAVEN the opportunity to observe Mars' atmospheric escape getting cranked up and dialed down.

Brain and his colleagues started to think about applying these insights to a hypothetical Mars-like planet in orbit around some type of M-star, or red dwarf, the most common class of stars in our galaxy.

The researchers did some preliminary calculations based on the MAVEN data. As with Mars, they assumed that this planet might be positioned at the edge of the habitable zone of its star. But because a red dwarf is dimmer overall than our Sun, a planet in the habitable zone would have to orbit much closer to its star than Mercury is to the Sun.

The brightness of a red dwarf at extreme ultraviolet (UV) wavelengths combined with the close orbit would mean that the hypothetical planet would get hit with about 5 to 10 times more UV radiation than the real Mars does. That cranks up the amount of energy available to fuel the processes responsible for atmospheric escape. Based on what MAVEN has learned, Brain and colleagues estimated how the individual escape processes would respond to having the UV cranked up.

Their calculations indicate that the planet's atmosphere could lose 3 to 5 times as many charged particles, a process called ion escape. About 5 to 10 times more neutral particles could be lost through a process called photochemical escape, which happens when UV radiation breaks apart molecules in the upper atmosphere.

Because more charged particles would be created, there also would be more sputtering, another form of atmospheric loss. Sputtering happens when energetic particles are accelerated into the atmosphere and knock molecules around, kicking some of them out into space and sending others crashing into their neighbors, the way a cue ball does in a game of pool.

Finally, the hypothetical planet might experience about the same amount of thermal escape, also called Jeans escape. Thermal escape occurs only for lighter molecules, such as hydrogen. Mars loses its hydrogen by thermal escape at the top of the atmosphere. On the exo-Mars, thermal escape would increase only if the increase in UV radiation were to push more hydrogen to the top of the atmosphere.

Altogether, the estimates suggest that orbiting at the edge of the habitable zone of a quiet M-class star, instead of our Sun, could shorten the habitable period for the planet by a factor of about 5 to 20. For an M-star whose activity is amped up like that of a Tasmanian devil, the habitable period could be cut by a factor of about 1,000—reducing it to a mere blink of an eye in geological terms. The solar storms alone could zap the planet with radiation bursts thousands of times more intense than the normal activity from our Sun.

However, Brain and his colleagues have considered a particularly challenging situation for habitability by placing Mars around an M-class star. A different planet might have some mitigating factors—for example, active geological processes that replenish the atmosphere to a degree, a magnetic field to shield the atmosphere from stripping by the stellar wind, or a larger size that gives more gravity to hold on to the atmosphere.

“Habitability is one of the biggest topics in astronomy, and these estimates demonstrate one way to leverage what we know about Mars and the Sun to help determine the factors that control whether planets in other systems might be suitable for life,” said Bruce Jakosky, MAVEN’s principal investigator at the University of Colorado Boulder.

MAVEN’s principal investigator is based at the University of Colorado’s Laboratory for Atmospheric and Space Physics, Boulder. The university provided two science instruments and leads science operations, as well as education and public outreach, for the mission. NASA’s Goddard Space Flight Center in Greenbelt, Maryland, manages the MAVEN project and provided two science instruments for the mission.

For more information, visit:

www.nasa.gov/maven

By Elizabeth ZubritskyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

WASP-18b Has Smothering Stratosphere Without Water

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

A NASA-led team has found evidence that the oversized planet WASP-18b is wrapped in a smothering stratosphere loaded with carbon monoxide and devoid of water. The findings come from a new analysis of observations made by the Hubble and Spitzer space telescopes.

The formation of a stratosphere layer in a planet's atmosphere is attributed to “sunscreen”-like molecules, which absorb UV and visible radiation coming from the star and then release that energy as heat. The new study suggests that the “hot Jupiter” WASP-18b, a massive planet that orbits very close to its host star, has an unusual composition, and the formation of this world might have been quite different from that of Jupiter as well as gas giants in other planetary systems.

“The composition of WASP-18b defies all expectations,” said Kyle Sheppard of NASA's Goddard Space Flight Center in Greenbelt, Maryland, lead author of the paper published in the Astrophysical Journal Letters. “We don't know of any other extrasolar planet where carbon monoxide so completely dominates the upper atmosphere.”

On Earth, ozone absorbs UV in the stratosphere, protecting our world from a lot of the Sun's harmful radiation. For the handful of exoplanets with stratospheres, the absorber is typically thought to be a molecule such as titanium oxide, a close relative of titanium dioxide, used on Earth as a paint pigment and sunscreen ingredient.

The researchers looked at data collected for WASP-18b, located 325 light-years from Earth, as part of a survey to find exoplanets with stratospheres. The heavyweight planet, which has the mass of 10 Jupiters, has been observed repeatedly, allowing astronomers to accumulate a relatively large trove of data. This study analyzed five eclipses from archived Hubble data and two from Spitzer.

From the light emitted by the planet's atmosphere at infrared wavelengths, beyond the visible region, it's possible to identify the spectral fingerprints of water and some other important molecules. The analysis revealed WASP-18b's peculiar fingerprint, which doesn't resemble any exoplanet examined so far. To determine which molecules were most likely to match it, the team carried out extensive computer modeling.

“The only consistent explanation for the data is an overabundance of carbon monoxide and very little water vapor in the atmosphere of WASP-18b, in addition to the presence of a stratosphere,” said Nikku Madhusudhan a co-author of the study from the University of Cambridge. “This rare combination of factors opens a new window into our understanding of physicochemical processes in exoplanetary atmospheres.”

The findings indicate that WASP-18b has hot carbon monoxide in the stratosphere and cooler carbon monoxide in the layer of the atmosphere below, called the troposphere. The team determined this by detecting two types of carbon monoxide signatures, an absorption signature at a wavelength of about 1.6 micrometers and an emission signature at about 4.5 micrometers. This is the first time researchers have detected both types of fingerprints for a single type of molecule in an exoplanet's atmosphere.

In theory, another possible fit for the observations is carbon dioxide, which has a similar fingerprint. The researchers ruled this out because if there were enough oxygen available to form carbon dioxide, the atmosphere also should have some water vapor.

To produce the spectral fingerprints seen by the team, the upper atmosphere of WASP-18b would have to be loaded with carbon monoxide. Compared to other hot Jupiters, this planet's atmosphere likely would contain 300 times more “metals,” or elements heavier than hydrogen and helium. This extremely high metallicity would indicate WASP-18b might have accumulated greater amounts of solid ices during its formation than Jupiter, suggesting it may not have formed the way other hot Jupiters did.

“The expected launch of the James Webb Space Telescope and other future space-based observatories will give us the opportunity to follow up with even more powerful instruments and to continue exploring the amazing array of exoplanets out there,” said Avi Mandell, an exoplanet scientist at Goddard and the second author of the paper.

For more information about NASA’s Hubble Space Telescope, visit:

www.nasa.gov/hubble

For more information about NASA’s Spitzer Space Telescope, visit:

www.nasa.gov/spitzer

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The Search for Life Beyond Earth: A Special Live NASA Event

2 min read

We’ve discovered thousands of worlds orbiting around other stars, called exoplanets, including many that are similar in size to Earth. But how do we know if some of these worlds might support life?

NASA has formed a community of scientists to apply what we’ve learned from our home planet to better understand the habitability of worlds beyond our solar system. On Friday, Nov. 17 from 1-2 PM ET, they’ll provide an update and overview of their efforts during a livestream event, “Next Steps in the Search for Habitable Worlds,” from the Habitable Worlds workshop in Laramie, Wyoming.   The one-hour interactive discussion will cross traditional disciplinary boundaries, encompassing much of the broad research topics supported by NASA’s Science Mission Directorate. Five researchers will address topics that include: • What makes a planet habitable? What does “habitability” mean when it comes to exoplanets? • How does a star impact a planet’s habitability? • Why do we focus on Earth-like planets? Could life appear on much stranger worlds than ours and, if so, could we recognize it? • How can we confirm that a planet around another star is habitable? And how might we find life on such a world? • How does our observations and understanding of Earth inform our search for life on planets around other stars?   The live event can be accessed at:

NASA TV Live

The public may submit questions before and during the live event on Twitter using #AskNASA.

Overview Most of the exoplanets discovered so far are in a relatively small region of our galaxy, the Milky Way.…

Universe

The Search for Life in the Universe

Overview Astrobiology is the study of the origin, evolution, and distribution of life in the universe. We might find life…

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Our Living Planet Shapes the Search for Life Beyond Earth

8 min read

NASA Science Editorial Team

By Carol Rasmussen, NASA's Jet Propulsion Laboratory

As a young scientist, Tony del Genio of NASA's Goddard Institute for Space Studies in New York City met Clyde Tombaugh, the discoverer of Pluto.

"I thought, 'Wow, this is a one-time opportunity,'" del Genio said. "I'll never meet anyone else who found a planet."

That prediction was spectacularly wrong. In 1992, two scientists discovered the first planet around another star, or exoplanet, and since then more people have found planets than throughout all of Earth's preceding history. As of this month, scientists have confirmed more than 3,500 exoplanets in more than 2,700 star systems. Del Genio has met many of these new planet finders.

Del Genio is now co-lead of a NASA interdisciplinary initiative to search for life on other worlds. This new position as the lead of this project may seem odd to those who know him professionally. Why? He has dedicated decades to studying Earth, not searching for life elsewhere.

We know of only one living planet: our own. But we know it very well. As we move to the next stage in the search for alien life, the effort will require the expertise of planetary scientists, heliophysicists and astrophysicists. However, the knowledge and tools NASA has developed to study life on Earth will also be one of the greatest assets to the quest.

There are two main questions in the search for life: With so many places to look, how can we focus in on the places most likely to harbor life? What are the unmistakable signs of life – even if it comes in a form we don't fully understand?

"Before we go looking for life, we're trying to figure out what kinds of planets could have a climate that's conducive to life," del Genio said. "We're using the same climate models that we use to project 21st century climate change on Earth to do simulations of specific exoplanets that have been discovered, and hypothetical ones."

Del Genio recognizes that life may well exist in forms and places so bizarre that it might be substantially different from Earth. But in this early phase of the search, "We have to go with the kind of life we know," he said.

Further, we should make sure we use the detailed knowledge of Earth. In particular, we should make sure of our discoveries on life in various environments on Earth, our knowledge of how our planet and its life have affected each other over Earth history, and our satellite observations of Earth's climate.

Above all else, that means liquid water. Every cell we know of – even bacteria around deep-sea vents that exist without sunlight – requires water.

Research scientist Morgan Cable of NASA's Jet Propulsion Laboratory in Pasadena, California, is looking within the solar system for locations that have the potential to support liquid water. Some of the icy moons around Saturn and Jupiter have oceans below the ice crust. These oceans were formed by tidal heating, that is, warming of the ice caused by friction between the surface ice and the core as a result of the gravitational interaction between the planet and the moon.

"We thought Enceladus was just boring and cold until the Cassini mission discovered a liquid water subsurface ocean," said Cable. The water is spraying into space, and the Cassini mission found hints in the chemical composition of the spray that the ocean chemistry is affected by interactions between heated water and rocks at the seafloor. The Galileo and Voyager missions provided evidence that Europa also has a liquid water ocean under an icy crust. Observations revealed a jumbled terrain that could be the result of ice melting and reforming.

As missions to these moons are being developed, scientists are using Earth as a testbed. Just as prototypes for NASA's Mars rovers made their trial runs on Earth's deserts, researchers are testing both hypotheses and technology on our oceans and extreme environments.

Cable gave the example of satellite observations of Arctic and Antarctic ice fields, which are informing the planning for a Europa mission. The Earth observations help researchers find ways to date the origin of jumbled ice. "When we visit Europa, we want to go to very young places, where material from that ocean is being expressed on the surface," she said. "Anywhere like that, the chances of finding evidence of life goes up – if they're there."

For any star, it's possible to calculate the range of distances where orbiting planets could have liquid water on the surface. This is called the star's habitable zone.

Astronomers have already located some habitable-zone planets, and research scientist Andrew Rushby, of NASA Ames Research Center, in Moffett Field, California, is studying ways to refine the search. Location alone isn't enough. "An alien would spot three planets in our solar system in the habitable zone [Earth, Mars and Venus]," Rushby said, "but we know that 67 percent of those planets are not very habitable." He recently developed a simplified model of Earth's carbon cycle and combined it with other tools to study which planets in the habitable zone would be the best targets to look at for life, considering probable tectonic activity and water cycles. He found that larger rocky planets are more likely than smaller ones to have surface temperatures where liquid water could exist, given the same amount of light from the star.

Renyu Hu, of JPL, refined the search for habitable planets in a different way, looking for the signature of a rocky planet. Basic physics tells us that smaller planets must be rocky and larger ones gaseous, but for planets ranging from Earth-sized to about twice that radius, astronomers can't tell a large rocky planet from a small gaseous planet. Hu pioneered a method to detect surface minerals on bare-rock exoplanets and defined the atmospheric chemical signature of volcanic activity, which wouldn't occur on a gas planet.

When scientists are evaluating a possible habitable planet, "life has to be the hypothesis of last resort," Cable said. "You must eliminate all other explanations." Identifying possible false positives for the signal of life is an ongoing area of research in the exoplanet community. For example, the oxygen in Earth's atmosphere comes from living things, but oxygen can also be produced by inorganic chemical reactions.

Shawn Domagal-Goldman, of NASA's Goddard Space Flight Center in Greenbelt, Maryland, looks for unmistakable, chemical signs of life, or biosignatures. One biosignature may be finding two or more molecules in an atmosphere that shouldn't be there at the same time. He uses this analogy: If you walked into a college dorm room and found three students and a pizza, you could conclude that the pizza had recently arrived, because college students quickly consume pizza. Oxygen "consumes" methane by breaking it down in various chemical reactions. Without inputs of methane from life on Earth's surface, our atmosphere would become totally depleted of methane within a few decades.

When humans start collecting direct images of exoplanets, even the closest one will appear as a handful of pixels in the detector - something like the famous "blue dot" image of Earth from Saturn. What can we learn about planetary life from a single dot?

Stephen Kane of the University of California, Riverside, has come up with a way to answer that question using NASA's Earth Polychromatic Imaging camera on the National Oceanic and Atmospheric Administration's Deep Space Climate Observatory (DSCOVR). These high-resolution images – 2,000 x 2,000 pixels - document Earth's global weather patterns and other climate-related phenomena. "I'm taking these glorious pictures and collapsing them down to a single pixel or handful of pixels," Kane explained. He runs the light through a noise filter that attempts to simulate the interference expected from an exoplanet mission.

DSCOVR takes a picture every half hour, and it's been in orbit for two years. Its more than 30,000 images are by far the longest continuous record of Earth from space in existence. By observing how the brightness of Earth changes when mostly land is in view compared with mostly water, Kane has been able to reverse-engineer Earth's rotation rate – something that has yet to be measured directly for exoplanets.

Every scientist involved in the search for life is convinced it's out there. Their opinions differ on when we'll find it.

"I think that in 20 years we will have found one candidate that might be it," says del Genio. Considering his experience with Tombaugh, he added, "But my track record for predicting the future is not so good."

Rushby, on the other hand, says, "It's been 20 years away for the last 50 years. I do think it's on the scale of decades. If I were a betting man, which I'm not, I'd go for Europa or Enceladus."

How soon we find a living exoplanet really depends on whether there's one relatively nearby, with the right orbit and size, and with biosignatures that we are able to recognize, Hu said. In other words, "There's always a factor of luck."

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

‘All these worlds are yours’

4 min read

NASA Science Editorial Team

Exoplanets transform our view of the galaxy — and ourselves

by Pat Brennan

Look deeply enough into the night sky, and you’ll soon see how radically the universe has changed.

You might have to borrow some space-based spyglasses -
NASA’s Kepler, Spitzer or Hubble space telescopes - to peer into the cosmic depths and watch the faint shadows of planets cross the faces of their stars. Or measure the stars’ wobble, the gravitational tugs of orbiting planets. But as your eyes adjust, the new reality becomes crystal clear. For the first time since we began huddling around campfires, weaving scattered stars into pictures and stories, we know with certainty that we belong to a galaxy packed with neighboring worlds – whole systems of stars and planets far beyond, and vastly different from, our own solar system.

This is not your parents’ universe. You can take a planet-hopping vacation across the seven Earth-sized worlds of the system known as TRAPPIST-1, for instance, just 40 light-years away. A somewhat longer trip, around 200 light-years, will take you to Kepler-16b, a planet orbiting two stars. The two suns in its sky make it a real-life Tatooine, straight out of “Star Wars.”

Or how about pitch-black WASP-12b, some 1,400 light-years away, orbiting its star so closely it’s being distorted into an egg shape as it is gradually pulled apart?

[Earth-sized planets: the newest, weirdest generation]

The count of confirmed exoplanets – planets around other stars – has passed 3,500 since 1995, when the detection of 51 Pegasi b, a roasting giant in a close orbit around a sun-like star, rang in the era of fast-paced exoplanet discovery. Dozens, then hundreds, then thousands began to jump out of telescope data.

The Kepler space telescope reeled in the largest haul, providing a census of planet types and sizes. A planet as light as Styrofoam, another that could be raining glass. Earth-sized worlds by the bushel, but also oddly sized “super Earths” and “sub-Neptunes,” planets larger than Earth but smaller than Neptune. These are the most common types of planets, though we know next to nothing about them: In our solar system they are conspicuously absent.

Reaction wheel failures ended the Kepler telescope’s primary mission in 2013 after four years of exoplanet observation. Some clever commands from ground-based engineers allowed it to continue functioning as K2, an extended mission mapping new star fields that lie within the plane of Earth’s orbit around the Sun. Its observation times are now shorter, but its ability to discover new exoplanets remains intact.

The K2 mission is, in fact, preparing the way ahead for two new, state-of-the-art planet hunters to be launched in the next two years. The Transiting Exoplanet Survey Satellite (TESS) and the James Webb Space Telescope will take their cues from K2, which is identifying interesting exoplanets that the new kids on the block can investigate in greater depth. The Webb telescope will capture the light from some of these planets, with the goal of determining which gases are present in their atmospheres.

Arthur C. Clarke

"2010: ODYSSEY TWO"

The age of direct imaging – actual pictures – of exoplanets is upon us, even if the first images are no bigger than a pixel. And the techniques pioneered by the Webb telescope could one day allow us to identify oxygen, carbon dioxide and methane in the skies of some far-off, blue and white marble. In other words, signs of life – and just maybe, another Earth-like planet.

For now we can take these journeys to exotic exoplanets only in our imaginations, though helped along by the visions of space artists. Their visualizations, based on known data, are so sharp they look like photographs. Using exoplanet virtual reality and your cell phone, you can stand on the surface of an orange-tinted world, and look back toward Earth through its alien skies.

[An image is worth a thousand worlds]

Welcome to our new exoplanet blog, part of NASA’s Exoplanet Exploration program. Hitch a ride with us as we take interstellar tours, discover new planets, and press ahead in the search for life. A brand-new universe is waiting.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery alert! ESO finds second-closest Earth-size planet in habitable zone

2 min read

NASA Science Editorial Team

Planet: Ross 128 b

Discovered by: X. Bonfils et al. using ESO's HARPS

Date: November 15, 2017

Key Facts: An important discovery from Europe reveals a likely terrestrial, Earth-mass planet only 11 light-years away. Second only to Proxima Centauri b, this discovery is now the second-nearest known terrestrial planet to Earth. Even better, the planet may orbit in the inner edge of its red star's habitable zone, where there could be water. While this world is 1.3 x Earth's mass, it wouldn't feel like Earth – it has a dim, red sun and a year that lasts about 10 days. This close orbit means the planet is likely tidally locked to its star, like the seven TRAPPIST-1 planets. This means that one side of the planet would always be day, and the other side would be plunged in eternal night.

What's new: Is there another Earth? That's the question discoveries like Ross 128 b are trying to answer. An Earth-size planet that could be temperate is a prime target in the search for life. Especially one this close to Earth, which gives scientists the hope that in the near future we'll have instruments on large telescopes sophisticated enough to analyze the atmosphere of the planet.

But even planets in our stellar backyard are challenging to measure, and it's impossible to see land or oceans with our current telescopes. Planets like Ross 128 b and Proxima b seem like they could be the right size and temperature to be Earth-like. But so do Venus and Mars, if you measured them from light-years away. To support life, Ross 128 b would need a few more vital ingredients, like water on its surface and an Earth-like atmosphere. Which we need better telescopes to see. So, it's more like Earth-adjacent ... for now.

And yes, the planet is named after a guy named Ross.

See details from the European Southern Observatory

Paper: "A temperate exo-Earth around a quiet M dwarf at 3.4 parsecs"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Halloween Special: Universe of Monsters

4 min read

NASA Science Editorial Team

Welcome to the universe of monsters! We've found homes for some of the most terrifying Halloween monsters, far away on real planets outside our solar system.

Lightning cracks against the maelstrom of a Neptune-like sky, illuminating the hideous figure of Frankenstein's monster. Just like the day of the monster's unnatural birth, when the harnessed power of lightning brought his scavenged parts to life. But don't judge him by his looks; Frankenstein's monster (we like to call him Frankenstein Jr.) is a gentle giant seeking to be understood. Scorned by humankind as a science experiment gone horrifically awry, we've found a home planet for Frank Jr. 122 light-years away. Water in the atmosphere and a weak radio signal once led astronomers to believe this safe haven for monster misfits had enormous lightning storms, many times stronger than those on Jupiter or Earth.

See more: Exoplanet Catalog

Was that chill on the back of your neck the brush of a bat's wings, or Dracula himself, hunting you through the night? Don't look over your shoulder; we've found a planet for Dracula to drink the blood of his unlucky victims. The father of vampires can build his castle on the night side of YZ Ceti d, a tidally locked planet with one side plunged in perpetual darkness. Perfect for a cursed count who might prefer the cover of night for his dark deeds. If he makes the journey through this rocky planet's twilight zone to the day side, he can stalk his prey under the eerie light of a blood-red sun.

See more: Discovery alert! Three Earth-mass neighbors

The night comes alive as the clouds part to reveal the full moon, and half-human lips release an unearthly howl. Werewolves could roam free on TRAPPIST-1 b, the innermost of seven tidally-locked planets. Only one side of the planet faces its red star; the other side is plunged in eternal night. On the night side, it's always dark enough to see the other six planets, which reflect the light of their red star like moons. With six worlds looming large in the sky, the chances of a full "moon" every night are high. Likely enough to keep a savage night creature in wolfish form forever.

See more: Largest batch of Earth-size, habitable zone planets

A dry, rasping rattle echoes off the cool walls of the tomb, a sound almost human in the solitude of the desert. Beware the mummy's curse, those who seek to enter the domain of this ancient foe. We'd like to relocate this unquiet creature to an ancient dusty home on Proxima Centauri b. This rocky world only 4 light-years away may have lost oceans of water to the radiation blasts of its star, leaving it a possible desert world. But sleeping fitfully beneath the sands won't bother the undead. In fact, this monster may prefer a drier climate to preserve what's left of its rotten remains.

See more: An Earth-like atmosphere may not survive Proxima b's orbit

When the skeletons rise on Halloween night, their bones clatter as they leave their graves. But before the skeleton war destroys the land of the living, we found a place a pile of bones won't mind. Over a hundred light-years away, a planet is metaphorically having its flesh stripped from its bones. Nicknamed "Osiris" after the Egyptian god of the dead, this gas giant is being destroyed by its voracious star at a rate of more than 35,000 km/hour (about 22,000 miles/hr). The parts that once made up the doomed world's atmosphere are smeared through space like an ominous tail. Soon, the planet (and any skeleton armies on it), will be destroyed by gravity.

See more: Happy Anniversary, Osiris!

Three dead planets shamble through the twisted magnetic fields of their corpse star that exploded eons ago. What better place to put a horde of zombies than the pulsar planets, each named after an undead creature? On the planets Poltergeist, Draugr, Phobetor, the ravenous departed could spread like the plague, with no harm done. They're well-suited for this planetary graveyard, bathed daily in the twin beams of radiation from their murderous star, "Lich."

See more: Will the real 'first exoplanet' please stand up?

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Overlooked Treasure: The First Evidence of Exoplanets

10 min read

Elizabeth Landau

Beneath an elegant office building with a Spanish-style red tiled roof in Pasadena, California, three timeworn storerooms safeguard more than a century of astronomy. Down the stairs and to the right is a basement of wonder. There are countless wooden drawers and boxes, stacked floor to ceiling, with telescope plates, sunspot drawings and other records. A faint ammonia-like smell, reminiscent of old film, fills the air.

Guarding one storeroom is a short black door with a sign saying "This door to be kept closed."

Carnegie Observatories hosts 250,000 photographic plates taken at Mount Wilson, Palomar and Las Campanas observatories, spanning more than 100 years. In their heydays, the Mount Wilson 60-inch and 100-inch telescopes – the bigger saw its first light on Nov. 1, 1917 – were the most powerful instruments of their kind. Each indelibly changed humanity's understanding of our place in the cosmos. But these technological marvels were ahead of their time – in one case, capturing signs of distant worlds that wouldn't be recognized for a century.

Mount Wilson is the site where some of the key discoveries about our galaxy and universe were made in the early 20th century. This is where Edwin Hubble realized that the Milky Way cannot be the extent of our universe, because Andromeda (or M31) is farther away than the most distant reaches of our galaxy. The photographic plate from the 100-inch Hooker Telescope from 1923, which captured this monumental realization, is blown up as a huge poster outside the Carnegie storerooms.

Hubble and Milton Humason, whose Mount Wilson career began as a janitor, worked together to explore the expanding nature of the universe. Using the legendary telescopes, as well as data from Lowell Observatory in Flagstaff, Arizona, they recognized that clusters of galaxies are traveling away from each other – and the more distant galaxies move away from each other at greater speeds.

But there is a far lesser known, 100-year-old discovery from Mount Wilson, one that was unidentified and unappreciated until recently. It's actually: The first evidence of exoplanets.

It started with Ben Zuckerman, professor emeritus of astronomy at the University of California, Los Angeles. He was preparing a talk about the compositions of planets and smaller rocky bodies outside our solar system for a July 2014 symposium at the invitation of Jay Farihi, whom he had helped supervise when Farihi was a graduate student at UCLA. Farihi had suggested that Zuckerman talk about the pollution of white dwarfs, which are which are dim, dense remnants of stars similar to the Sun that have exhausted their nuclear fuel and blown off their outer layers. By "pollution," astronomers mean heavy elements invading the photospheres – the outer atmospheres – of these stars. The thing is, all those extra elements shouldn't be there – the strong gravity of the white dwarf should pull the elements into the star's interior, and out of sight.

The first polluted white dwarf identified is called van Maanen's Star (or "van Maanen 2" in the scientific literature), after its discoverer Adriaan van Maanen. Van Maanen found this object in 1917 by spotting its subtle motion relative to other stars between 1914 and 1917. Astronomer Walter Sydney Adams, who would later become director of Mount Wilson, captured the spectrum – a chemical fingerprint – of van Maanen's Star on a small glass plate using Mount Wilson's 60-inch telescope. Adams interpreted the spectrum to be of an F-type star, presumably based on the presence and strength of calcium and other heavy-element absorption features, with a temperature somewhat higher than our Sun. In 1919, van Maanen called it a "very faint star."

Today, we know that van Maanen's Star, which is about 14 light-years away, is the closest white dwarf to Earth that is not part of a binary system.

"This star is an icon," Farihi said recently. "It is the first of its type. It's really the proto-prototype."

While preparing his talk, Zuckerman had what he later called a "true 'eureka' moment." Van Maanen's Star, unbeknownst to the astronomers who studied it in 1917 and those who thought about it for decades after, must be the first observational evidence that exoplanets exist.

Heavy elements in the star's outermost layer could not have been produced inside the star, because they would immediately sink due to the white dwarf's intense gravitational field. As more white dwarfs with heavy elements in their photospheres were discovered in the 20th century, scientists came to believe that the exotic materials must have come from the interstellar medium – in other words, elements floating in the space between the stars.

But in 1987, more than 70 years after the Mount Wilson spectrum of van Maanen's Star, Zuckerman and his colleague Eric Becklin reported an excess of infrared light around a white dwarf, which they thought might come from a faint "failed star" called a brown dwarf. This was, in 1990, interpreted to be a hot, dusty disk orbiting a white dwarf. By the early 2000s, a new theory of polluted white dwarfs had emerged: Exoplanets could push small rocky bodies toward the star, whose powerful gravity would pulverize them into dust. That dust, containing heavy elements from the torn-apart body, would then fall on the star.

"The bottom line is: if you're an asteroid or comet, you can't just change your address. You need something to move you," Farihi said. "By far, the greatest candidates are planets to do that."

NASA's Spitzer Space Telescope has been instrumental in expanding the field of polluted white dwarfs orbited by hot, dusty disks. Since launch in 2004, Spitzer has confirmed about 40 of these special stars. Another space telescope, NASA's Wide-field Infrared Survey Explorer, also detected a handful, bringing the total up to about four dozen known today. Because these objects are so faint, infrared light is crucial to identifying them.

"We can't measure the exact amount of infrared light coming from these objects using telescopes on the ground," Farihi said. "Spitzer, specifically, just burst this wide open."

Supporting the new "dusty disk" theory of polluted white dwarfs, in 2007, Zuckerman and colleagues published observations of a white dwarf atmosphere with 17 elements – materials similar to those found in the Earth-Moon system. (The late UCLA professor Michael Jura, who made crucial contributions to the study of polluted white dwarfs, was part of this team.) This was further evidence that at least one small, rocky body – or even a planet – had been torn apart by the gravity of a white dwarf. Scientists now generally agree that a single white dwarf star with heavy elements in its spectrum likely has at least one rocky debris belt – the remnants of bodies that collided violently and never formed planets – and probably at least one major planet.

So, heavy elements that happened to be floating in the interstellar medium could not account for the observations. "About 90 years after van Maanen's discovery, astronomers said, 'Whoa, this interstellar accretion model can't possibly be right,'" Zuckerman said.

Inspired by Zuckerman, Farihi became enamored with the idea that someone had taken a spectrum with the first evidence of exoplanets in 1917, and that a record must exist of that observation. "I got my teeth in the question and I wouldn't let go," he said.

Farihi reached out to the Carnegie Observatories, which owns the Mount Wilson telescopes and safeguards their archives. Carnegie Director John Mulchaey put volunteer Dan Kohne on the case.

Kohne dug through the archives and, two days later, Mulchaey sent Farihi an image of the spectrum.

"I can't say I was shocked, frankly, but I was pleasantly blown out of my seat to see that the signature was there, and could be seen even with the human eye," Farihi said.

The spectrum of van Maanen's Star that Farihi had requested is now located in a small archival sleeve, labeled with the handwritten date "1917 Oct 24" and a modern yellow sticky note: "possibly 1st record of an exoplanet."

Cynthia Hunt, an astronomer who serves as chair of Carnegie's history committee, took the glass plate out of the envelope and placed it onto a viewer that lit it up. The spectrum itself just about 1/6th of an inch, or a bit over 0.4 centimeters.

Though the plate seems unremarkable at first glance, Farihi saw two obvious "fangs" representing dips in the spectrum. To him, this was the smoking gun: Two absorption lines from the same calcium ion, meaning there were heavy elements in the photosphere of the white dwarf – indicating it likely has at least one exoplanet. He wrote about it in 2016 in New Astronomy Reviews.

Scientists have long thought the gravity of giant planets could be keeping debris belts in place, especially in young planetary systems. A recent study in The Astrophysical Journal showed that young stars with disks of dust and debris are more likely to have giant planets orbiting at great distance from their parent star than those without disks.

A white dwarf is not a young star – on the contrary, it forms when a low-to-medium-mass star has already burned all of the fuel in its interior. But the principle is the same: The gravitational pull of giant exoplanets could throw small, rocky bodies into the white dwarfs.

Our own Sun will become a red giant in about 5 billion years, expanding so much it may even swallow Earth before it blows off its outer layers and becomes a white dwarf. At that point, Jupiter's large gravitational influence may be more disruptive to the asteroid belt, flinging objects toward our much-dimmer Sun. This kind of scenario could explain the heavy elements at van Maanen's Star.

Spitzer's observations of van Maanen's Star have not found any planets there so far. In fact, to date, no exoplanets have been confirmed orbiting white dwarfs, although one does have an object thought to be a massive planet. Other compelling evidence has emerged just in the last couple of years. Using the W. M. Keck Observatory in Hawaii, scientists, including Zuckerman, recently announced that they had found evidence of a Kuiper-Belt-like object having been eaten by a white dwarf.

Scientists are still exploring polluted white dwarfs and looking for the exoplanets they may host. About 30 percent of all white dwarfs we know about are polluted, but their debris disks are harder to spot. Jura put forward that with lots of asteroids coming in and colliding with debris, dust may be converted into gas, which would not have the same highly detectable infrared signal as dust.

Farihi was thrilled about how his Mount Wilson archive detective work turned out. In 2016, he described the historical find in the context of a review paper about polluted white dwarfs, arguing that white dwarfs are "compelling targets for exoplanetary system research."

Who knows what other overlooked treasures await discovery in the archives of great observatories – the sky-watching records of a cosmos rich in subtlety. Surely, other clues will be found by those motivated by curiosity who ask the right questions.

"It's personal interaction with data that can really spur us to get invested in the questions that we're asking," Farihi said.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Observes Exoplanet that Snows Sunscreen

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA's Hubble Space Telescope has found a blistering hot planet outside our solar system where it "snows" sunscreen. The problem is the sunscreen (titanium oxide) precipitation only happens on the planet's permanent nighttime side. Any possible visitors to the exoplanet, called Kepler-13Ab, would need to bottle up some of that sunscreen, because they won't find it on the sizzling hot, daytime side, which always faces its host star.

Hubble astronomers suggest that powerful winds carry the titanium oxide gas around to the colder nighttime side, where it condenses into crystalline flakes, forms clouds, and precipitates as snow. Kepler-13Ab's strong surface gravity — six times greater than Jupiter's — pulls the titanium oxide snow out of the upper atmosphere and traps it in the lower atmosphere.

Astronomers using Hubble didn't look for titanium oxide specifically. Instead, they observed that the giant planet's atmosphere is cooler at higher altitudes, which is contrary to what was expected. This finding led the researchers to conclude that a light-absorbing gaseous form of titanium oxide, commonly found in this class of star-hugging, gas giant planet known as a "hot Jupiter," has been removed from the dayside's atmosphere.

The Hubble observations represent the first time astronomers have detected this precipitation process, called a "cold trap," on an exoplanet.

Without the titanium oxide gas to absorb incoming starlight on the daytime side, the atmospheric temperature grows colder with increasing altitude. Normally, titanium oxide in the atmospheres of hot Jupiters absorbs light and reradiates it as heat, making the atmosphere grow warmer at higher altitudes.

These kinds of observations provide insight into the complexity of weather and atmospheric composition on exoplanets, and may someday be applicable to analyzing Earth-size planets for habitability.

"In many ways, the atmospheric studies we're doing on hot Jupiters now are testbeds for how we're going to do atmospheric studies on terrestrial, Earth-like planets," said lead researcher Thomas Beatty of Pennsylvania State University in University Park. "Hot Jupiters provide us with the best views of what climates on other worlds are like. Understanding the atmospheres on these planets and how they work, which is not understood in detail, will help us when we study these smaller planets that are harder to see and have more complicated features in their atmospheres."

Beatty's team selected Kepler-13Ab because it is one of the hottest of the known exoplanets, with a dayside temperature of nearly 5,000 degrees Fahrenheit. Past observations of other hot Jupiters have revealed that the upper atmospheres increase in temperature. Even at their much colder temperatures, most of our solar system's gas giants also exhibit this phenomenon.

Kepler-13Ab is so close to its parent star that it is tidally locked. One side of the planet always faces the star; the other side is in permanent darkness. (Similarly, our moon is tidally locked to Earth; only one hemisphere is permanently visible from Earth.)

The observations confirm a theory from several years ago that this kind of precipitation could occur on massive, hot planets with powerful gravity.

"Presumably, this precipitation process is happening on most of the observed hot Jupiters, but those gas giants all have lower surface gravities than Kepler-13Ab," Beatty explained. "The titanium oxide snow doesn't fall far enough in those atmospheres, and then it gets swept back to the hotter dayside, revaporizes, and returns to a gaseous state."

The researchers used Hubble's Wide Field Camera 3 to conduct spectroscopic observations of the exoplanet's atmosphere in near-infrared light. Hubble made the observations as the distant world traveled behind its star, an event called a secondary eclipse. This type of eclipse yields information on the temperature of the constituents in the atmosphere of the exoplanet's dayside.

"These observations of Kepler-13Ab are telling us how condensates and clouds form in the atmospheres of very hot Jupiters, and how gravity will affect the composition of an atmosphere," Beatty explained. "When looking at these planets, you need to know not only how hot they are but what their gravity is like."

The Kepler-13 system resides 1,730 light-years from Earth.

The team's results appeared in The Astronomical Journal.

Related Links

The science paper by T. Beatty et al.

NASA's Hubble Portal

Contacts:

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

Thomas BeattyPennsylvania State University, University Park814-863-7346tbeatty@psu.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Giant exoplanet hunters: Look for debris disks

4 min read

Elizabeth Landau

There's no map showing all the billions of exoplanets hiding in our galaxy– they're so distant and faint compared to their stars, it's hard to find them. Now, astronomers hunting for new worlds have established a possible signpost for giant exoplanets.

A new study finds that giant exoplanets that orbit far from their stars are more likely to be found around young stars that have a disk of dust and debris than those without disks. The study, published in The Astronomical Journal, focused on planets more than five times the mass of Jupiter. This study is the largest to date of stars with dusty debris disks, and has found the best evidence yet that giant planets are responsible for keeping that material in check.

"Our research is important for how future missions will plan which stars to observe," said Tiffany Meshkat, lead author and assistant research scientist at IPAC/Caltech in Pasadena, California. Meshkat worked on this study as a postdoctoral researcher at NASA's Jet Propulsion Laboratory in Pasadena. "Many planets that have been found through direct imaging have been in systems that had debris disks, and now we know the dust could be indicators of undiscovered worlds."

Astronomers found the likelihood of finding long-period giant planets is nine times greater for stars with debris disks than stars without disks. Caltech graduate student Marta Bryan performed the statistical analysis that determined this result.

Researchers combined data from 130 single-star systems with debris disks detected by NASA's Spitzer Space Telescope, and compared them with 277 stars that do not appear to host disks. The two star groups were between a few million and 1 billion years old. Of the 130 stars, 100 were previously scanned for exoplanets. As part of this study, researchers followed up on the other 30 using the W. M. Keck Observatory in Hawaii and the European Southern Observatory's Very Large Telescope in Chile. They did not detect any new planets in those 30 systems, but the additional data helped characterize the abundance of planets in systems with disks.

The research does not directly resolve why the giant exoplanets would cause debris disks to form. Study authors suggest the massive gravity of giant planets causes small bodies called planetesimals to collide violently, rather than form proper planets, and remain in orbit as part of a disk.

"It's possible we don't find small planets in these systems because, early on, these massive bodies destroyed the building blocks of rocky planets, sending them smashing into each other at high speeds instead of gently combining," said co-author Dimitri Mawet, a Caltech associate professor of astronomy and a JPL senior research scientist.

On the other hand, giant exoplanets are easier to detect than rocky planets, and it is possible that there are some in these systems that have not yet been found.

Our own solar system is home to gas giants responsible for making "debris belts" – the asteroid belt between Mars and Jupiter, shaped by Jupiter, and the Kuiper Belt, shaped by Neptune. Many of the systems Meshkat and Mawet studied also have two belts, but they are also much younger than ours– up to 1 billion years old, compared to our system's present age of 4.5 billion years. The youth of these systems partly explains why they contain much more dust – resulting from the collisions of small bodies – than ours does.

One system discussed in the study is Beta Pictoris, which has been directly imaged from ground-based telescopes. This system has a debris disk, comets and one confirmed exoplanet. In fact, scientists predicted this planet's existence well before it was confirmed, based on the presence and structure of the prominent disk.

In a different scenario, the presence of two dust belts in a single debris disk suggests there are likely more planets in the system whose gravity maintains these belts, as is the case in the HR8799 system of four giant planets. The gravitational forces of giant planets nudge passing comets inward toward the star, which could mimic the period of our solar system's history about 4 billion years ago known as the Late Heavy Bombardment. Scientists think that during that period, the migration of Jupiter, Saturn, Uranus and Neptune deflected dust and small bodies into the Kuiper and asteroid belts we see today. When the Sun was young, there would have been a lot more dust in our solar system as well.

"By showing astronomers where future missions such as NASA's James Webb Space Telescope have their best chance to find giant exoplanets, this research paves the way to future discoveries," said Karl Stapelfeldt of JPL, chief scientist of NASA's Exoplanet Exploration Program Office and study co-author.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New NASA Study Improves Search for Habitable Worlds

6 min read

New NASA research is helping to refine our understanding of candidate planets beyond our solar system that might support life.

“Using a model that more realistically simulates atmospheric conditions, we discovered a new process that controls the habitability of exoplanets and will guide us in identifying candidates for further study,” said Yuka Fujii of NASA’s Goddard Institute for Space Studies (GISS), New York, New York and the Earth-Life Science Institute at the Tokyo Institute of Technology, Japan, lead author of a paper on the research published in the Astrophysical Journal Oct. 17.

Previous models simulated atmospheric conditions along one dimension, the vertical. Like some other recent habitability studies, the new research used a model that calculates conditions in all three dimensions, allowing the team to simulate the circulation of the atmosphere and the special features of that circulation, which one-dimensional models cannot do. The new work will help astronomers allocate scarce observing time to the most promising candidates for habitability.

Liquid water is necessary for life as we know it, so the surface of an alien world (e.g. an exoplanet) is considered potentially habitable if its temperature allows liquid water to be present for sufficient time (billions of years) to allow life to thrive. If the exoplanet is too far from its parent star, it will be too cold, and its oceans will freeze. If the exoplanet is too close, light from the star will be too intense, and its oceans will eventually evaporate and be lost to space. This happens when water vapor rises to a layer in the upper atmosphere called the stratosphere and gets broken into its elemental components (hydrogen and oxygen) by ultraviolet light from the star. The extremely light hydrogen atoms can then escape to space. Planets in the process of losing their oceans this way are said to have entered a “moist greenhouse” state because of their humid stratospheres.

In order for water vapor to rise to the stratosphere, previous models predicted that long-term surface temperatures had to be greater than anything experienced on Earth – over 150 degrees Fahrenheit (66 degrees Celsius). These temperatures would power intense convective storms; however, it turns out that these storms aren’t the reason water reaches the stratosphere for slowly rotating planets entering a moist greenhouse state.

“We found an important role for the type of radiation a star emits and the effect it has on the atmospheric circulation of an exoplanet in making the moist greenhouse state,” said Fujii. For exoplanets orbiting close to their parent stars, a star’s gravity will be strong enough to slow a planet’s rotation. This may cause it to become tidally locked, with one side always facing the star – giving it eternal day – and one side always facing away –giving it eternal night.

When this happens, thick clouds form on the dayside of the planet and act like a sun umbrella to shield the surface from much of the starlight. While this could keep the planet cool and prevent water vapor from rising, the team found that the amount of near-Infrared radiation (NIR) from a star could provide the heat needed to cause a planet to enter the moist greenhouse state. NIR is a type of light invisible to the human eye. Water as vapor in air and water droplets or ice crystals in clouds strongly absorbs NIR light, warming the air. As the air warms, it rises, carrying the water up into the stratosphere where it creates the moist greenhouse.

This process is especially relevant for planets around low-mass stars that are cooler and much dimmer than the Sun. To be habitable, planets must be much closer to these stars than our Earth is to the Sun. At such close range, these planets likely experience strong tides from their star, making them rotate slowly. Also, the cooler a star is, the more NIR it emits. The new model demonstrated that since these stars emit the bulk of their light at NIR wavelengths, a moist greenhouse state will result even in conditions comparable to or somewhat warmer than Earth's tropics. For exoplanets closer to their stars, the team found that the NIR-driven process increased moisture in the stratosphere gradually. So, it's possible, contrary to old model predictions, that an exoplanet closer to its parent star could remain habitable.

This is an important observation for astronomers searching for habitable worlds, since low-mass stars are the most common in the galaxy. Their sheer numbers increase the odds that a habitable world may be found among them, and their small size increases the chance to detect planetary signals.

The new work will help astronomers screen the most promising candidates in the search for planets that could support life. "As long as we know the temperature of the star, we can estimate whether planets close to their stars have the potential to be in the moist greenhouse state," said Anthony Del Genio of GISS, a co-author of the paper. "Current technology will be pushed to the limit to detect small amounts of water vapor in an exoplanet's atmosphere. If there is enough water to be detected, it probably means that planet is in the moist greenhouse state."

In this study, researchers assumed a planet with an atmosphere like Earth, but entirely covered by oceans. These assumptions allowed the team to clearly see how changing the orbital distance and type of stellar radiation affected the amount of water vapor in the stratosphere. In the future, the team plans to vary planetary characteristics such as gravity, size, atmospheric composition, and surface pressure to see how they affect water vapor circulation and habitability.

The research was funded by the NASA Astrobiology Program through the Nexus for Exoplanet System Science; the NASA Postdoctoral Program, administered by Oak Ridge Affiliated Universities, Oak Ridge, Tennessee, and Universities Space Research Association, Columbia, Maryland; and a Grant-in-Aid from the Japan Society for the Promotion of Science, Tokyo, Japan (No.15K17605).

Bill Steigerwald

NASA Goddard Space Flight Center

william.a.steigerwald@nasa.gov

Discovery alert! A sizzling super Earth

1 min read

NASA Science Editorial Team

Planet: K2-131b (aka EPIC 228732031b)

Discovered by: Fei Dei et al. using NASA's Kepler telescope

Date: October 19, 2017

Key Facts: This discovery is a super Earth two times Earth's size, that orbits a yellow Sun-like star. But don't get too excited about life on this planet– temperatures there are hot enough to vaporize metal. This sizzling-hot world takes only nine hours to orbit its star, a journey which takes Mercury 88 days. K2-131b is likely to be a lifeless inferno, where the planet’s sun never sets on the dayside.

What's new: A super Earth isn't super because it's twice as cool as Earth– it's super because it's twice the size. This planet is about 6.5 times more massive than Earth, and almost certainly rocky like our own planet. From the surface, its sun would appear 41 degrees wide in the sky– that's 80 times the width of the full moon! The Kepler space telescope found this super Earth (and many others) during its ongoing K2 mission.

See details and check the official NASA planet count at the NASA Exoplanet Archive

Paper: "The discovery and mass measurement of a new ultra-short-period planet: EPIC 228732031b"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Discovery alert! A nearby super Earth

2 min read

NASA Science Editorial Team

Planet: GJ 625 b

Discovered by: A. Suárez Mascareño et al. using HARPS-N spectrograph on the Telescopio Nazionale Galileo

Date: September 28, 2017

Key Facts: This discovery is a super Earth only 21 light-years away in the inner habitable zone of its small, red 'M dwarf' star. Almost 3 times more massive than Earth, this exoplanet is 21 light-years away. It takes only two weeks to orbit its star, closer than Mercury is to the Sun. But since M dwarf stars are cool compared to our Sun, the planet still has the potential for water.

What's new: A super Earth isn't super because it's twice as cool as Earth– it's super because it's twice as massive. Besides the mass of this planet, we don't know anything about the surface or atmosphere, aka whether it would be friendly to life. But super-Earth-size planets around M dwarf stars are increasingly popular targets in the search for life. They are the most common planet type in the galaxy. So next time you imagine life out there, try picturing it on a world with a red star.

See details and check the official NASA planet count at the NASA Exoplanet Archive

Paper: "A super-Earth on the inner edge of the habitable zone of the nearby M-dwarf GJ 625"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Want to See the Surface of Another Earth? Use Our Sun

8 min read

NASA Science Editorial Team

A space telescope placed far beyond Pluto could one day deliver extreme close-ups of planets around other stars, revealing alien oceans, continents and perhaps even signs of life, new work on advanced mission concepts shows.

The secret to the telescope's extraordinary power is the biggest lens available in our solar system: the Sun itself. The Sun's gravity could be used to create a gigantic image from the feeble glimmer of a planet dozens of light-years away.

Capturing direct images of planets orbiting other stars is the next frontier for space telescope designers, with new imaging technology already in the early stages of development and testing. But even the sharpest optics now under development would offer only a single pixel of exoplanet imagery – a tiny dot of light.

Despite immense technological challenges, a few astronomical visionaries are looking much farther ahead: a solar lensing space telescope that could zoom in on small slices of an exoplanet's surface. They could provide an image many pixels across – a detailed portrait of an alien world.

Such a solar lensing mission could pave the way to the stars. The Voyager 1 spacecraft is already exploring interstellar space; the first such missions in the years ahead likely would make the interstellar medium a scientific destination, to learn more about the Sun's immediate environment and the conditions on the solar system's edge.

Nitin Arora,

JPL engineer

"It's our next step, to go beyond the solar system," said Slava Turyshev, a physicist at NASA's Jet Propulsion Laboratory in Pasadena, California. "And so that's where we need to go."

Turyshev recently took a big step of his own. He was the first to publish the intricate quantum mechanical equations that capture the behavior of light at the gravitational lens focal point, beginning some 50 billion miles (80 billion kilometers) away from Earth. Turyshev's equations show that a close-up image of, say, an Earth twin 100 light-years away could be recovered by a suitable space telescope, at least in principle.

"That was a roadblock," Turyshev said. "The equations were previously unsolved. [But now] everything has checked out well. We have a good understanding, and confidence in the solution."

Turyshev also received a NASA Innovative Advanced Concepts (NIAC) grant to further develop the idea.

While Turyshev works out the optical details of the solar lens, other specialists concentrate on the engineering.

JPL engineer Nitin Arora is part of a team developing a suite of conceptual plans for robotic interstellar voyages – including what it would take to get a space telescope to the gravitational lensing point at the icy outer reaches of the solar system.

Such early concept development does not necessarily lead to real future missions. And while Turyshev says the mathematics are unambiguous, the technological picture so far is sketchy.

But both men are brimming with optimism about the prospects for such a mission, perhaps within decades.

“You [could] see geological features on that planet,” Arora said. “I’m pretty sure you could see lakes and oceans, mountain ranges.”

Sending a telescope so far into deep space would require precision technology yet to be invented. To find such a tiny pinprick of a target – an Earth-sized planet orbiting a star 100 light years away – the telescope’s pointing accuracy will have to be at least 100 times that of today’s instruments.

And the target planet won’t be sitting still; it will be orbiting its star. To cope with the motion of the exoplanet at such extreme close-up range, smearing the planet into a blur, advanced image processing could be used. But another possibility involves tracking the exoplanet by moving the telescope itself in a kind of corkscrew pattern. This would call for delicate thruster control that would have to be invented, too.

“How to fly there, how long it will take, how to point your communications: it’s all challenging,” Turyshev said.

The broad outlines have been known for a century. Gravitational lensing was predicted by Albert Einstein. He realized that the gravity of a massive body like a star would bend light rays around it. During a total solar eclipse in 1919, Sir Arthur Eddington measured starlight bent by the Sun’s gravity, the first of many landmark confirmations of Einstein’s general theory of relativity.

A space telescope in just the right spot would see the image of an exoplanet amplified by orders of magnitude. The Sun would bend the light from the planet around it, focusing it at a point on the opposite side and, in effect, magnifying the exoplanet into a gigantic image.

But the list of potential telescopic troubles is a long one.

The first problem is the distance. The yardstick for such far-flung trips is the distance from Earth to the Sun, 93 million miles, known as an astronomical unit. Pluto is about 40 astronomical units, or AU, from the Sun.

The minimum distance for a solar lensing telescope is 547 AU. And in reality, proper positioning would likely require the telescope to be placed even farther out – perhaps as far as 2,000 AU or more.

The Kuiper belt of icy space bodies, which includes Pluto, extends to about 55 AU. The Oort cloud, the realm of dormant comets that are the most distant objects gravitationally bound to the Sun, forms a shell extending from 5,000 to 100,000 AU.

The nearest star, Proxima Centauri, would require a journey of 271,000 AU.

Just getting to the solar lensing position beyond the Kuiper belt would likely take decades using today’s technology, said Geoffrey Landis, a scientist at NASA’s John Glenn Research Center in Cleveland, Ohio, who wrote a critique of solar gravitational lensing concepts.

“Think about New Horizons,” he said of the space probe that made a spectacular flyby of Pluto in July 2015 after a nine-year journey. “It was the fastest probe ever sent into space [at launch]. It did not get to Pluto very quickly; it’s a very long way. The gravitational lens of the Sun [position] is more than 10 times as far away as Pluto.”

The trip time could be cut substantially with exotic new propulsion systems, like ion thrusters, solar sails, or even laser-pushed sails.

Reaching the solar gravitational lens within 25 years – instead of the 50-year time frame suggested by present-day technology – might even require a new form of nuclear propulsion, Arora said.

“We might want to use a mix of two propulsion technologies,” he said, starting with a nuclear fission reactor or perhaps solar-thermal propulsion. This could be combined with an “Oberth” assist from the Sun – flying close to our star, dipping deeply into its gravitational field, then making a perihelion maneuver to greatly increase the spacecraft’s speed and fling it toward the outskirts of the solar system.

Solve the problem of propulsion, and the next item on the list involves imaging. Interfering light from the exoplanet’s parent star, and from other sources, would have to be neutralized. And placement of the telescope would have to be well beyond the focal point for the light rays being bent around the Sun; otherwise, our own Sun’s glare would swamp the tiny, distant flicker from the exoplanet.

Once in place, the solar lensing telescope would not be confronted by an image of an entire exoplanet. Instead, the planet’s light would be smeared into a ring around the Sun, an effect produced as the Sun’s gravity bends light from an object – in this case, the distant exoplanet – that is behind the Sun but is also in alignment with the Sun and the telescope. This smearing effect is known as an Einstein ring.

Within the Einstein ring, strips of the planet’s light could, at least in principle, be captured by the telescope. So in addition to the blur caused by the exoplanet’s movement, which would somehow have to be corrected, these strips would have to be reassembled to create a coherent image of the exoplanet’s surface.

And after the great investment in designing, building and launching such a telescope, and perhaps decades of transit time to the right spot in the dark, frozen reaches of the solar system, it turns out that the telescope’s range would be extremely limited. It could only observe a single target.

The problem is that to turn to a different exoplanet, even one separated from the first target by a single degree, the telescope would have to move some 10 AU—a bit farther than Saturn is from the Sun.

To justify such a complex but limited telescope, a worthwhile target would have to be identified in advance: an Earth-like exoplanet where signs of life already have been detected by other instruments. So far, we don't know of any such planet.

But if we did, seeing such a world up close would be a game-changer for our understanding of our place in the universe.

“It is very fulfilling and exciting to be involved in something that can shape humanity’s future, and change life as we know it,” Arora said.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Nine

5 min read

NASA Science Editorial Team

The super Earth that came home for dinner

by Pat Brennan

It might be lingering bashfully on the icy outer edges of our solar system, hiding in the dark, but subtly pulling strings behind the scenes: stretching out the orbits of distant bodies, perhaps even tilting the entire solar system to one side.

If a planet is there, it’s extremely distant and will stay that way (with no chance – in case you’re wondering – of ever colliding with Earth, or bringing “days of darkness”). It is a possible Planet Nine, a world perhaps 10 times the mass of Earth and 20 times farther from the sun than Neptune. The signs so far are indirect, mainly its gravitational footprints, but that adds up to a compelling case nonetheless.

One of its most dedicated trackers, in fact, says it is now harder to imagine our solar system without a Planet Nine than with one.

“There are now five different lines of observational evidence pointing to the existence of Planet Nine,” said Konstantin Batygin, a planetary astrophysicist at Caltech whose team may be closing in. “If you were to remove this explanation, and imagine Planet Nine does not exist, then you generate more problems than you solve. All of a sudden, you have five different puzzles, and you must come up with five different theories to explain them.”

Batygin and his co-author, Caltech astronomer Mike Brown, described the first three breadcrumbs on Planet Nine’s trail in a January 2016 paper, published in the Astronomical Journal. Six known objects in the distant Kuiper Belt, a region of icy bodies stretching from Neptune outward toward interstellar space, all have elliptical orbits pointing in the same direction. That would be unlikely – and suspicious – enough. But these orbits also are tilted the same way, about 30 degrees “downward” compared to the pancake-like plane within which the planets orbit the sun.

Breadcrumb number three: Computer simulations of the solar system with Planet Nine included show that there should be more objects tilted with respect to the solar plane. In fact, the tilt would be on the order of 90 degrees, as if the plane of the solar system and these objects formed an “X” when viewed edge-on. Sure enough, Brown realized that five such objects already known to astronomers fill the bill.

Two more clues emerged after the original paper. A second article from the team, this time led by Batygin’s graduate student, Elizabeth Bailey, showed that Planet Nine could have tilted the planets of our solar system during the last 4.5 billion years. This could explain a longstanding mystery: Why is the plane in which the planets orbit tilted about 6 degrees compared to the sun's equator?

“Over long periods of time, Planet Nine will make the entire solar-system plane precess or wobble, just like a top on a table,” Batygin said.

The last telltale sign of Planet Nine’s presence involves the solar system’s contrarians: objects from the Kuiper Belt that orbit in the opposite direction from everything else in the solar system. Planet Nine’s orbital influence would explain why these bodies from the distant Kuiper Belt end up “polluting” the inner Kuiper Belt.

“No other model can explain the weirdness of these high-inclination orbits,” Batygin said. “It turns out that Planet Nine provides a natural avenue for their generation. These things have been twisted out of the solar system plane with help from Planet Nine and then scattered inward by Neptune.”

The remaining step is to find Planet Nine itself. Batygin and Brown are using the Subaru Telescope in Hawaii’s Mauna Kea Observatory to try to do just that. The instrument is the “best tool” for picking out dim, extremely distant objects lost in huge swaths of sky, Batygin said.

But where did Planet Nine come from? Batygin says he spends little time ruminating on its origin – whether it is a fugitive from our own solar system or, just maybe, a wandering rogue planet captured by the sun’s gravity.

“I think Planet Nine’s detection will tell us something about its origin,” he said.

Other scientists offer a different possible explanation for the Planet Nine evidence cited by Batygin. A recent analysis based on a sky mapping project called the Outer Solar System Origins Survey, which discovered more than 800 new “trans-Neptunian objects,” or TNOs, suggests that the evidence also could be consistent with a random distribution of such objects. Still, the analysis, from a team led by Cory Shankman of the University of Victoria, could not rule out Planet Nine.

If Planet Nine is found, it will be a homecoming of sorts, or at least a family reunion. Over the past 20 years, surveys of planets around other stars in our galaxy have found the most common types to be “super Earths” and their somewhat larger cousins – bigger than Earth but smaller than Neptune.

Yet these common, garden-variety planets are conspicuously absent from our solar system. Weighing in at roughly 10 times Earth’s mass, the proposed Planet Nine would make a good fit.

Planet Nine could turn out to be our missing super Earth.

Science Alert! Hellish Skies on a Hot World

2 min read

NASA Science Editorial Team

A gas giant 815 light-years away. It's a type of planet sometimes called a "hot Jupiter" because of it's similarity to our Jupiter, but incredible hot temperatures. Click or tap to rotate the planet.

WASP-19b

A heat absorbing molecule, titanium oxide, was found in the atmosphere of an already hellishly hot gas planet. Besides making this planet about the same temperature as a small star, it's a new level of detail discovered in the atmosphere of planet beyond our solar system.

European Southern Observatory

September 2017

WASP-19b is about the same size as Jupiter, but only takes 19 hours to orbit its star, which is why it's so hot. (Imagine if Eath's year only lasted hours!) The planet's atmosphere is about 3,632 degrees Fahrenheit, or 2,000 in Celsius.

The better scientists get at understanding exoplanet atmospheres, the more likely it is we'll recognize a planet with an atmosphere like Earth's. NASA missions like the upcoming James Webb Space Telescope will look for familiar elements in the atmospheres of nearby worlds.

Read more: European Southern Observatory

Paper: "Detection of titanium oxide in the atmosphere of a hot Jupiter” in Nature

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery alert! Colossal planet spotted

1 min read

NASA Science Editorial Team

Planet: MOA-2012-BLG-0006L b

Discovered by: R. Poleski and the OGLE microlensing collaboration

Date: September 15, 2017

Key Facts: This new discovery is so massive, astronomers can't say for certain whether it's a planet or a small failed star. The probable gas giant is a world of extremes: over eight times more massive than Jupiter, it also takes about 32 years to complete one orbit around its red star.

Our take: Microlensing helps us find planets toward the bright center of the Milky Way that otherwise we couldn't see. In gravitational microlensing, light from a distant star is bent and focused by gravity as a planet passes between the star and Earth. The catch is that we only get to view a microlensing planet once, before it fades back into the black of space. We're not sure how a planet the size of this gas giant was formed, but further microlensing studies could help us find clues to the existence of other planets like it.

Read more: NASA Exoplanet Archive

Paper: "A companion on the planet/brown dwarf mass boundary on a wide orbit discovered by gravitational microlensing"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA’s Hubble Captures Blistering Pitch-Black Planet

3 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA's Hubble Space Telescope has observed a planet outside our solar system that looks as black as fresh asphalt because it eats light rather than reflecting it back into space. This light-eating prowess is due to the planet's unique capability to trap at least 94 percent of the visible starlight falling into its atmosphere.

The oddball exoplanet, called WASP-12b, is one of a class of so-called "hot Jupiters," gigantic, gaseous planets that orbit very close to their host star and are heated to extreme temperatures. The planet's atmosphere is so hot that most molecules are unable to survive on the blistering day side of the planet, where the temperature is 4,600 degrees Fahrenheit. Therefore, clouds probably cannot form to reflect light back into space. Instead, incoming light penetrates deep into the planet's atmosphere where it is absorbed by hydrogen atoms and converted to heat energy.

"We did not expect to find such a dark exoplanet," said Taylor Bell of McGill University and the Institute for Research on Exoplanets in Montreal, Quebec, Canada, lead researcher of the Hubble study. "Most hot Jupiters reflect about 40 percent of starlight."

But the planet's nighttime side is a different story. WASP-12b has a fixed day side and night side because it orbits so close to the star that it is tidally locked. The nighttime side is more than 2,000 degrees Fahrenheit cooler, which allows water vapor and clouds to form. Previous Hubble observations of the day/night boundary detected evidence of water vapor and possibly clouds and hazes in the atmosphere. WASP-12b is about 2 million miles away from its star and completes an orbit once a day.

"This new Hubble research further demonstrates the vast diversity among the strange population of hot Jupiters," Bell said. "You can have planets like WASP-12b that are 4,600 degrees Fahrenheit and some that are 2,200 degrees Fahrenheit, and they're both called hot Jupiters. Past observations of hot Jupiters indicate that the temperature difference between the day and night sides of the planet increases with hotter day sides. This previous research suggests that more heat is being pumped into the day side of the planet, but the processes, such as winds, that carry the heat to the night side of the planet don't keep up the pace."

The researchers determined the planet's light-eating capabilities by using Hubble's Space Telescope Imaging Spectrograph to search in mostly visible light for a tiny dip in starlight as the planet passed directly behind the star. The amount of dimming tells astronomers how much reflected light is given off by the planet. However, the observations did not detect reflected light, meaning that the daytime side of the planet is absorbing almost all the starlight falling onto it.

First spotted in 2008, WASP-12b circles a Sun-like star residing 1,400 light-years away in the constellation Auriga. Since its discovery, several telescopes have studied the exoplanet, including Hubble, NASA's Spitzer Space Telescope, and NASA's Chandra X-ray Observatory. Previous observations by Hubble's Cosmic Origins Spectrograph (COS) revealed that the planet may be downsizing. COS detected material from the planet's super-heated atmosphere spilling onto the star.

The results appear in the Sept. 14 issue of The Astrophysical Journal Letters.

For additional information, visit: http://hubblesite.org/news_release/news/2017-38.

For more information about Hubble, visit: www.nasa.gov/hubble

Contacts:

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4493 / 410-338-4514dweaver@stsci.edu /

Taylor BellMcGill University / Institute for Research on Exoplanets, Montreal, Quebec, Canadataylor.bell@mail.mcgill.ca

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble delivers first hints of possible water content of TRAPPIST-1 planets

3 min read

NASA Science Editorial Team

An international team of astronomers used the NASA/ESA Hubble Space Telescope to estimate whether there might be water on the seven earth-sized planets orbiting the nearby dwarf star TRAPPIST-1. The results suggest that the outer planets of the system might still harbor substantial amounts of water. This includes the three planets within the habitable zone of the star, lending further weight to the possibility that they may indeed be habitable.

On February 22, 2017 astronomers announced the discovery of seven Earth-sized planets orbiting the ultracool dwarf star TRAPPIST-1, 40 light-years away. This makes TRAPPIST-1 the planetary system with the largest number of Earth-sized planets discovered so far.

Following up on the discovery, an international team of scientists led by the Swiss astronomer Vincent Bourrier from the Observatoire de l'Université de Genève, used the Space Telescope Imaging Spectrograph (STIS) on the NASA/ESA Hubble Space Telescope to study the amount of ultraviolet radiation received by the individual planets of the system. “Ultraviolet radiation is an important factor in the atmospheric evolution of planets,” explains Bourrier. “As in our own atmosphere, where ultraviolet sunlight breaks molecules apart, ultraviolet starlight can break water vapour in the atmospheres of exoplanets into hydrogen and oxygen.”

While lower-energy ultraviolet radiation breaks up water molecules — a process called photodissociation — ultraviolet rays with more energy (XUV radiation) and X-rays heat the upper atmosphere of a planet, which allows the products of photodissociation, hydrogen and oxygen, to escape.

As it is very light, hydrogen gas can escape the exoplanets' atmospheres and be detected around the exoplanets with Hubble, acting as a possible indicator of atmospheric water vapor. The observed amount of ultraviolet radiation emitted by TRAPPIST-1 indeed suggests that the planets could have lost gigantic amounts of water over the course of their history.

This is especially true for the innermost two planets of the system, TRAPPIST-1b and TRAPPIST-1c, which receive the largest amount of ultraviolet energy. “Our results indicate that atmospheric escape may play an important role in the evolution of these planets,” summarises Julien de Wit, from MIT, USA, co-author of the study.

The inner planets could have lost more than 20 Earth-oceans-worth of water during the last eight billion years. However, the outer planets of the system — including the planets e, f and g which are in the habitable zone — should have lost much less water, suggesting that they could have retained some on their surfaces. The calculated water loss rates as well as geophysical water release rates also favour the idea that the outermost, more massive planets retain their water. However, with the currently available data and telescopes no final conclusion can be drawn on the water content of the planets orbiting TRAPPIST-1.

“While our results suggest that the outer planets are the best candidates to search for water with the upcoming James Webb Space Telescope, they also highlight the need for theoretical studies and complementary observations at all wavelengths to determine the nature of the TRAPPIST-1 planets and their potential habitability,” concludes Bourrier.

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

X-rays reveal temperament of possible planet-hosting stars

4 min read

NASA Science Editorial Team

◆ X-rays may provide valuable information about whether a star system will be hospitable to life on planets.

◆ Researchers used Chandra and XMM-Newton to study 24 stars like the Sun that were at least one billion years old.

A new X-ray study has revealed that stars like the Sun and their less massive cousins calm down surprisingly quickly after a turbulent youth. This result has positive implications for the long-term habitability of planets orbiting such stars.

A team of researchers used data from NASA's Chandra X-ray Observatory and ESA's XMM-Newton to see how the X-ray brightness of stars similar to the Sun behaves over time. The X-ray emission from a star comes from a thin, hot, outer layer, called the corona. From studies of solar X-ray emission, astronomers have determined that the corona is heated by processes related to the interplay of turbulent motions and magnetic fields in the outer layers of a star.

High levels of magnetic activity can produce bright X-rays and ultraviolet light from stellar flares. Strong magnetic activity can also generate powerful eruptions of material from the star's surface. Such energetic radiation and eruptions can impact planets and could damage or destroy their atmospheres, as pointed out in previous studies, including Chandra work reported in 2011 and 2013.

Since stellar X-rays mirror magnetic activity, X-ray observations can tell astronomers about the high-energy environment around the star. The new study uses X-ray data from Chandra and XMM-Newton to show that stars like the Sun and their less massive cousins decrease in X-ray brightness surprisingly quickly.

Katja Poppenhaeger

Harvard Smithsonian Center for Astrophysics

Specifically, the researchers examined 24 stars that have masses similar to the Sun or less, and ages of a billion years or older. (For context, the Sun is 4.5 billion years old.) The rapid observed decline in X-ray brightness implies a rapid decline in energetic activity, which may provide a hospitable environment for the formation and evolution of life on any orbiting planets.

"This is good news for the future habitability of planets orbiting Sun-like stars, because the amount of harmful X-rays and ultraviolet radiation striking these worlds from stellar flares would be less than we used to think," said Rachel Booth, a graduate student at Queen's University in Belfast, UK, who led the study.

This result is different from other recent work on Sun-like and lower mass stars with ages less than a billion years. The new work shows that older stars drop in activity far more quickly than their younger counterparts.

"We've heard a lot about the volatility of stars less massive than the Sun, like TRAPPIST-1 and Proxima Centauri, and how that's bad for life-supporting atmospheres on their planets," said Katja

Poppenhaeger, a co-author from Queen’s University and the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Mass. “It’s refreshing to have some good news to share about potential habitability.”

To understand how quickly stellar magnetic activity level changes over time, astronomers need accurate ages for many different stars. This is a difficult task, but new precise age estimates have recently become available from studies of the way that a star pulsates using NASA’s Kepler and ESA’s CoRoT missions. These new age estimates were used for most of the 24 stars studied here.

Astronomers have observed that most stars are very magnetically active when they are young, since the stars are rapidly rotating. As the rotating star loses energy over time, the star spins more slowly and the magnetic activity level, along with the associated X-ray emission, drops.

“We’re not exactly sure why older stars settle down relatively quickly,” said co-author Chris Watson of Queen’s University. “However, we know it’s led to the successful formation of life in at least one case – around our own Sun.”

One possibility is that the decrease in rate of spin of the older stars occurs more quickly than it does for the younger stars. Another possibility is that the X-ray brightness declines more quickly with time for older, more slowly rotating stars than it does for younger stars.

A paper describing these results has been accepted for publication in the Monthly Notices of the Royal Astronomical Society, and is available online. The other co-authors are from Aarhus University in Denmark and Scott Wolk from CfA.

NASA’s Marshall Space Flight Center in Huntsville, Alabama, manages the Chandra program for NASA’s Science Mission Directorate in Washington. The Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, controls Chandra’s science and flight operations.

To read more, please visit:

NASA's Chandra X-ray Observatory.

For more Chandra images, multimedia and related materials, please visit:

http://www.nasa.gov/chandra

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

X-rays Reveal Temperament of Possible Planet-Hosting Stars

6 min read

A new X-ray study has revealed that stars like the Sun and their less massive cousins calm down surprisingly quickly after a turbulent youth. This result has positive implications for the long-term habitability of planets orbiting such stars.

A team of researchers used data from NASA's Chandra X-ray Observatory and ESA's XMM-Newton to see how the X-ray brightness of stars similar to the Sun behaves over time. The X-ray emission from a star comes from a thin, hot, outer layer, called the corona. From studies of solar X-ray emission, astronomers have determined that the corona is heated by processes related to the interplay of turbulent motions and magnetic fields in the outer layers of a star.

High levels of magnetic activity can produce bright X-rays and ultraviolet light from stellar flares. Strong magnetic activity can also generate powerful eruptions of material from the star's surface. Such energetic radiation and eruptions can impact planets and could damage or destroy their atmospheres, as pointed out in previous studies, including Chandra work reported in 2011 and 2013.

Since stellar X-rays mirror magnetic activity, X-ray observations can tell astronomers about the high-energy environment around the star. The new study uses X-ray data from Chandra and XMM-Newton to show that stars like the Sun and their less massive cousins decrease in X-ray brightness surprisingly quickly.

Specifically, the researchers examined 24 stars that have masses similar to the Sun or less, and ages of a billion years or older. (For context, the Sun is 4.5 billion years old.) The rapid observed decline in X-ray brightness implies a rapid decline in energetic activity, which may provide a hospitable environment for the formation and evolution of life on any orbiting planets.

"This is good news for the future habitability of planets orbiting Sun-like stars, because the amount of harmful X-rays and ultraviolet radiation striking these worlds from stellar flares would be less than we used to think," said Rachel Booth, a graduate student at Queen's University in Belfast, UK, who led the study.

This result is different from other recent work on Sun-like and lower mass stars with ages less than a billion years. The new work shows that older stars drop in activity far more quickly than their younger counterparts.

"We've heard a lot about the volatility of stars less massive than the Sun, like TRAPPIST-1 and Proxima Centauri, and how that's bad for life-supporting atmospheres on their planets," said Katja Poppenhaeger, a co-author from Queen's University and the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Mass. "It's refreshing to have some good news to share about potential habitability."

To understand how quickly stellar magnetic activity level changes over time, astronomers need accurate ages for many different stars. This is a difficult task, but new precise age estimates have recently become available from studies of the way that a star pulsates using NASA's Kepler and ESA's CoRoT missions. These new age estimates were used for most of the 24 stars studied here.

Astronomers have observed that most stars are very magnetically active when they are young, since the stars are rapidly rotating. As the rotating star loses energy over time, the star spins more slowly and the magnetic activity level, along with the associated X-ray emission, drops.

“We’re not exactly sure why older stars settle down relatively quickly,” said co-author Chris Watson of Queen’s University. “However, we know it’s led to the successful formation of life in at least one case – around our own Sun.”

One possibility is that the decrease in rate of spin of the older stars occurs more quickly than it does for the younger stars. Another possibility is that the X-ray brightness declines more quickly with time for older, more slowly rotating stars than it does for younger stars.

A paper describing these results has been accepted for publication in the Monthly Notices of the Royal Astronomical Society, and is available online. The other co-authors are Victor Silva Aguirre from Aarhus University in Denmark and Scott Wolk from CfA.

NASA’s Marshall Space Flight Center in Huntsville, Alabama, manages the Chandra program for NASA’s Science Mission Directorate in Washington. The Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, controls Chandra’s science and flight operations.

Read More from NASA’s Chandra X-ray Observatory.

For more Chandra images, multimedia and related materials, visit:

https://www.nasa.gov/chandra

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Team Passes Major Technological Milestone for Characterizing Exoplanets

5 min read

NASA researchers say they have passed a major milestone in their quest to mature more powerful tools for directly detecting and analyzing the atmospheres of giant planets outside the solar system — one of the observational goals of NASA's proposed Wide-Field Infrared Space Telescope, also known as WFIRST.

In tests conducted at the High-Contrast Imaging Testbed at NASA's Jet Propulsion Laboratory, or JPL, in Pasadena, California — one of the world's most advanced testbeds of its kind — researchers created what they call a region of very deep contrast between a simulated star and its planet. They also demonstrated the ability to detect and analyze the planet's faint light over a relatively large portion of the visible to near-infrared wavelength band.

An instrument developed by scientists at NASA's Goddard Space Flight Center in Greenbelt, Maryland — the Prototype Imaging Spectrograph for Coronagraphic Exoplanet Studies, or PISCES — played an important role in the demonstration, showing that it could separate light of one or more Jupiter-sized exoplanets by their wavelength (color) and record the data at every position around a star.

To appreciate the researchers' milestone, it's important to understand the challenge itself.

The light from these planets is exceedingly faint — fainter than their host stars by a factor of 100 million or more, and from our perspective on Earth, these planets appear quite close to their stars. With a conventional imaging camera, the planet's light is lost in the glare of the star. However, with a coronagraph — a device that suppresses the glare and creates a dark zone around a star — the faint light of an exoplanet can be revealed.

Working in concert with the coronagraph, an integral field spectrograph, or IFS, such as PISCES, would be able to separate the exoplanet's light by its wavelength and record the data, revealing details about the planet's physical properties, including the chemical composition and structure of its atmosphere.

During the test, the Goddard-JPL team maintained a very deep contrast over 18 percent of the coronagraph's wavelength band — a record that bodes well for future missions like WFIRST, which has baselined a coronagraph and an IFS-type instrument on the mission. (To put this in perspective, the human eye can see the full visible spectrum of colors, from blue to red, which corresponds to a 50 percent bandpass. In comparison, a laser pointer has one single color, which is much smaller than one percent.)

"Achieving a contrast this deep over such a broad band has never been done before and was one of our goals. Ideally, we would like to observe the entire spectrum of the planet — in other words, see all its colors at once — but that's not yet possible with current coronagraphic technologies. Eighteen percent, as demonstrated by PISCES, is the current state of the art," said Goddard scientist and PISCES Instrument Scientist Michael McElwain. In comparison, JPL's laboratory coronagraph maintained the same level of dark contrast over 10 percent of the optical-wavelength bands before the commissioning of the table-top PISCES last year.

"We are not done yet and are still trying to get to higher contrasts, but the 100 million-to-one over 18 percent of the optical wavelength band is an important and significant milestone," said Maxime Rizzo, a postdoctoral student who is working with McElwain and his team to advance PISCES. "With the increased bandpass, we can get many colors at once. This enables us to identify more molecules in the atmospheres and get a big picture."

PISCES, which McElwain developed with funding from Goddard's Internal Research and Development program and the prestigious Nancy Grace Roman Technology Fellowship, separates light a little differently than more traditional spectrographs.

As an IFS-type device, PISCES takes a coronagraphic image and samples it with a micro-lens array made up of more than 5,800 tiny glass segments no larger than the width of three human hairs. The micro-lens creates an array of "spots" that is then dispersed by a prism and finally re-imaged onto a detector. In practice, each micro-lens, or lenslet, isolates a small portion of the coronagraphic image, creating micro-spectra for the light that passes through each tiny lenslet. The multiple spectra then are combined into a data cube that scientists analyze.

The IFS provides all the wavelength information simultaneously across the entire field of view. With more traditional imaging observations, scientists must cycle through the different wavelengths, which takes time and requires a mechanism to change the filters — requirements not desirable with an orbiting observatory that only has limited time to spend on a target. The optical system itself changes over time due to thermal and dynamic variations, further underscoring the need for simultaneous spectral observations.

"That's why WFIRST planners baselined the IFS-type spectrograph in the first place," Rizzo said. "In this case, PISCES offered information over a full 18 percent of the bandpass, instead of the traditional 10 percent that had been demonstrated at JPL without an IFS. PISCES showed that it could enable more science."

Even though the team demonstrated the deep contrast over a greater portion of the visible to near-infrared bandpass, and in doing so, raised the technology's readiness level, work remains, said Avi Mandell, the WFIRST IFS project scientist. "The success has opened up all new starlight-suppression ideas that we want to test."

For more information about WFIRST, visit: www.nasa.gov/wfirst

For more technology news, go to https://gsfctechnology.gsfc.nasa.gov/newsletter/Current.pdf

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

An eclipse by any other name: Doing science with transits and occultations

6 min read

Alicia Cermak

An otherworldly atmosphere takes hold when a total solar eclipse blocks the Sun’s light, yet the mechanics of the event are actually rather mundane. All you need is for one celestial body (in this case, the Moon) to block your view of a more distant object (here, the Sun). But different flavors of this phenomenon make some very sophisticated science possible. From the study of Pluto’s atmosphere to the discovery of planets around other stars, NASA researchers are using eclipse-like events to learn more about the universe.

On August 21, solar eclipse fans along the path of totality will enjoy a view of the Moon masking the entire disk of the Sun. Scientists use the term "occultation" for this situation, where the nearer object completely blocks the one behind. When the more distant body is a star, researchers can glean a wealth of information from the way the star’s light passes near and around the object. They can tell, for instance, whether the object is surrounded by rings or if it has an atmosphere.

In 2015, NASA’s Stratospheric Observatory for Infrared Astronomy, or SOFIA – an airborne observatory featuring a 2.5-meter infrared telescope mounted in a highly modified Boeing 747SP aircraft – used an occultation to learn more about Pluto. As the dwarf planet blotted out a distant star, it cast a dim, fast-moving shadow on the surface of the Earth, mostly across the middle of the Pacific Ocean. As the dark spot raced over the surface at 53,000 mph, SOFIA flew right through the middle of it, and had about 130 seconds to measure the light of the hidden star that seeped around the occulting object, Pluto, and scattered through its atmosphere. From this data, scientists learned about the structure, pressure and density of Pluto’s atmosphere some three billion miles from Earth.

SOFIA’s measurements were all the more valuable as they could be compared to the data from another mission, collected just two weeks later, when NASA’S New Horizons spacecraft flew by Pluto at a distance of a mere 7,750 miles. This allowed researchers to calibrate decades of existing Earth-based Pluto occultation data studying its atmosphere, enhancing their analyses of all those earlier observations.

Recently, in June, SOFIA studied another occultation, this time with a small, icy body that is likely a remnant from the earliest days of our solar neighborhood, called 2014 MU69. New Horizons plans to fly by MU69 to learn about the formation of our solar system. However, if it turns out MU69 is surrounded by rings or debris, the spacecraft’s flyby would have to be adjusted to a safe distance.

"The MU69 occultation observations were much more challenging when compared to those done in support of the Pluto flyby in 2015, as MU69 is much smaller and we had more open questions about its location with respect to the background star, whose light it would block. It really brought occultation science to a whole new level of precision," said Kimberly Ennico Smith, SOFIA project scientist at NASA's Ames Research Center in Silicon Valley. "The researchers, instrument team and flight crew worked together to optimize our observing strategy."

The New Horizons team will continue to pore through the new data for additional clues about 2014 MU69 to better understand its shape, size and the environment around the object. It will be the most distant object ever explored by a spacecraft—more than a billion miles beyond Pluto.

Sometimes the partners in an eclipse-like dance do not yield the full-coverage effect of the upcoming solar eclipse or the MU69 occultation. In an event called a transit, the nearer object blocks very little of a star that lies beyond. Instead, you may see a small dark spot crossing the stellar face, as in the 2012 transit of Venus across the Sun.

If both objects are very far away – in other solar systems – our telescopes can't yet make out the smaller partner. What some instruments, such as NASA's Kepler space telescope, can see is the minuscule dimming of the star that occurs when an orbiting planet blocks a fraction of its light. Using this method, Kepler has, to date, discovered more than 4,500 potential exoplanets orbiting other stars. Of these, nearly 2,500 have been confirmed as bona fide exoplanets.

With measurements made during a transit, scientists can calculate the size of the exoplanet and its distance from its star. When multiple transits are observed, the orbital period, or year, of an exoplanet also can be calculated. These characteristics are important factors in determining if an exoplanet resides in the just-right “Goldilocks” or habitable zone of their star, where liquid water might exist on the surface.

“Astronomers are adept at leveraging the improbable and ephemeral coincidences of nature and using them to learn something remarkable,” said Natalie Batalha, the Kepler mission project scientist, at Ames. “Catching shadows, Kepler opened our eyes to the terrestrial-size planets that populate the galaxy.”

Several upcoming NASA missions will use the transit method to continue the hunt for exoplanets, including TESS and WFIRST. The next major step in exoplanet research may be to capture direct images of the exoplanets themselves. It's an exciting, challenging prospect, given that the planets are billions of times fainter than the stars they orbit.

Today, NASA researchers are developing a sophisticated tool that will let us see these distant planets by intentionally blocking the light of their star.

“During a solar eclipse, many solar system planets become visible, which are otherwise lost in the glare of the Sun,” said Ruslan Belikov, who co-leads, along with Eduardo Bendek, the Exoplanet Technologies research group at Ames. “In the same way, by ‘eclipsing’ the light from another star, a telescope can see planets that are otherwise lost in the glare of that star.”

The lab's technology, called a coronagraph, essentially creates an artificial eclipse inside a telescope.

“By coupling the coronagraph, which occults the star, with an instrument for analyzing the light reflected from the exoplanets' atmosphere, NASA's next generation of space telescopes will be able to explore these worlds and assess if they can harbor life,” said Bendek.

Whether an occultation briefly blots out a star entirely, or a transit causes its light to fade by a minuscule degree, these cousins to the eclipse are helping NASA answer certain questions, and also ask many more that will form the basis of exciting future investigations. On August 21, remember that an eclipse by any other name yields science just as sweet.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Discovery alert! Three Earth-mass neighbors

1 min read

NASA Science Editorial Team

System: YZ Ceti

Discovered by: European Southern Observatory

Date: August 14, 2017

Key Facts: Three Earth-mass worlds found around a small red star only 12 light-years away.

What's new: YZ Ceti is the nearest multi-planet system found orbiting a red dwarf star or "M dwarf." While the three planets are outside their star's habitable zone, they are all about the same mass as Earth. YZ Ceti b, c, and d are the lowest mass planets found with the planet-hunting method radial velocity. NASA's TESS and James Webb telescopes will study more exoplanets around nearby stars in 2018, in hopes of finding another Earth.

See details and check the official NASA planet count at the NASA Exoplanet Archive

Paper: "A system of Earth-mass planets around the nearby M dwarf YZ Cet"

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

TRAPPIST-1 is Older Than Our Solar System

5 min read

NASA Science Editorial Team

If we want to know more about whether life could survive on a planet outside our solar system, it's important to know the age of its star. Young stars have frequent releases of high-energy radiation called flares that can zap their planets' surfaces. If the planets are newly formed, their orbits may also be unstable. On the other hand, planets orbiting older stars have survived the spate of youthful flares, but have also been exposed to the ravages of stellar radiation for a longer period of time.

Scientists now have a good estimate for the age of one of the most intriguing planetary systems discovered to date– TRAPPIST-1, a system of seven Earth-size worlds orbiting an ultra-cool dwarf star about 40 light-years away. Researchers say in a new study that the TRAPPIST-1 star is quite old: between 5.4 and 9.8 billion years. This is up to twice as old as our own solar system, which formed some 4.5 billion years ago.

Adam Burgasser

University of California, San Diego

The seven wonders of TRAPPIST-1 were revealed earlier this year in a NASA news conference, using a combination of results from the Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile, NASA's Spitzer Space Telescope, and other ground-based telescopes. Three of the TRAPPIST-1 planets reside in the star's "habitable zone," the orbital distance where a rocky planet with an atmosphere could have liquid water on its surface. All seven planets are likely tidally locked to their star, each with a perpetual dayside and nightside.

At the time of its discovery, scientists believed the TRAPPIST-1 system had to be at least 500 million years old, since it takes stars of TRAPPIST-1's low mass (roughly 8 percent that of the Sun) roughly that long to contract to its minimum size, just a bit larger than the planet Jupiter. However, even this lower age limit was uncertain; in theory, the star could be almost as old as the universe itself. Are the orbits of this compact system of planets stable? Might life have enough time to evolve on any of these worlds?

"Our results really help constrain the evolution of the TRAPPIST-1 system, because the system has to have persisted for billions of years. This means the planets had to evolve together, otherwise the system would have fallen apart long ago," said Adam Burgasser, an astronomer at the University of California, San Diego, and the paper's first author. Burgasser teamed up with Eric Mamajek, deputy program scientist for NASA's Exoplanet Exploration Program based at NASA's Jet Propulsion Laboratory, Pasadena, California, to calculate TRAPPIST-1's age. Their results will be published in The Astrophysical Journal.

It is unclear what this older age means for the planets' habitability. On the one hand, older stars flare less than younger stars, and Burgasser and Mamajek confirmed that TRAPPIST-1 is relatively quiet compared to other ultra-cool dwarf stars. On the other hand, since the planets are so close to the star, they have soaked up billions of years of high-energy radiation, which could have boiled off atmospheres and large amounts of water. In fact, the equivalent of an Earth ocean may have evaporated from each TRAPPIST-1 planet except for the two most distant from the host star: planets g and h. In our own solar system, Mars is an example of a planet that likely had liquid water on its surface in the past, but lost most of its water and atmosphere to the Sun's high-energy radiation over billions of years.

Eric Mamajek

NASA exoplanet scientist

However, old age does not necessarily mean that a planet's atmosphere has been eroded. Given that the TRAPPIST-1 planets have lower densities than Earth, it is possible that large reservoirs of volatile molecules such as water could produce thick atmospheres that would shield the planetary surfaces from harmful radiation. A thick atmosphere could also help redistribute heat to the dark sides of these tidally locked planets, increasing habitable real estate. But this could also backfire in a "runaway greenhouse" process, in which the atmosphere becomes so thick the planet surface overheats – as on Venus.

"If there is life on these planets, I would speculate that it has to be hardy life, because it has to be able to survive some potentially dire scenarios for billions of years," Burgasser said.

Fortunately, low-mass stars like TRAPPIST-1 have temperatures and brightnesses that remain relatively constant over trillions of years, punctuated by occasional magnetic flaring events. The lifetimes of tiny stars like TRAPPIST-1 are predicted to be much, much longer than the 13.7 billion-year age of the universe (the Sun, by comparison, has an expected lifetime of about 10 billion years).

"Stars much more massive than the Sun consume their fuel quickly, brightening over millions of years and exploding as supernovae," Mamajek said. "But TRAPPIST-1 is like a slow-burning candle that will shine for about 900 times longer than the current age of the universe."

Some of the clues Burgasser and Mamajek used to measure the age of TRAPPIST-1 included how fast the star is moving in its orbit around the Milky Way (speedier stars tend to be older), its atmosphere’s chemical composition, and how many flares TRAPPIST-1 had during observational periods. These variables all pointed to a star that is substantially older than our Sun.

Future observations with NASA's Hubble Space Telescope and upcoming James Webb Space Telescope may reveal whether these planets have atmospheres, and whether such atmospheres are like Earth's.

"These new results provide useful context for future observations of the TRAPPIST-1 planets, which could give us great insight into how planetary atmospheres form and evolve, and persist or not," said Tiffany Kataria, exoplanet scientist at JPL, who was not involved in the study.

Future observations with Spitzer could help scientists sharpen their estimates of the TRAPPIST-1 planets’ densities, which would inform their understanding of their compositions.

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Scientists Improve Brown Dwarf Weather Forecasts

5 min read

NASA Science Editorial Team

Dim objects called brown dwarfs, less massive than the Sun but more massive than Jupiter, have powerful winds and clouds–specifically, hot patchy clouds made of iron droplets and silicate dust. Scientists recently realized these giant clouds can move and thicken or thin surprisingly rapidly, in less than an Earth day, but did not understand why.

Now, researchers have a new model for explaining how clouds move and change shape in brown dwarfs, using insights from NASA's Spitzer Space Telescope. Giant waves cause large-scale movement of particles in brown dwarfs' atmospheres, changing the thickness of the silicate clouds, researchers report in the journal Science. The study also suggests these clouds are organized in bands confined to different latitudes, traveling with different speeds in different bands.

"This is the first time we have seen atmospheric bands and waves in brown dwarfs," said lead author Daniel Apai, associate professor of astronomy and planetary sciences at the University of Arizona in Tucson.

Just as in Earth’s ocean, different types of waves can form in planetary atmospheres. For example, in Earth’s atmosphere, very long waves mix cold air from the polar regions to mid-latitudes, which often lead clouds to form or dissipate.

The distribution and motions of the clouds on brown dwarfs in this study are more similar to those seen on Jupiter, Saturn, Uranus and Neptune. Neptune has cloud structures that follow banded paths too, but its clouds are made of ice. Observations of Neptune from NASA's Kepler spacecraft, operating in its K2 mission, were important in this comparison between the planet and brown dwarfs.

"The atmospheric winds of brown dwarfs seem to be more like Jupiter’s familiar regular pattern of belts and zones than the chaotic atmospheric boiling seen on the Sun and many other stars," said study co-author Mark Marley at NASA's Ames Research Center in California's Silicon Valley.

Brown dwarfs can be thought of as failed stars because they are too small to fuse chemical elements in their cores. They can also be thought of as "super planets" because they are more massive than Jupiter, yet have roughly the same diameter. Like gas giant planets, brown dwarfs are mostly made of hydrogen and helium, but they are often found apart from any planetary systems. In a 2014 study using Spitzer, scientists found that brown dwarfs commonly have atmospheric storms.

Due to their similarity to giant exoplanets, brown dwarfs are windows into planetary systems beyond our own. It is easier to study brown dwarfs than planets because they often do not have a bright host star that obscures them.

"It is likely the banded structure and large atmospheric waves we found in brown dwarfs will also be common in giant exoplanets," Apai said.

Using Spitzer, scientists monitored brightness changes in six brown dwarfs over more than a year, observing each of them rotate 32 times. As a brown dwarf rotates, its clouds move in and out of the hemisphere seen by the telescope, causing changes in the brightness of the brown dwarf. Scientists then analyzed these brightness variations to explore how silicate clouds are distributed in the brown dwarfs.

Researchers had been expecting these brown dwarfs to have elliptical storms resembling Jupiter's Great Red Spot, caused by high-pressure zones. The Great Red Spot has been present in Jupiter for hundreds of years and changes very slowly: Such "spots" could not explain the rapid changes in brightness that scientists saw while observing these brown dwarfs. The brightness levels of the brown dwarfs varied markedly just over the course of an Earth day.

To make sense of the ups and downs of brightness, scientists had to rethink their assumptions about what was going on in the brown dwarf atmospheres. The best model to explain the variations involves large waves, propagating through the atmosphere with different periods. These waves would make the cloud structures rotate with different speeds in different bands.

University of Arizona researcher Theodora Karalidi used a supercomputer and a new computer algorithm to create maps of how clouds travel on these brown dwarfs.

"When the peaks of the two waves are offset, over the course of the day there are two points of maximum brightness," Karalidi said. "When the waves are in sync, you get one large peak, making the brown dwarf twice as bright as with a single wave."

The results explain the puzzling behavior and brightness changes that researchers previously saw. The next step is to try to better understand what causes the waves that drive cloud behavior.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena, California. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA. For more information about Spitzer, visit:

http://spitzer.caltech.edu

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Detects Exoplanet with Glowing Water Atmosphere

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Scientists have discovered the strongest evidence to date for a stratosphere on a planet outside our solar system, or exoplanet. A stratosphere is a layer of atmosphere in which temperature increases with higher altitudes.

"This result is exciting because it shows that a common trait of most of the atmospheres in our solar system -- a warm stratosphere -- also can be found in exoplanet atmospheres," said Mark Marley, study co-author based at NASA's Ames Research Center in California's Silicon Valley. "We can now compare processes in exoplanet atmospheres with the same processes that happen under different sets of conditions in our own solar system."

Reporting in the journal Nature, scientists used data from NASA's Hubble Space Telescope to study WASP-121b, a type of exoplanet called a "hot Jupiter." Its mass is 1.2 times that of Jupiter, and its radius is about 1.9 times Jupiter's -- making it puffier. But while Jupiter revolves around our sun once every 12 years, WASP-121b has an orbital period of just 1.3 days. This exoplanet is so close to its star that if it got any closer, the star's gravity would start ripping it apart. It also means that the top of the planet's atmosphere is heated to a blazing 4,600 degrees Fahrenheit (2,500 Celsius), hot enough to boil some metals. The WASP-121 system is estimated to be about 900 light years from Earth – a long way, but close by galactic standards.

Previous research found possible signs of a stratosphere on the exoplanet WASP-33b as well as some other hot Jupiters. The new study presents the best evidence yet because of the signature of hot water molecules that researchers observed for the first time.

“Theoretical models have suggested stratospheres may define a distinct class of ultra-hot planets, with important implications for their atmospheric physics and chemistry,” said Tom Evans, lead author and research fellow at the University of Exeter, United Kingdom. “Our observations support this picture.”

To study the stratosphere of WASP-121b, scientists analyzed how different molecules in the atmosphere react to particular wavelengths of light, using Hubble's capabilities for spectroscopy. Water vapor in the planet's atmosphere, for example, behaves in predictable ways in response to certain wavelengths of light, depending on the temperature of the water.

Starlight is able to penetrate deep into a planet's atmosphere, where it raises the temperature of the gas there. This gas then radiates its heat into space as infrared light. However, if there is cooler water vapor at the top of the atmosphere, the water molecules will prevent certain wavelengths of this light from escaping to space. But if the water molecules at the top of the atmosphere have a higher temperature, they will glow at the same wavelengths.

"The emission of light from water means the temperature is increasing with height," said Tiffany Kataria, study co-author based at NASA's Jet Propulsion Laboratory, Pasadena, California. "We're excited to explore at what longitudes this behavior persists with upcoming Hubble observations."

The phenomenon is similar to what happens with fireworks, which get their colors from chemicals emitting light. When metallic substances are heated and vaporized, their electrons move into higher energy states. Depending on the material, these electrons will emit light at specific wavelengths as they lose energy: sodium produces orange-yellow and strontium produces red in this process, for example. The water molecules in the atmosphere of WASP-121b similarly give off radiation as they lose energy, but in the form of infrared light, which the human eye is unable to detect.

In Earth's stratosphere, ozone gas traps ultraviolet radiation from the sun, which raises the temperature of this layer of atmosphere. Other solar system bodies have stratospheres, too; methane is responsible for heating in the stratospheres of Jupiter and Saturn's moon Titan, for example.

In solar system planets, the change in temperature within a stratosphere is typically around 100 degrees Fahrenheit (about 56 degrees Celsius). On WASP-121b, the temperature in the stratosphere rises by 1,000 degrees (560 degrees Celsius). Scientists do not yet know what chemicals are causing the temperature increase in WASP-121b's atmosphere. Vanadium oxide and titanium oxide are candidates, as they are commonly seen in brown dwarfs, "failed stars" that have some commonalities with exoplanets. Such compounds are expected to be present only on the hottest of hot Jupiters, as high temperatures are needed to keep them in a gaseous state.

"This super-hot exoplanet is going to be a benchmark for our atmospheric models, and it will be a great observational target moving into the Webb era," said Hannah Wakeford, study co-author who worked on this research while at NASA's Goddard Space Flight Center, Greenbelt, Maryland.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, Inc., in Washington. Caltech manages JPL for NASA.

For more information about Hubble, visit:

https://nasa.gov/hubblehttp://hubblesite.org

For more information about exoplanets, visit:

https://exoplanets.nasa.gov

Contacts:

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4514villard@stsci.edu

In May 2024, a geomagnetic storm hit Earth, sending auroras across the planet’s skies in a once-in-a-generation light display. These dazzling sights are possible because of the interaction of coronal mass ejections – explosions of plasma and magnetic field from the Sun – with Earth’s magnetic field, which protects us from the radiation the Sun […]

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hidden stars may make planets appear smaller

6 min read

NASA Science Editorial Team

In the search for planets similar to our own, an important point of comparison is the planet's density. A low density tells scientists a planet is more likely to be gaseous like Jupiter, and a high density is associated with rocky planets like Earth. But a new study suggests some are less dense than previously thought because of a second, hidden star in their systems.

As telescopes stare at particular patches of sky, they can't always differentiate between one star and two. A system of two closely orbiting stars may appear in images as a single point of light, even from sophisticated observatories such as NASA's Kepler space telescope. This can have significant consequences for determining the sizes of planets that orbit just one of these stars, says a forthcoming study in the Astronomical Journal by Elise Furlan of Caltech/IPAC-NExScI in Pasadena, California, and Steve Howell at NASA's Ames Research Center in California's Silicon Valley.

"Our understanding of how many planets are small like Earth, and how many are big like Jupiter, may change as we gain more information about the stars they orbit," Furlan said. "You really have to know the star well to get a good handle on the properties of its planets."

Some of the most well-studied planets outside our solar system– or exoplanets– are known to orbit lone stars. We know Kepler-186f, an Earth-size planet in the habitable zone of its star, orbits a star that has no companion (the habitable zone is the distance at which a rocky planet could support liquid water on its surface). TRAPPIST-1, the ultra-cool dwarf star that is home to seven Earth-size planets, does not have a companion either. That means there is no second star complicating the estimation of the planets' diameters, and therefore their densities.

But other stars have a nearby companion, high-resolution imaging has recently revealed. David Ciardi, chief scientist at the NASA Exoplanet Science Institute (NExScI) at Caltech, led a large-scale effort to follow up on stars that Kepler had studied using a variety of ground-based telescopes. This, combined with other research, has confirmed that many of the stars where Kepler found planets have binary companions. In some cases, the diameters of the planets orbiting these stars were calculated without taking the companion star into consideration. That means estimates for their sizes should be smaller, and their densities higher, than their true values.

Previous studies determined that roughly half of all the sun-like stars in our sun's neighborhood have a companion within 10,000 astronomical units (an astronomical unit is equal to the average distance between the sun and Earth, 93 million miles or 150 million kilometers). Based on this, about 15 percent of stars in the Kepler field could have a bright, close companion– meaning planets around these stars may be less dense than previously thought.

When a telescope spots a planet crossing in front of its star– an event called a "transit"– astronomers measure the resulting apparent decrease in the star's brightness. The amount of light blocked during a transit depends on the size of the planet– the bigger the planet, the more light it blocks, and the greater the dimming that is observed. Scientists use this information to determine the radius– half the diameter– of the planet.

If there are two stars in the system, the telescope measures the combined light of both stars. But a planet orbiting one of these stars will cause just one of them to dim. So, if you don't know that there is a second star, you will underestimate the size of the planet.

For example, if a telescope observes that a star dims by 5 percent, scientists would determine the transiting planet's size relative to that one star. But if a second star adds its light, the planet must be larger to cause the same amount of dimming.

If the planet orbits the brighter star in a binary pair, most of the light in the system comes from that star anyway, so the second star won't have a big effect on the planet's calculated size. But if the planet orbits the fainter star, the larger, primary star contributes more light to the system, and the correction to the calculated planet radius can be large– it could double, triple or increase even more. This will affect how the planet's orbital distance is calculated, which could impact whether the planet is found to be in the habitable zone.

If the stars are roughly equal in brightness, the "new" radius of the planet is about 40 percent larger than if the light were assumed to come from a single star. Because density is calculated using the cube of the radius, this would mean a nearly three-fold decrease in density. The impact of this correction is most significant for smaller planets because it means a planet that had once been considered rocky could, in fact, be gaseous.

In the new study, Furlan and Howell focused on 50 planets in the Kepler observatory's field of view whose masses and radii were previously estimated. These planets all orbit stars that have stellar companions within about 1,700 astronomical units. For 43 of the 50 planets, previous reports of their sizes did not take into account the contribution of light from a second star. That means a revision to their reported sizes is necessary.

In most cases, the change to the planets' reported sizes would be small. Previous research showed that 24 of the 50 planets orbit the bigger, brighter star in a binary pair. Moreover, Furlan and Howell determined that 11 of these planets would be too large to be planets if they orbited the fainter companion star. So, for 35 of the 50 planets, the published sizes will not change substantially.

But for 15 of the planets, they could not determine whether they orbit the fainter or the brighter star in a binary pair. For five of the 15 planets, the stars in question are of roughly equal brightness, so their densities will decrease substantially regardless of which star they orbit.

This effect of companion stars is important for scientists characterizing planets discovered by Kepler, which has found thousands of exoplanets. It will also be significant for NASA's upcoming Transiting Exoplanet Survey Satellite (TESS) mission, which will look for small planets around nearby, bright stars and small, cool stars.

"In further studies, we want to make sure we are observing the type and size of planet we believe we are," Howell said. "Correct planet sizes and densities are critical for future observations of high-value planets by NASA's James Webb Space Telescope. In the big picture, knowing which planets are small and rocky will help us understand how likely we are to find planets the size of our own elsewhere in the galaxy."

Elizabeth LandauJet Propulsion Laboratory, Pasadena,
Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

An Earth-like atmosphere may not survive Proxima b’s orbit

6 min read

NASA Science Editorial Team

Proxima b, an Earth-size planet right outside our solar system in the habitable zone of its star, may not be able to keep a grip on its atmosphere, leaving the surface exposed to harmful stellar radiation and reducing its potential for habitability.

At only four light-years away, Proxima b is our closest known extra-solar neighbor. However, due to the fact that it hasn't been seen crossing in front of its host star, the exoplanet eludes the usual method for learning about its atmosphere. Instead, scientists must rely on models to understand whether the exoplanet is habitable.

One such computer model considered what would happen if Earth orbited Proxima Centauri, our nearest stellar neighbor and Proxima b’s host star, at the same orbit as Proxima b. The NASA study, published on July 24, 2017, in The Astrophysical Journal Letters, suggests Earth’s atmosphere wouldn’t survive in close proximity to the violent red dwarf.

“We decided to take the only habitable planet we know of so far — Earth — and put it where Proxima b is,” said Katherine Garcia-Sage, a space scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and lead author of the study. The research was supported by NASA’s NExSS coalition — leading the search for life on planets beyond our solar system — and the NASA Astrobiology Institute.

Just because Proxima b’s orbit is in the habitable zone, which is the distance from its host star where water could pool on a planet’s surface, doesn’t mean it’s habitable. It doesn’t take into account, for example, whether water actually exists on the planet, or whether an atmosphere could survive at that orbit. Atmospheres are also essential for life as we know it: Having the right atmosphere allows for climate regulation, the maintenance of a water-friendly surface pressure, shielding from hazardous space weather, and the housing of life’s chemical building blocks.

Garcia-Sage and her colleagues’ computer model used Earth’s atmosphere, magnetic field and gravity as proxies for Proxima b’s. They also calculated how much radiation Proxima Centauri produces on average, based on observations from NASA’s Chandra X-ray Observatory.

With these data, their model simulates how the host star’s intense radiation and frequent flaring affect the exoplanet’s atmosphere.

“The question is, how much of the atmosphere is lost, and how quickly does that process occur?” said Ofer Cohen, a space scientist at the University of Massachusetts, Lowell and co-author of the study. “If we estimate that time, we can calculate how long it takes the atmosphere to completely escape — and compare that to the planet’s lifetime.”

An active red dwarf star like Proxima Centauri strips away atmosphere when high-energy extreme ultraviolet radiation ionizes atmospheric gases, knocking off electrons and producing a swath of electrically charged particles. In this process, the newly formed electrons gain enough energy that they can readily escape the planet’s gravity and race out of the atmosphere.

Opposite charges attract, so as more negatively charged electrons leave the atmosphere, they create a powerful charge separation that pulls positively charged ions along with them, out into space.

In Proxima Centauri's habitable zone, Proxima b encounters bouts of extreme ultraviolet radiation hundreds of times greater than Earth does from the sun. That radiation generates enough energy to strip away not just the lightest molecules — hydrogen — but also, over time, heavier elements such as oxygen and nitrogen.

The model shows Proxima Centauri's powerful radiation drains the Earth-like atmosphere as much as 10,000 times faster than what happens at Earth.

"This was a simple calculation based on average activity from the host star," Garcia-Sage said. "It doesn't consider variations like extreme heating in the star's atmosphere or violent stellar disturbances to the exoplanet's magnetic field — things we'd expect provide even more ionizing radiation and atmospheric escape."

To understand how the process can vary, the scientists looked at two other factors that exacerbate atmospheric loss. First, they considered the temperature of the neutral atmosphere, called the thermosphere. They found as the thermosphere heats with more stellar radiation, atmospheric escape increases.

The scientists also considered the size of the region over which atmospheric escape happens, called the polar cap. Planets are most sensitive to magnetic effects at their magnetic poles. When magnetic field lines at the poles are closed, the polar cap is limited and charged particles remain trapped near the planet. On the other hand, greater escape occurs when magnetic field lines are open, providing a one-way route to space.

"This study looks at an under-appreciated aspect of habitability, which is atmospheric loss in the context of stellar physics," said Shawn Domagal-Goldman, a Goddard space scientist not involved in the study. "Planets have lots of different interacting systems, and it's important to make sure we include these interactions in our models."

The scientists show that with the highest thermosphere temperatures and a completely open magnetic field, Proxima b could lose an amount equal to the entirety of Earth's atmosphere in 100 million years — that's just a fraction of Proxima b's 4 billion years thus far. When the scientists assumed the lowest temperatures and a closed magnetic field, that much mass escapes over 2 billion years.

"Things can get interesting if an exoplanet holds on to its atmosphere, but Proxima b's atmospheric loss rates here are so high that habitability is implausible," said Jeremy Drake, an astrophysicist at the Harvard-Smithsonian Center for Astrophysics and co-author of the study. "This questions the habitability of planets around such red dwarfs in general."

Red dwarfs like Proxima Centauri or the TRAPPIST-1 star are often the target of exoplanet hunts, because they are the coolest, smallest and most common stars in the galaxy. Because they are cooler and dimmer, planets have to maintain tight orbits for liquid water to be present.

But unless the atmospheric loss is counteracted by some other process — such as a massive amount of volcanic activity or comet bombardment — this close proximity, scientists are finding more often, is not promising for an atmosphere's survival or sustainability.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA-funded Citizen Science Project Discovers New Brown Dwarf

6 min read

One night three months ago, Rosa Castro finished her dinner, opened her laptop, and uncovered a novel object that was neither planet nor star. Therapist by day and amateur astronomer by night, Castro joined the NASA-funded Backyard Worlds: Planet 9 citizen science project when it began in February — not knowing she would become one of four volunteers to help identify the project's first brown dwarf, formally known as WISEA J110125.95+540052.8.

After devoting hours to skimming online, publicly available "flipbooks" containing time-lapse images, she spotted a moving object unlike any other. The search process involves fixating on countless colorful dots, she explained. When an object is different, it simply stands out. Castro, who describes herself as extremely detail oriented, has contributed nearly 100 classifications to this specific project.

A paper about the new brown dwarf was published on May 24 in The Astrophysical Journal Letters. Four citizen scientists are co-authors of the paper, including Castro. Since then, Backyard Worlds: Planet 9 has identified roughly 117 additional brown dwarf candidates.

The collaboration was inspired by the recently proposed ninth planet, possibly orbiting at the fringes of our solar system beyond Pluto.

"We realized we could do a much better job identifying Planet Nine if we opened the search to the public," said lead researcher Marc Kuchner, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "Along the way, we're hoping to find thousands of interesting brown dwarfs."

It's been roughly two decades since researchers first discovered brown dwarfs, and the scientific community opened its eyes to this new class of objects between stars and planets. Although they are as common as stars and form in much the same way, brown dwarfs lack the mass necessary to sustain nuclear fusion reactions. They therefore do not have the energy to maintain their luminosity, so they slowly cool over the course of their lifetimes. Their low temperatures also render them intrinsically dim.

For years, Kuchner has been fascinated by infrared images of the entire sky captured by NASA's Wide-field Infrared Survey Explorer (WISE), launched in 2009. The space telescope is specially designed to observe cold objects emitting light at long wavelengths — objects like brown dwarfs. With its initial mission complete, WISE was deactivated in 2011. It was then reactivated in 2013 as NEOWISE, a new mission funded by the NEO Observations Program with a different goal: to search for potentially hazardous near-Earth objects (NEOs).

Previously, Kuchner had focused on stationary objects seen by WISE. But the Backyard Worlds: Planet 9 project shows the WISE and NEOWISE data in a way custom-tailored for finding fast-moving objects. His team layers many images of the same location to create a single, comprehensive snapshot. These are then combined with several similarly "co-added" pictures to form flipbooks that show motion over time.

Anyone with internet access can scour these flipbooks and click on anomalies. If they would like to call the science team's attention to an object they found, they can submit a report to the researchers or share their insights on a public forum. Kuchner and his colleagues then follow up the best candidates using ground-based telescopes to glean more information.

According to Backyard Worlds: Planet 9 citizen scientist Dan Caselden, participants are free to dig as deep into the results as they choose. A security researcher by trade, Caselden developed a series of tools allowing fellow participants to streamline their searches and visualize their results, as well as aggregate various user statistics. He also helped identify several of the additional brown dwarf candidates while the first discovery was being confirmed.

Kuchner and his co-author, Adam Schneider of Arizona State University, Tempe, agree WISEA J110125.95+540052.8 is an exciting discovery for several reasons. “What’s special about this object — besides the way it was discovered — is that it’s unusually faint,” Schneider said. “That means our citizen scientists are probing much deeper than anyone has before.”

While computers efficiently sift through deluges of data, they can also get lost in details that human eyes and brains easily disregard as irrelevant.

However, mining this information is extremely arduous for a single scientist or even a small group of researchers. That’s precisely why collaborating with an enthusiastic public is so effective — many eyes catch details that one pair alone could miss.

While Kuchner is delighted by this early discovery, his ultimate goal for Backyard Worlds: Planet 9 is to find the smallest and coldest brown dwarfs, called Y dwarfs. Some of these Y dwarfs many even be lurking closer to us than Proxima Centauri, the nearest star to the sun.

Their low temperatures make Y dwarfs extremely dim, according to Adam Burgasser at the University of California San Diego. “They’re so faint that it takes quite a bit of work to pull them from the images, that’s where Kuchner’s project will help immensely,” he said. “Anytime you get a diverse set of people looking at the data, they’ll bring unique perspectives that can lead to unexpected discoveries.”

Kuchner anticipates the Backyard Worlds effort will continue for several more years — allowing more volunteers like Caselden and Castro to contribute.

As Castro put it: “I am not a professional. I’m just an amateur astronomer appreciating the night sky. If I see something odd, I’ll admire and enjoy it.”

Backyard Worlds: Planet 9 is a collaboration between NASA, UC Berkeley, the American Museum of Natural History in New York, Arizona State University, the Space Telescope Science Institute in Baltimore and Zooniverse, a collaboration of scientists, software developers and educators who collectively develop and manage citizen science projects on the internet.

NASA’s Jet Propulsion Laboratory in Pasadena, California, manages the NEOWISE mission for NASA’s Planetary Defense Coordination Office within the Science Mission Directorate in Washington. The Space Dynamics Laboratory in Logan, Utah, built the science instrument. Ball Aerospace & Technologies Corp. of Boulder, Colorado, built the spacecraft. Science operations and data processing take place at the Infrared Processing and Analysis Center at Caltech in Pasadena. Caltech manages JPL for NASA.

For more information about Backyard Worlds: Planet 9, visit:

http://backyardworlds.org

For more information about NASA’s WISE mission, visit:

https://www.nasa.gov/wise

Download images from NASA Goddard’s Scientific Visualization Studio

By Raleigh McElveryNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

404

The cosmic object you were looking for has disappeared beyond the event horizon.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Announces Independent Review Panel Members for Wide Field Infrared Survey Telescope

3 min read

Editor’s note, Sept. 29, 2023: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

NASA has convened an independent, external technical, management and cost review of the Wide Field Infrared Survey Telescope (WFIRST) at the recommendation of the National Academy of Sciences (NAS). Recommended by NAS review panels in 2014 and again in 2016, this independent review is composed of leaders in space science, including senior engineers, scientists and project managers who are neither affiliated with the mission nor NASA federal employees. The panel will take a close look at WFIRST — now in phase A — ensuring its scope and cost at this early stage in the life cycle of the mission remain aligned.

“We are confident this review will provide the insight and confidence among key stakeholders necessary to move toward what promises to be an exciting science investigation bound to reshape our understanding of the universe,” said Thomas Zurbuchen, associate administrator for NASA’s Science Mission Directorate in Washington.

Selected as the top priority of the NAS 2010 Decadal Survey for Astronomy and Astrophysics, the WFIRST mission is scheduled to launch in the mid-2020s to study the evolution of the universe, dark energy and exoplanets. The recent NAS Midterm Assessment Report on NASA’s progress in implementing the decadal survey recognized the continued scientific value of the mission, finding that “WFIRST [is] an ambitious and powerful facility that will significantly advance the scientific program envisioned by [the decadal survey], from the atmospheres of planets around nearby stars to the physics of the accelerating universe.” The assessment also recognized that the risk of cost growth in the mission’s development could adversely affect the balance of NASA’s astrophysics program among small, medium and large class missions and research. The report recommended that before moving to the next phase of mission development, NASA should appoint an independent technical, management and cost review of WFIRST, including an assessment of the incremental cost of its coronagraph instrument.

Now that this independent review panel has been assembled, the panel is expected to complete its assessment and submit a report highlighting its findings and recommendations in the fall. NASA will integrate these recommendations into the design and project plan for WFIRST before advancing to the mission’s next development phase.

The panel, which might be supplemented during the conduct of the review, is comprised of the following notable leaders in the space science community, and was selected by the co-chairs of the independent review.

WFIRST will be complementary to the James Webb Space Telescope, which is scheduled to launch in 2018. Once the Webb telescope launches, WFIRST is NASA’s next large space telescope under development.

For more information about NASA’s WFIRST mission, visit:

https://www.nasa.gov/wfirst

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

An image is worth a thousand worlds

8 min read

Pat Brennan

The moon hanging in the night sky sent Robert Hurt's mind into deep space – to a region some 40 light-years away, in fact, where seven Earth-sized planets crowded close to a dim, red sun.

Hurt, a visualization scientist at Caltech's IPAC center, was walking outside his home in Mar Vista, California, shortly after he learned of the discovery of these rocky worlds around a star called TRAPPIST-1 and got the assignment to visualize them. The planets had been revealed by NASA's Spitzer Space Telescope and ground-based observatories.

"I just stopped dead in my tracks, and I just stared at it," Hurt said in an interview. "I was imagining that could be, not our moon, but the next planet over – what it would be like to be in a system where you could look up and see continental features on the next planet."

So began a kind of inspirational avalanche. Hurt and his colleague, multimedia producer Tim Pyle, developed a series of arresting, photorealistic images of what the new system's tightly packed planets might look like – so tightly packed that they would loom large in each other's skies. Their visions of the TRAPPIST-1 system would appear in leading news outlets around the world.

Artists like Hurt and Pyle, who render vibrant visualizations based on data from Spitzer and other missions, are hybrids of sorts, blending expertise in both science and art. From squiggles on charts and columns of numbers, they conjure red, blue and green worlds, with half-frozen oceans or bubbling lava. Or they transport us to the surface of a world with a red-orange sun fixed in place, and a sky full of planetary companions.

"For the public, the value of this is not just giving them a picture of something somebody made up," said Douglas Hudgins, a program scientist for the Exoplanet Exploration Program at NASA Headquarters in Washington. "These are real, educated guesses of how something might look to human beings. An image is worth a thousand words."

Hurt says he and Pyle are building on the work of artistic pioneers.

"There's actually a long history and tradition for space art and science-based illustration," he said. "If you trace its roots back to the artist Chesley Bonestell (famous in the 1950s and '60s), he really was the artist who got this idea: Let's go and imagine what the planets in our solar system might actually look like if you were, say, on Jupiter's moon, Io. How big would Jupiter appear in the sky, and what angle would we be viewing it from?"

To begin work on their visualizations, Hurt divided up the seven TRAPPIST-1 planets with Pyle, who shares an office with him at Caltech's IPAC center in Pasadena, California.

Hurt holds a Ph.D. in astrophysics, and has worked at the center since he was a post-doctoral researcher in 1996 – when astronomical art was just his hobby.

"They created a job for me," he said.

Pyle, whose background is in Hollywood special effects, joined Hurt in 2004.

Hurt turns to Pyle for artistic inspiration, while Pyle relies on Hurt to check his science.

“Robert and I have our desks right next to each other, so we’re constantly giving each other feedback,” Pyle said. “We’re each upping each other’s game, I think.”

The TRAPPIST-1 worlds offered both of them a unique challenge. The two already had a reputation for illustrating many exoplanets – planets around stars beyond our own – but never seven Earth-sized worlds in a single system. The planets cluster so close to their star that a “year” on each of them – the time they take to complete a single orbit can be numbered in Earth days.

And like the overwhelming majority of the thousands of exoplants found so far, they were detected using indirect means. No telescope exists today that is powerful enough to photograph them.

Real science informed their artistic vision. Using data from the telescopes that reveal each planet’s diameter as well as its “weight,” or mass, and known stellar physics to determine the amount of light each planet would receive, the artists went to work.

Both consulted closely with the planets' discovery team as they planned for a NASA announcement to coincide with a report in the journal Nature.

“When we’re doing these artist’s concepts, we’re never saying, ‘This is what these planets actually look like,’” Pyle said. “We’re doing plausible illustrations of what they could look like, based on what we know so far. Having this wide range of seven planets actually let us illustrate almost the whole breadth of what would be plausible. This was going to be this incredible interstellar laboratory for what could happen on an Earth-sized planet.”

For TRAPPIST-1b, Pyle took Jupiter’s volcanic moon, Io, as an inspiration, based on suggestions from the science team. For the outermost world, TRAPPIST-1h, he chose two other Jovian moons, the ice-encased Ganymede and Europa.

After talking to the scientists, Hurt portrayed TRAPPIST-1c as dry and rocky. But because all seven planets are probably tidally locked, forever presenting one face to their star and the other to the cosmos, he placed an ice cap on the dark side.

TRAPPIST-1d was one of three that fall inside the “habitable zone” of the star, or the right distance away from it to allow possible liquid water on the surface.

“The researchers told us they would like to see it portrayed as something they called an ‘eyeball world,’” Hurt said. “You have a dry, hot side that’s facing the star and an ice cap on the back side. But somewhere in between, you have (a zone) where the ice could melt and be sustained as liquid water.”

At this point, Hurt said, art intervened. The scientists rejected his first version of the planet, which showed liquid water intruding far into the “dayside” of TRAPPIST-1d. They argued that the water would most likely be found well within the planet’s dark half.

“Then I kind of pushed back, and said, ‘If it’s on the dark side, no one can look at it and understand we’re saying there’s water there,’” Hurt said. They struck a compromise: more water toward the dayside than the science team might expect, but a better visual representation of the science.

The same push and pull between science and art extends to other forms of astronomical visualization, whether it’s a Valentine's Day cartoon of a star pulsing like a heart in time with its planet, or materials for the blockbuster announcement of the first detection of gravitational waves by the Laser Interferometer Gravitational-Wave Observatory in February 2016. They've also illustrated asteroids, neutron stars, pulsars and brown dwarfs.

Visualizations based on data can also inform science, leading to genuine scientific insights. The scientists’ conclusions about TRAPPIST-1 at first seemed to suggest the planets would be bathed in red light, potentially obscuring features like blue-hued bodies of water.

“It makes it hard to really differentiate what is going on,” Hurt said.

Hurt decided to investigate. A colleague provided him with a spectrum of a red dwarf star similar to TRAPPIST-1. He overlaid that with the “responsivity curves” of the human eye, and found that most of the scientists’ “red” came from infrared light, invisible to human eyes. Subtract that, and what is left is a more reddish-orange hue that we might see standing on the surface of a TRAPPIST-1 world – “kind of the same color you would expect to get from a low-wattage light bulb,” Hurt said. “And the scientists looked at that and said, ‘Oh, ok, great, it’s orange.’ When the math tells you the answer, there really isn’t a lot to argue about.”

For Hurt, the real goal of scientific illustration is to excite the public, engage them in the science, and provide a snapshot of scientific knowledge.

“If you look at the whole history of space art, reaching back many, many decades, you will find you have a visual record,” he said. “The art is a historical record of our changing understanding of the universe. It becomes a part of the story, and a part of the research, I think.”

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

Felicia ChouNASA Headquarters, Washington202-358-1726felicia.chou@nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Hubble’s Tale of Two Exoplanets: Nature vs. Nurture

3 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Is it a case of nature versus nurture when it comes to two "cousin" exoplanets? In a unique experiment, scientists used NASA's Hubble Space Telescope to study two "hot Jupiter" exoplanets. Because these planets are virtually the same size and temperature, and orbit around nearly identical stars at the same distance, the team hypothesized that their atmospheres should be alike. What they found surprised them.

Lead researcher Giovanni Bruno of the Space Telescope Science Institute in Baltimore, Maryland, explained, "What we're seeing in looking at the two atmospheres is that they're not the same. One planet—WASP-67 b—is cloudier than the other—HAT-P-38 b. We don't see what we're expecting, and we need to understand why we find this difference."

The team used Hubble's Wide Field Camera 3 to look at the planets' spectral fingerprints, which measure chemical composition. "The effect that clouds have on the spectral signature of water allows us to measure the amount of clouds in the atmosphere," Bruno said. "More clouds mean that the water feature is reduced." The teams found that for WASP-67 b there are more clouds at the altitudes probed by these measurements.

"This tells us that there had to be something in their past that is changing the way these planets look," said Bruno.

Today the planets whirl around their yellow dwarf stars once every 4.5 Earth days, tightly orbiting their stars closer than Mercury orbits our sun. But in the past, the planets probably migrated inward toward the star from the locations where they formed.

Perhaps one planet formed differently than the other, under a different set of circumstances. "You can say it's nature versus nurture," explains co-investigator Kevin Stevenson. "Right now, they appear to have the same physical properties. So, if their measured composition is defined by their current state, then it should be the same for both planets. But that's not the case. Instead, it looks like their formation histories could be playing an important role."

The clouds on these hot, Jupiter-like gas giants are nothing like those on Earth. Instead, they are probably alkali clouds, composed of molecules such as sodium sulfide and potassium chloride. The average temperature on each planet is more than 1,300 degrees Fahrenheit.

The exoplanets are tidally locked, with the same side always facing the parent star. This means they have a very hot day-side and a cooler night-side. Instead of sporting multiple cloud bands like Jupiter does, each probably has just one broad equatorial band that slowly moves the heat around from the day-side to the night-side.

The team is just beginning to learn what factors are important in making some exoplanets cloudy and some clear. To better understand what the planets' pasts may have been, scientists will need future observations with Hubble and the soon-to-be-launched James Webb Space Telescope.

The team's results were presented on June 5 at the 230th meeting of the American Astronomical Society in Austin, Texas.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, Inc., in Washington, D.C.

For more information about NASA's Hubble Space Telescope, visit:

www.nasa.gov/hubble

For additional information, visit:

http://hubblesite.org/news_release/news/2017-22

Contact:Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4514villard@stsci.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Flares May Threaten Planet Habitability Near Red Dwarfs

5 min read

NASA Science Editorial Team

Cool dwarf stars are hot targets for exoplanet hunting right now. The discoveries of planets in the habitable zones of the TRAPPIST-1 and LHS 1140 systems, for example, suggest that Earth-sized worlds might circle billions of red dwarf stars, the most common type of star in our galaxy. But, like our own sun, many of these stars erupt with intense flares. Are red dwarfs really as friendly to life as they appear, or do these flares make the surfaces of any orbiting planets inhospitable?

[See Earth-sized planets: The newest, weirdest generation]

To address this question, a team of scientists has combed 10 years of ultraviolet observations by NASA's Galaxy Evolution Explorer (GALEX) spacecraft looking for rapid increases in the brightness of stars due to flares. Flares emit radiation across a wide swath of wavelengths, with a significant fraction of their total energy released in the ultraviolet bands where GALEX observed. At the same time, the red dwarfs from which the flares arise are relatively dim in ultraviolet. This contrast, combined with the GALEX detectors' sensitivity to fast changes, allowed the team to measure events with less total energy than many previously detected flares. This is important because, although individually less energetic and therefore less hostile to life, smaller flares might be much more frequent and add up over time to create an inhospitable environment.

“What if planets are constantly bathed by these smaller, but still significant, flares?” asked Scott Fleming of the Space Telescope Science Institute (STScI) in Baltimore. “There could be a cumulative effect.”

To detect and accurately measure these flares, the team had to analyze data over very short time intervals. From images with exposure times of nearly half an hour, the team was able to reveal stellar variations lasting just seconds.

First author Chase Million of Million Concepts in State College, Pennsylvania, led a project called gPhoton that reprocessed more than 100 terabytes of GALEX data held at the Mikulski Archive for Space Telescopes (MAST), located at the Space Telescope Science Institute. The team then used custom software developed by Million and Clara Brasseur, also at the institute, to search several hundred red dwarf stars, and they detected dozens of flares.

“We have found dwarf star flares in the whole range that we expected GALEX to be sensitive to, from itty bitty baby flares that last a few seconds, to monster flares that make a star hundreds of times brighter for a few minutes,” said Million.

The flares GALEX detected are similar in strength to flares produced by our own sun. However, because a planet would have to orbit much closer to a cool, red dwarf star to maintain a temperature friendly to life as we know it, such planets would be subjected to more of a flare’s energy than Earth.

Large flares can strip away a planet’s atmosphere. Strong ultraviolet light from flares that penetrates to a planet’s surface could damage organisms or prevent life from arising.

Currently, team members Rachel Osten and Brasseur are examining stars observed by both the GALEX and Kepler missions to look for similar flares. The team expects to eventually find hundreds of thousands of flares hidden in the GALEX data.

"These results show the value of a survey mission like GALEX, which was instigated to study the evolution of galaxies across cosmic time and is now having an impact on the study of nearby habitable planets," said Don Neill, research scientist at Caltech in Pasadena, who was part of the GALEX collaboration. "We did not anticipate that GALEX would be used for exoplanets when the mission was designed."

New and powerful instruments like NASA's James Webb Space Telescope, scheduled for launch in 2018, ultimately will be needed to study atmospheres of planets orbiting nearby red dwarf stars and search for signs of life. But as researchers pose new questions about the cosmos, archives of data from past projects and missions, like those held at MAST, continue to produce exciting new scientific results.

These results were presented in a news conference at a meeting of the American Astronomical Society in Austin, Texas.

The GALEX mission, which ended in 2013 after more than a decade of scanning the skies in ultraviolet light, was led by scientists at Caltech. NASA's Jet Propulsion Laboratory, also in Pasadena, managed the mission and built the science instrument. JPL is managed by Caltech for NASA.

STScI conducts Hubble Space Telescope science operations and is the mission and science operations center for the James Webb Space Telescope. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington.

Elizabeth LandauJet Propulsion Laboratory, Pasadena, California818-354-6425elizabeth.landau@jpl.nasa.gov

Christine Pulliam / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4366 / 410-338-4514cpulliam@stsci.edu / villard@stsci.edu

Chase MillionMillion Concepts, State College, Pennsylvania765-914-5336chase.million@gmail.com

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers find planet hotter than most stars

6 min read

NASA Science Editorial Team

A newly discovered Jupiter-like world is so hot, it’s being vaporized by its own star.

With a dayside temperature of more than 7,800 degrees Fahrenheit (4,600 Kelvin), KELT-9b is a planet that is hotter than most stars. But its blue A-type star, called KELT-9, is even hotter– in fact, it is probably unraveling the planet through evaporation.

"This is the hottest gas giant planet that has ever been discovered," said Scott Gaudi, astronomy professor at The Ohio State University in Columbus, who led a study on the topic. He worked on this study while on sabbatical at NASA's Jet Propulsion Laboratory, Pasadena, California. The unusual planet is described in the journal Nature and at a presentation at the American Astronomical Society summer meeting this week in Austin, Texas.

KELT-9b is 2.8 times more massive than Jupiter, but only half as dense. Scientists would expect the planet to have a smaller radius, but the extreme radiation from its host star has caused the planet's atmosphere to puff up like a balloon.

Because the planet is tidally locked to its star– as the moon is to Earth– one side of the planet is always facing toward the star, and one side is in perpetual darkness. Molecules such as water, carbon dioxide and methane can’t form on the dayside because it is bombarded by too much ultraviolet radiation. The properties of the nightside are still mysterious– molecules may be able to form there, but probably only temporarily.

“It’s a planet by any of the typical definitions of mass, but its atmosphere is almost certainly unlike any other planet we’ve ever seen just because of the temperature of its dayside,” Gaudi said.

The KELT-9 star is only 300 million years old, which is young in star time. It is more than twice as large, and nearly twice as hot, as our sun. Given that the planet’s atmosphere is constantly blasted with high levels of ultraviolet radiation, the planet may even be shedding a tail of evaporated planetary material like a comet.

“KELT-9 radiates so much ultraviolet radiation that it may completely evaporate the planet," said Keivan Stassun, a professor of physics and astronomy at Vanderbilt University, Nashville, Tennessee, who directed the study with Gaudi.

But this scenario assumes the star doesn’t grow to engulf the planet first.

“KELT-9 will swell to become a red giant star in a few hundred million years,” said Stassun. “The long-term prospects for life, or real estate for that matter, on KELT-9b are not looking good.”

The planet is also unusual in that it orbits perpendicular to the spin axis of the star. That would be analogous to the planet orbiting perpendicular to the plane of our solar system. One "year" on this planet is less than two days.

[See the planet data in NASA's Exoplanet Archive]

KELT-9b is nowhere close to habitable, but Gaudi said there’s a good reason to study worlds that are unlivable in the extreme.

“As has been highlighted by the recent discoveries from the MEarth collaboration, the planet around Proxima Centauri, and the astonishing system discovered around TRAPPIST-1, the astronomical community is clearly focused on finding Earthlike planets around small, cooler stars like our sun. They are easy targets and there’s a lot that can be learned about potentially habitable planets orbiting very low-mass stars in general. On the other hand, because KELT-9b’s host star is bigger and hotter than the sun, it complements those efforts and provides a kind of touchstone for understanding how planetary systems form around hot, massive stars,” Gaudi said.

The KELT-9b planet was found using one of the two telescopes called KELT, or Kilodegree Extremely Little Telescope. In late May and early June 2016, astronomers using the KELT-North telescope at Winer Observatory in Arizona noticed a tiny drop in the star’s brightness– only about half of one percent– which indicated that a planet may have passed in front of the star. The brightness dipped once every 1.5 days, which means the planet completes a “yearly” circuit around its star every 1.5 days.

Subsequent observations confirmed the signal to be due to a planet, and revealed it to be what astronomers call a “hot Jupiter”– the kind of planet the KELT telescopes are designed to spot.

Astronomers at Ohio State, Lehigh University in Bethlehem, Pennsylvania, and Vanderbilt jointly operate two KELTs (one each in the northern and southern hemispheres) to fill a large gap in the available technologies for finding exoplanets. Other telescopes are designed to look at very faint stars in much smaller sections of the sky, and at very high resolution. The KELTs, in contrast, look at millions of very bright stars at once, over broad sections of sky, and at low resolution.

"This discovery is a testament to the discovery power of small telescopes, and the ability of citizen scientists to directly contribute to cutting-edge scientific research," said Joshua Pepper, astronomer and assistant professor of physics at Lehigh University in Bethlehem, Pennsylvania, who built the two KELT telescopes.

The astronomers hope to take a closer look at KELT-9b with other telescopes– including NASA's Spitzer and Hubble space telescopes, and eventually the James Webb Space Telescope. Observations with Hubble would enable them to see if the planet really does have a cometary tail, and allow them to determine how much longer that planet will survive its current hellish condition.

“Thanks to this planet’s star-like heat, it is an exceptional target to observe at all wavelengths, from ultraviolet to infrared, in both transit and eclipse. Such observations will allow us to get as complete a view of its atmosphere as is possible for a planet outside our solar system,” said Knicole Colon, paper co-author who was based at NASA Ames Research Center in California’s Silicon Valley during the time of this study.

The study was largely funded by the National Science Foundation (NSF) through an NSF CAREER Grant, NSF PAARE Grant and an NSF Graduate Research Fellowship. Additional support came from NASA via the Jet Propulsion Laboratory and the Exoplanet Exploration Program; the Harvard Future Faculty Leaders Postdoctoral Fellowship; Theodore Dunham, Jr., Grant from the Fund for Astronomical Research; and the Japan Society for the Promotion of Science.

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

Pam Frost GorderThe Ohio State University, Columbus, Ohio614-292-9475Gorder.1@osu.edu

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers Confirm Orbital Details of TRAPPIST-1h

6 min read

NASA Science Editorial Team

Scientists using NASA's Kepler space telescope identified a regular pattern in the orbits of the planets in the TRAPPIST-1 system that confirmed suspected details about the orbit of its outermost and least understood planet, TRAPPIST-1h.

TRAPPIST-1 is only eight percent the mass of our sun, making it a cooler and less luminous star. It’s home to seven Earth-size planets, three of which orbit in their star's habitable zone -- the range of distances from a star where liquid water could pool on the surface of a rocky planet. The system is located about 40 light-years away in the constellation of Aquarius. The star is estimated to be between 3 billion and 8 billion years old.

Scientists announced that the system has seven Earth-sized planets at a NASA press conference on Feb. 22. NASA's Spitzer Space Telescope, the TRAPPIST (Transiting Planets and Planetesimals Small Telescope) in Chile and other ground-based telescopes were used to detect and characterize the planets. But the collaboration only had an estimate for the period of TRAPPIST-1h.

Astronomers from the University of Washington have used data from the Kepler spacecraft to confirm that TRAPPIST-1h orbits its star every 19 days. At six million miles from its cool dwarf star, TRAPPIST-1h is located beyond the outer edge of the habitable zone, and is likely too cold for life as we know it. The amount of energy (per unit area) planet h receives from its star is comparable to what the dwarf planet Ceres, located in the asteroid belt between Mars and Jupiter, gets from our sun.

“It’s incredibly exciting that we’re learning more about this planetary system elsewhere, especially about planet h, which we barely had information on until now,” said Thomas Zurbuchen, associate administrator of NASA’s Science Mission Directorate at Headquarters in Washington. “This finding is a great example of how the scientific community is unleashing the power of complementary data from our different missions to make such fascinating discoveries.”

"It really pleased me that TRAPPIST-1h was exactly where our team predicted it to be. It had me worried for a while that we were seeing what we wanted to see -- after all, things are almost never exactly what you expect them to be in this field," said Rodrigo Luger, doctoral student at UW in Seattle, and lead author of the study published in the journal Nature Astronomy. "Nature usually surprises us at every turn, but, in this case, theory and observation matched perfectly."

Using the prior Spitzer data, the team recognized a mathematical pattern in the frequency at which each of the six innermost planets orbits their star. This complex but predictable pattern, called an orbital resonance, occurs when planets exert a regular, periodic gravitational tug on each other as they orbit their star.

To understand the concept of resonance, consider Jupiter's moons Io, Europa and Ganymede, which is the farthest out of the three. For every time Ganymede orbits Jupiter, Europa orbits twice and Io makes four trips around the planet. This 1:2:4 resonance is considered stable and if one moon were nudged off course, it would self-correct and lock back into a stable orbit. It is this harmonious influence between the seven TRAPPIST-1 siblings that keeps the system stable.

These relationships, said Luger, suggested that by studying the orbital velocities of its neighboring planets, scientists could predict the exact orbital velocity, and hence also orbital period, of planet h, even before the Kepler observations. The team calculated six possible resonant periods for planet h that would not disrupt the stability of the system, but only one was not ruled out by additional data. The other five possibilities could have been observed in the Spitzer and ground-based data collected by the TRAPPIST team.

“All of this”, Luger said, “indicates that these orbital relationships were forged early in the life of the TRAPPIST-1 system, during the planet formation process.”

"The resonant structure is no coincidence, and points to an interesting dynamical history in which the planets likely migrated inward in lock-step," said Luger. "This makes the system a great laboratory for planet formation and migration theories."

The Kepler spacecraft stared at the patch of sky home to the TRAPPIST-1 system from Dec. 15, 2016, to March 4, 2017. collecting data on the star's minuscule changes in brightness due to transiting planets as part of its second mission, K2. On March 8, the raw, uncalibrated data was released to the scientific community to begin follow-up studies.

The work to confirm TRAPPIST-1h's orbital period immediately began, and scientists from around the world took to social media to share in real-time the new information gleaned about the star's behavior and its brood of planets. Within two hours of the data release, the team confirmed its prediction of a 19-day orbital period.

"Pulling results out of data is always stimulating, but it was a rare treat to watch scientists across the world collaborate and share their progress in near-real time on social media as they analyzed the data and identified the transits of TRAPPIST-1h," said Jessie Dotson, project scientist for the K2 mission at NASA's Ames Research Center in California's Silicon Valley. "The creativity and expediency by which the data has been put to use has been a particularly thrilling aspect of K2's community-focused approach."

TRAPPIST-1's seven-planet chain of resonances established a record among known planetary systems, the previous holders being the systems Kepler-80 and Kepler-223, each with four resonant planets.

The TRAPPIST-1 system was first discovered in 2016 by the TRAPPIST collaboration, and was thought to have just three planets at that time. Additional planets were found with Spitzer and ground-based telescopes. NASA's Hubble Space Telescope is following up with atmospheric observations, and the James Webb Space Telescope will be able to probe potential atmospheres in further detail.

Ames manages the Kepler and K2 missions for NASA’s Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corp. operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

Michele JohnsonAmes Research Center, Moffett Field, Calif.650-604-6982michele.johnson@nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

SOFIA Confirms Nearby Planetary System is Similar to Our Own

4 min read

NASA Science Editorial Team

NASA's flying observatory, the Stratospheric Observatory for Infrared Astronomy, SOFIA, recently completed a detailed study of a nearby planetary system. The investigations confirmed that this nearby planetary system has an architecture remarkably similar to that of our solar system.

Located 10.5 light-years away in the southern hemisphere of the constellation Eridanus, the star Epsilon Eridani, eps Eri for short, is the closest planetary system around a star similar to the early sun. It is a prime location to research how planets form around stars like our sun, and is also the storied location of the Babylon 5 space station in the science fictional television series of the same name.

Previous studies indicate that eps Eri has a debris disk, which is the name astronomers give to leftover material still orbiting a star after planetary construction has completed. The debris can take the form of gas and dust, as well as small rocky and icy bodies. Debris disks can be broad, continuous disks or concentrated into belts of debris, similar to our solar system's asteroid belt and the Kuiper Belt – the region beyond Neptune where hundreds of thousands of icy-rocky objects reside. Furthermore, careful measurements of the motion of eps Eri indicates that a planet with nearly the same mass as Jupiter circles the star at a distance comparable to Jupiter's distance from the sun.

With the new SOFIA images, Kate Su of the University of Arizona and her research team were able to distinguish between two theoretical models of the location of warm debris, such as dust and gas, in the eps Eri system. These models were based on prior data obtained with NASA's Spitzer space telescope.

One model indicates that warm material is in two narrow rings of debris, which would correspond respectively to the positions of the asteroid belt and the orbit of Uranus in our solar system. Using this model, theorists indicate that the largest planet in a planetary system might normally be associated with an adjacent debris belt.

The other model attributes the warm material to dust originating in the outer Kuiper-Belt-like zone and filling in a disk of debris toward the central star. In this model, the warm material is in a broad disk, and is not concentrated into asteroid belt-like rings nor is it associated with any planets in the inner region.

Using SOFIA, Su and her team ascertained that the warm material around eps Eri is in fact arranged like the first model suggests; it is in at least one narrow belt rather than in a broad continuous disk.

These observations were possible because SOFIA has a larger telescope diameter than Spitzer, 100 inches (2.5 meters) in diameter compared to Spitzer's 33.5 inches (0.85 meters), which allowed the team onboard SOFIA to discern details that are three times smaller than what could be seen with Spitzer. Additionally, SOFIA's powerful mid-infrared camera called FORCAST, the Faint Object infraRed CAmera for the SOFIA Telescope, allowed the team to study the strongest infrared emission from the warm material around eps Eri, at wavelengths between 25-40 microns, which are undetectable by ground-based observatories.

“The high spatial resolution of SOFIA combined with the unique wavelength coverage and impressive dynamic range of the FORCAST camera allowed us to resolve the warm emission around eps Eri, confirming the model that located the warm material near the Jovian planet’s orbit,” said Su. “Furthermore, a planetary mass object is needed to stop the sheet of dust from the outer zone, similar to Neptune’s role in our solar system. It really is impressive how eps Eri, a much younger version of our solar system, is put together like ours.”

This study was published in the Astronomical Journal on April 25, 2017.

SOFIA is a Boeing 747SP jetliner modified to carry a 100-inch diameter telescope. It is a joint project of NASA and the German Aerospace Center, DLR. NASA’s Ames Research Center in California’s Silicon Valley manages the SOFIA program, science and mission operations in cooperation with the Universities Space Research Association headquartered in Columbia, Maryland, and the German SOFIA Institute (DSI) at the University of Stuttgart. The aircraft is based at NASA’s Armstrong Flight Research Center's Hangar 703, in Palmdale, California.

For more information about SOFIA, visit:

http://www.nasa.gov/sofia

Study SOFIA's science mission and scientific instruments at:

http://www.dsi.uni-stuttgart.de/index.en.html

Nick Veroniconveronico@sofia.usra.edu

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Study Finds Unexpectedly Primitive Atmosphere Around ‘Warm Neptune’

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

A study combining observations from NASA’s Hubble and Spitzer space telescopes reveals that the distant planet HAT-P-26b has a primitive atmosphere composed almost entirely of hydrogen and helium. Located about 437 light years away, HAT-P-26b orbits a star roughly twice as old as the sun.

The analysis is one of the most detailed studies to date of a “warm Neptune,” or a planet that is Neptune-sized and close to its star. The researchers determined that HAT-P-26b’s atmosphere is relatively clear of clouds and has a strong water signature, although the planet is not a water world. This is the best measurement of water to date on an exoplanet of this size.

The discovery of an atmosphere with this composition on this exoplanet has implications for how scientists think about the birth and development of planetary systems. Compared to Neptune and Uranus, the planets in our solar system with about the same mass, HAT-P-26b likely formed either closer to its host star or later in the development of its planetary system, or both.

“Astronomers have just begun to investigate the atmospheres of these distant Neptune-mass planets, and almost right away, we found an example that goes against the trend in our solar system,” said Hannah Wakeford, a postdoctoral researcher at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and lead author of the study published in the May 12, 2017, issue of Science. “This kind of unexpected result is why I really love exploring the atmospheres of alien planets.”

To study HAT-P-26b’s atmosphere, the researchers used data from transits— occasions when the planet passed in front of its host star. During a transit, a fraction of the starlight gets filtered through the planet’s atmosphere, which absorbs some wavelengths of light but not others. By looking at how the signatures of the starlight change as a result of this filtering, researchers can work backward to figure out the chemical composition of the atmosphere.

In this case, the team pooled data from four transits measured by Hubble and two seen by Spitzer. Together, those observations covered a wide range of wavelengths from yellow light through the near-infrared region.

“To have so much information about a warm Neptune is still rare, so analyzing these data sets simultaneously is an achievement in and of itself,” said co-author Tiffany Kataria of NASA's Jet Propulsion Laboratory in Pasadena, California.

Because the study provided a precise measurement of water, the researchers were able to use the water signature to estimate HAT-P-26b’s metallicity. Astronomers calculate the metallicity, an indication of how rich the planet is in all elements heavier than hydrogen and helium, because it gives them clues about how a planet formed.

To compare planets by their metallicities, scientists use the sun as a point of reference, almost like describing how much caffeine beverages have by comparing them to a cup of coffee. Jupiter has a metallicity about 2 to 5 times that of the sun. For Saturn, it’s about 10 times as much as the sun. These relatively low values mean that the two gas giants are made almost entirely of hydrogen and helium.

The ice giants Neptune and Uranus are smaller than the gas giants but richer in the heavier elements, with metallicities of about 100 times that of the sun. So, for the four outer planets in our solar system, the trend is that the metallicities are lower for the bigger planets.

Scientists think this happened because, as the solar system was taking shape, Neptune and Uranus formed in a region toward the outskirts of the enormous disk of dust, gas and debris that swirled around the immature sun. Summing up the complicated process of planetary formation in a nutshell: Neptune and Uranus would have been bombarded with a lot of icy debris that was rich in heavier elements. Jupiter and Saturn, which formed in a warmer part of the disk, would have encountered less of the icy debris.

Two planets beyond our solar system also fit this trend. One is the Neptune-mass planet HAT-P-11b. The other is WASP-43b, a gas giant twice as massive as Jupiter.

But Wakeford and her colleagues found that HAT-P-26b bucks the trend. They determined its metallicity is only about 4.8 times that of the sun, much closer to the value for Jupiter than for Neptune.

“This analysis shows that there is a lot more diversity in the atmospheres of these exoplanets than we were expecting, which is providing insight into how planets can form and evolve differently than in our solar system,” said David K. Sing of the University of Exeter and the second author of the paper. “I would say that has been a theme in the studies of exoplanets: Researchers keep finding surprising diversity.”

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, Inc., in Washington.

NASA's Jet Propulsion Laboratory in Pasadena, California, manages the Spitzer Space Telescope for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

For more information about Spitzer, visit:

www.nasa.gov/spitzer

For images and more information about Hubble, visit:

http://www.nasa.gov/hubble

Contacts:

Elizabeth Zubritsky/Nancy Neal-JonesNASA's Goddard Space Flight Center, Greenbelt, Md.

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunters Named in TIME’s Top 100 Most Influential People

4 min read

Three extraordinary planet-hunters have been recognized by TIME Magazine as this year’s top 100 most influential people: Natalie Batalha from NASA’s Ames Research Center in California’s Silicon Valley; Michael Gillon from the University of Liège in Belgium; and Guillem Anglada-Escudé from the Queen Mary University in London.

“It is truly exciting to see these planet-hunters among the other movers and the shakers of the world,” said Paul Hertz, Astrophysics division director at Headquarters in Washington. “These scientists have transformed the world’s understanding of our place in the universe, and NASA congratulates them for their well-deserved recognition.”

Natalie Batalha is the project scientist for NASA’s Kepler mission, the agency’s first dedicated planet-seeking mission tasked to determine whether worlds around other stars are common by looking for telltale dips in a star’s brightness caused by crossing, or transiting, planets. Thanks to Kepler, some scientists believe there is at least one world around every star in the sky. To date, Kepler has found more than 2500 planets, including a “bigger, older cousin” to Earth. In total, the Kepler spacecraft has found nearly 5100 possible planets. Batalha is the first woman at NASA to receive the Time 100 designation. Read more about Batalha’s accomplishments.

Michael Gillon led the research that discovered seven Earth-size planets around TRAPPIST-1, a nearby ultra-cool dwarf star, approximately 40 light years away. He is the principal investigator of the TRAPPIST (“The Transiting Planets and Planetesimals Small Telescope”) project, a pair of telescopes in Chile and Morocco. In 2016, Gillon and colleagues announced three planets around TRAPPIST-1. Following up with NASA’s Spitzer Space Telescope and ground-based telescopes, Gillon and colleagues revealed in 2017 that there are actually seven planets around the star. Three of the seven worlds of TRAPPIST-1 are in the habitable zone, but any of them could have liquid water. The TRAPPIST-1 planets are some of the best targets for NASA’s upcoming James Webb Space Telescope to look for signs of habitability. Gillon is also the project leader and principal investigator of SPECULOOS, an upcoming ground-based telescope project for which TRAPPIST is the prototype. Read more about the TRAPPIST-1 discovery

Guillem Anglada-Escudé led the research team who discovered Proxima b, a roughly Earth-sized exoplanet orbiting at a distance from its star that would allow temperatures mild enough for liquid water to pool on its surface. Proxima b orbits our nearest neighboring star Proxima Centauri just over four light-years from Earth. Proxima is the smallest member of a triple star system known as Alpha Centauri and is the closest star to Earth, besides our own sun. Read more about the European Southern Observatory-led Proxima b discovery.

Anglada-Escude’s research spans the realm of astrobiology, the study of the origin, evolution, distribution, and future of life in the universe. From 2009 to 2013, Anglada-Escude participated in a research study to learn more about life’s chemical and physical evolution, from the interstellar medium, through planetary systems, to the emergence and detection of life. Learn more about the five-year research study supported by the NASA Astrobiology Institute.

NASA’s search for distant worlds continues with the Transiting Exoplanet Survey Satellite (TESS) launching in 2018, which will find new planets the same way Kepler does, but right in the stellar backyard of our solar system, covering 400 times the sky area. Webb will also launch in 2018, and peer into possible atmospheres of distant worlds to look for chemical hints of life.

—

For more information, visit:

http://time.com/collection/2017-time-100/4742707/natalie-batalha-guillem-anglada-escude-michael-gillon/

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunters Named in TIME’s Top 100 Most Influential People

3 min read

NASA Science Editorial Team

Three extraordinary planet-hunters have been recognized by TIME Magazine as this year’s top 100 most influential people: Natalie Batalha from NASA’s Ames Research Center in California’s Silicon Valley; Michael Gillon from the University of Liège in Belgium; and Guillem Anglada-Escudé from the Queen Mary University in London.

“It is truly exciting to see these planet-hunters among the other movers and the shakers of the world,” said Paul Hertz, Astrophysics division director at Headquarters in Washington. “These scientists have transformed the world’s understanding of our place in the universe, and NASA congratulates them for their well-deserved recognition.”

Natalie Batalha is the project scientist for NASA’s Kepler mission, the agency’s first dedicated planet-seeking mission tasked to determine whether worlds around other stars are common by looking for telltale dips in a star’s brightness caused by crossing, or transiting, planets. Thanks to Kepler, some scientists believe there is at least one world around every star in the sky. To date, Kepler has found more than 2500 planets, including a “bigger, older cousin” to Earth. In total, the Kepler spacecraft has found nearly 5100 possible planets. Batalha is the first woman at NASA to receive the Time 100 designation.

Michael Gillon led the research that discovered seven Earth-size planets around TRAPPIST-1, a nearby ultra-cool dwarf star, approximately 40 light years away. He is the principal investigator of the TRAPPIST (“The Transiting Planets and Planetesimals Small Telescope”) project, a pair of telescopes in Chile and Morocco. In 2016, Gillon and colleagues announced three planets around TRAPPIST-1. Following up with NASA’s Spitzer Space Telescope and ground-based telescopes, Gillon and colleagues revealed in 2017 that there are actually seven planets around the star. Three of the seven worlds of TRAPPIST-1 are in the habitable zone, but any of them could have liquid water. The TRAPPIST-1 planets are some of the best targets for NASA’s upcoming James Webb Space Telescope to look for signs of habitability. Gillon is also the project leader and principal investigator of SPECULOOS, an upcoming ground-based telescope project for which TRAPPIST is the prototype. Read more about the TRAPPIST-1 discovery.

Guillem Anglada-Escudé led the research team who discovered Proxima b, a roughly Earth-sized exoplanet orbiting at a distance from its star that would allow temperatures mild enough for liquid water to pool on its surface. Proxima b orbits our nearest neighboring star Proxima Centauri just over four light-years from Earth. Proxima is the smallest member of a triple star system known as Alpha Centauri and is the closest star to Earth, besides our own sun. Read more about the European Southern Observatory-led Proxima b discovery.

Anglada-Escude’s research spans the realm of astrobiology, the study of the origin, evolution, distribution, and future of life in the universe. From 2009 to 2013, Anglada-Escude participated in a research study to learn more about life's chemical and physical evolution, from the interstellar medium, through planetary systems, to the emergence and detection of life.

NASA’s search for distant worlds continues with the Transiting Exoplanet Survey Satellite (TESS) launching in 2018, which will find new planets the same way Kepler does, but right in the stellar backyard of our solar system, covering 400 times the sky area. Webb will also launch in 2018, and peer into possible atmospheres of distant worlds to look for chemical hints of life.

For more information, visit:

http://time.com/collection/2017-time-100/4742707/natalie-batalha-guillem-anglada-escude-michael-gillon/

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Earth-sized ‘Tatooine’ planets could be habitable

4 min read

Elizabeth Landau

With two suns in its sky, Luke Skywalker's home planet Tatooine in "Star Wars" looks like a parched, sandy desert world. In real life, thanks to observatories on the ground and in space, we know that two-star systems can indeed support planets, although many planets discovered so far around double-star systems are large and gaseous. Scientists wondered: If an Earth-size planet were orbiting two suns, could it support life?

Max Popp

Princeton University

It turns out, such a planet could be quite hospitable if located at the right distance from its two stars, and wouldn't necessarily even have deserts. In a particular range of distances from two sun-like host stars, a planet covered in water would remain habitable and retain its water for a long time, according to a study in the journal Nature Communications.

"This means that double-star systems of the type studied here are excellent candidates to host habitable planets, despite the large variations in the amount of starlight hypothetical planets in such a system would receive," said Max Popp, associate research scholar at Princeton University in New Jersey, and the Max Planck Institute of Meteorology in Hamburg, Germany.

Read more: Are planets like those in Star Wars 'Rogue One' really out there?

Popp and Siegfried Eggl, a Caltech postdoctoral scholar at NASA's Jet Propulsion Laboratory, Pasadena, California, created a model for a planet in the Kepler-35 system. In reality, the stellar pair Kepler-35A and B host a planet called Kepler-35b, a giant planet about eight times the size of Earth, with an orbit of 131.5 Earth days. For their study, researchers neglected the gravitational influence of this planet and added a hypothetical water-covered, Earth-size planet around the Kepler-35 AB stars. They examined how this planet’s climate would behave as it orbited the host stars with periods between 341 and 380 days.

This artist's concept shows the real gas giant Kepler-35b, which orbits two stars.

"Our research is motivated by the fact that searching for potentially habitable planets requires a lot of effort, so it is good to know in advance where to look," Eggl said. "We show that it's worth targeting double-star systems."

In exoplanet research, scientists speak of a region called the "habitable zone," the range of distances around a star where a terrestrial planet is most likely to have liquid water on its surface. In this case, because two stars are orbiting each other, the habitable zone depends on the distance from the center of mass that both stars are orbiting. To make things even more complicated, a planet around two stars would not travel in a circle; instead, its orbit would wobble through the gravitational interaction with the two stars.

Popp and Eggl found that on the far edge of the habitable zone in the Kepler-35 double-star system, the hypothetical water-covered planet would have a lot of variation in its surface temperatures. Because such a cold planet would have only a small amount of water vapor in its atmosphere, global average surface temperatures would swing up and down by as much as 3.6 degrees Fahrenheit (2 degrees Celsius) in the course of a year.

"This is analogous to how, on Earth, in arid climates like deserts, we experience huge temperature variations from day to night," Eggl said. "The amount of water in the air makes a big difference."

But, closer to the stars, near the inner edge of the habitable zone, the global average surface temperatures on the same planet stay almost constant. That is because more water vapor would be able to persist in the atmosphere of the hypothetical planet and act as a buffer to keep surface conditions comfortable.

As with single-star systems, a planet beyond the outer edge of the habitable zone of its two suns would eventually end up in a so-called "snowball" state, completely covered with ice. Closer than the inner edge of the habitable zone, an atmosphere would insulate the planet too much, creating a runaway greenhouse effect and turning the planet into a Venus-like world inhospitable to life as we know it.

Another feature of the study's climate model is that, compared to Earth, a water-covered planet around two stars would have less cloud coverage. That would mean clearer skies for viewing double sunsets on these exotic worlds.

Elizabeth LandauJet Propulsion Laboratory, Pasadena, CA818-354-6425elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Will wobbling stars guide us to ‘100 Earths’?

4 min read

NASA Science Editorial Team

By Pat Brennan,NASA's Exoplanet Exploration Program

The hunt for planets around other stars so far has been a rousing success: more than 5,500 confirmed in our Milky Way galaxy, where, we now know, hundreds of billions more likely await discovery. Most of these exoplanets were found using the "transit method": looking for a tiny, tell-tale “shadow” as the orbiting planet crossed the face of its star.

But in order to know whether a planet is likely to be rocky or gaseous, scientists need to be able to calculate density, and, in many cases, they need another way of getting at that besides the transit method. Debra Fischer, a Yale University professor of astronomy, is a leading expert in the “radial velocity” or “wobble” method for finding exoplanets.

With this method, astronomers track the changing speed of a star as it is tugged around by orbiting planets. The size and nature of the tugs can reveal how massive these planets are, as well as how long it takes them to orbit their stars – critical information in the search for rocky, watery, life-bearing worlds. Future space missions designed to study planetary atmospheres could follow up on these planets, picking apart the spectrum of light to look for gases that might indicate the presence of life, such as oxygen and methane.

Fischer took time recently to chat about a new planet-hunting instrument her team is developing as part of the “100 Earths” project, and her hopes for the future of exoplanet astronomy.

That I’m a planet finder, a planet hunter, or an astronomer. I tell them I detect planets orbiting nearby stars. And now we’re trying to build more sensitive instruments to detect smaller planets with the Doppler (“wobble”) technique.

Right now, my team is building a spectrograph called EXPRES, the Extreme Precision Spectrograph, that we will be delivering by the end of this year (to the Lowell Observatory’s Discovery Channel Telescope in Happy Jack, Arizona). I’ve put everything I know from 20 years of planet hunting into the design of this spectrograph. The title of our science program is “The Search for 100 Earths.” We’re targeting nearby, bright stars. We know now from Kepler (NASA’s Kepler Space Telescope) that virtually all of these stars will have planetary systems. Perhaps half of them will have small, rocky planets – half or more. We are emboldened, really, by the promise of Kepler.

Many NASA missions that are being planned today have an exoplanet focus. Kepler, retired in 2020, was designed to find exoplanets. TESS, the Transiting Exoplanet Survey Satellite. JWST (the James Webb Space Telescope, is studying exoplanets. The Nancy Grace Roman Space Telescope has this huge exoplanet component. Now I’m a community co-chair for a NASA study of a future observatory concept called LUVOIR (the Large Ultraviolet Optical Infrared Surveyor). This mission will serve astronomers who are studying the origin of the universe and the evolution of galaxies. It will also obtain the spectra of the atmospheres of Earth-like planets around nearby stars to search for biosignatures.

I think the first step – the thing we can to today – is to identify Earth analogs around nearby stars, determine their orbits and measure the masses of the planets. The measurement of planet masses is something that can be uniquely done with the Doppler technique. If you don’t have the mass, then when we have a spectrum of the planet's atmosphere with a NASA observatory, the interpretation will be ambiguous. You need the mass of the planet to understand whether things like oxygen and methane have a geological or biological origin.

Life is driving the crazy chemistry we have here on Earth with oxygen, carbon dioxide, methane, coexisting in our atmosphere.

Go for it. This is an incredibly exciting time in astronomy, in exoplanets. The field is just absolutely booming. And I think it’s very important to have a lot of diversity in the field. I have absolutely no doubt that the way I approach problems is different from the generation of men I have worked with. Because of that, I hope that I am taking the field in a unique and slightly different direction. And that’s what young women coming into the field can do – create something new. This is really important to the vitality of science.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Role Models, Footsteps, and the Search or Life

6 min read

NASA Science Editorial Team

By Pat Brennan, NASA's Exoplanet Exploration Program

A star among planet hunters, Natalie Batalha wields a formidable weapon: NASA’s Kepler space telescope. Kepler’s first four years of staring into the heavens revealed the bulk of the more than 3,400 exoplanets – planets circling other stars – found so far in our galaxy. When a malfunction ended Kepler's initial run in 2013, engineers found a way to keep the spacecraft going. Originally, Kepler stared at just one patch of sky. Now, operating in the K2 mission, it stares at different patches of sky for about 80 days at a stretch.

It is still discovering planets.

Batalha has been with the Kepler team since the space telescope was still on the drawing board, and has served in various science leadership roles. She led an analysis that revealed the first rocky planet Kepler found outside our solar system, called Kepler-10b, in 2011. Now, as the Project Scientist for Kepler at the NASA Ames Research Center in California's Silicon Valley, Batalha is preparing for the end of the prime mission. That will come when the team delivers its final planet candidate catalog and associated data products in the summer of 2017.

More: Meet Jessie Dotson, co-lead for Kepler

Batalha took some time recently to talk about her work, about having a role model, then becoming one, and about watching her daughter follow in her footsteps.

I work on planet detection, characterization, and occurrence-rate studies. I’m also starting to turn my attention toward the broader subject of planetary habitability. With Kepler, we sought to find planets in the habitable zone (the range of orbits where liquid water can possibly exist on the surface). The long-term goal is to transition from finding habitable zone planets to finding habitable environments, and even living worlds.

Kepler was funded to do something very specific: determine the fraction of stars that harbor potentially habitable, terrestrial-size planets. That is what we mean by “occurrence rate”: how frequently planets of a given size and orbit occur in the galaxy. Kepler has delivered a statistically significant sample of new discoveries, thousands of planets, that we can study as a population. We find that small planets are much more common than large planets in the inner regions of a planetary system. M stars (red dwarfs) seem to make terrestrial-sized planets more frequently than G-type stars (like our sun). We’re able to study these more general population-type questions because we have such a large sample of discoveries.

Kepler has demonstrated a diversity of exoplanets that we didn’t expect. For example, the most common planet known to humanity right now is one we don’t even have in our solar system: these super-Earth, sub-Neptune type planets. We don’t know anything about them. We don’t have any examples here at home.

We have found lava worlds with one hemisphere that’s an ocean – an ocean not of water but of molten rock. We have found disintegrating planets literally breaking up before our eyes, because of orbits close to the parent star. We have found circumbinary planets, planets that are orbiting not one but two stars. We find planets as old as the galaxy itself; I think that was a huge surprise. It means that the raw materials for planet formation are available in the earliest stages of a galaxy’s life. We find planets associated with dead stars, orbiting white dwarfs. We also find interesting architectures: dynamically compact (planetary) systems, packed so tightly that planets feel gravitational interactions from one another.

We have learned that every star has at least one planet, and that there are tens of billions of potentially habitable, Earth-size planets. I think that latter fact has opened up a pathway for the search for life on exoplanets. Knowing there are many potentially habitable worlds catalyzes the search for life in a very tangible way.

I always tell people just do what they love. I'm trying to remember what I told my own daughter (Natasha, now 27 and an astrophysics graduate student). There may be moments, especially in our field, which still suffers from gender imbalance, when you look around to find you're different than most of the people sitting in the room. You're going to have to work through that and stick it out. That's an uncomfortable place to be. It's going to cause you to doubt yourself. It's important to pause and remember that you are capable and have something to offer. It is normal to find this work challenging. If you love it, persist.

One thing I've noticed over the years is that the students that tend to work with me on research projects are more frequently female. Not that I'm actively seeking them out; it just seems to be a natural thing that happens. To me, that highlights the need for role models. The lack of role models in the field is damaging. The expression is, you can't be what you can't see. The quickest way to close the gender gap is to provide role models.

In my undergraduate years, I never had any female professors teach my physics or astronomy classes. When I was in high school, though, I had the example of the astronaut Sally Ride. At that time, I didn't know what I wanted to be. I went to college as a prospective business major, not a science major. When I paused and asked myself what I would do if I could do anything, the answer was to work for NASA. Immediately, that role model, Sally Ride, popped into my head.

With our own children, we were really careful (with both mom and dad working in astrophysics) not to make it astronomy 24/7 at home. In fourth grade, when our oldest daughter was 10 years old, she did a "famous American" report. She chose Sally Ride as the subject. She learned that Sally Ride was the first American woman in space and decided she wanted to be the first human on Mars. Now she's really interested in the search for life on exoplanets. We're sometimes even on (teleconferences) together, which is great fun.

It's nice that Sally Ride influenced us both, and it makes me very happy to know that my own daughter will serve as a role model herself one day for future generations of explorers.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

A fearless astronomer behind a game-changing telescope

4 min read

Pat Brennan

By Pat Brennan,NASA's Exoplanet Exploration Program

Asteroids and exoplanets: NASA’s versatile astrophysicist, Jessie Dotson, has both topics covered, and a lot more besides. Dotson is the Project Scientist for the NASA Kepler space telescope’s K2 mission. She also leads the characterization team for a research effort she helped create, the Asteroid Threat Assessment Project.

She works at the NASA Ames Research Center in California's Silicon Valley, where she established the Kepler Guest Observer Office, and where she served for six years as branch chief for astrophysics – a hive of about 60 researchers who investigate asteroids, exoplanets (planets around other stars), galaxies and astrochemistry. Before that, Dotson served as instrument scientist for NASA's Stratospheric Observatory for Infrared Astronomy (SOFIA) mission, a 747 fitted with a sophisticated telescope to view the universe in infrared light.

Dotson also has developed cameras, spectrometers for analyzing light, and other instruments. These have been used in ground, airborne and space-based observatories.

She caught her breath recently to discuss her work on Kepler, and Kepler’s influence on scientific culture.

I actually split my time between two things. I’m project scientist for K2, and I really see my role there as enabling the scientific community to get the most they can out of this fantastic telescope and data set that NASA has created. The other thing I spend time on right now – I’m part of a project at Ames, the Asteroid Threat Assessment Project. We’re actually trying to better understand what the threat is to humanity on all different scales due to an asteroid impact.

Jessie Dotson

NASA astrophysicist

Some days it’s very complicated. I have this split personality. Other days I look at it [like this]: I get to work on the most interesting things at the coolest agency ever.

We’re getting close to what we call the “closeout” of Kepler, where the final catalog of planet detections for the prime Kepler mission (2009-2013) is going to be finished up. The spacecraft is going to continue operating as the K2 mission until we run out of fuel. It might be nine months from now, it might be 18 months from now; we don’t know. It’s not forever.

I think the Kepler spacecraft in both mission incarnations, Kepler and K2, has had a significant impact. Kepler, no doubt, completely changed the field of exoplanets, and changed our awareness of how plentiful they are. But I think it also changed the sociology of the field. Before Kepler, every exoplanet was precious and it was a very closed field. But as they became more and more prevalent and we knew there weren’t just a few, but thousands and thousands of them, and as the Kepler mission went on, we started making the data public right away. Now, K2 makes it public right away also.

The sociology of the entire field has changed. [On March 8], K2 made raw data from its Campaign 12 public at 9 a.m. East Coast time. (The data included TRAPPIST-1, a system of seven Earth-sized planets first revealed by a collaboration of NASA's Spitzer Space Telescope and ground-based telescopes.) That day, people were finding new things about the star and posting all this stuff in real time on Twitter. Sixty hours after the raw data was released, a 36-page paper with 32 authors from seven countries was submitted to a journal. When you open up a field, this is what happens.

K2 is helping us find planets in very different kinds of systems than Kepler did, because we're looking at a wider variety of regions in the sky and we're finding young planets, disintegrating planets around white dwarfs, just to name a few. We get data on planets around nearby stars and brighter stars, so we'll be able to characterize these planets more precisely with subsequent follow up observations.

I think when you find a question you're interested in pursuing, be brave and pursue it. You might have to adjust as you learn more. When pursuing science, you have to be realistic. But it helps to be a little bit fearless. And it's okay to be fearless.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

‘Genius’ granted

2 min read

NASA Science Editorial Team

Sara Seager, an astrophysicist and planetary scientist exploring the possibility of life throughout the galaxy, is the recipient of a 2013 MacArthur "Genius" fellowship. Adapting the principles of existing planetary science to the study of exoplanets (planets outside the solar system), she is quickly advancing a subfield initially viewed with skepticism by the scientific community. A mere hypothesis until the mid-1990s, nearly 900 exoplanets in more than 600 planetary systems have since been identified, with thousands of more planet candidates known.

Early in her career, Seager determined that the nature of an exoplanet’s atmosphere could be observed during an eclipse, when the planet’s atmospheric light spectrum is especially distinct from its much brighter host star. She then envisioned and formalized a comprehensive framework for guiding and interpreting observations of planets in this manner, including parameters for calculating planet density and remotely detecting biosignature gases (spectroscopic signatures of chemical compounds that are indicative of life) in their atmospheric spectra. Her early predictions led to the first detection of an exoplanet atmosphere by observations from the Hubble Space Telescope.

While continuing to create and refine theoretical models of exoplanet atmospheres and interiors, she is also spearheading advanced hardware design and space mission projects, including ExoplanetSat, a university collaboration to build low-cost “nano-satellites” to observe planetary transits. ExoplanetSat is a new concept for space science: a fleet of dozens of cheap copies of an ultra-small space telescope that will open up a new avenue for wide-ranging space exploration. A visionary scientist contributing importantly in every aspect of her field, Seager is finding new celestial frontiers and fueling curiosity about life in worlds beyond our reach.

Seager received a B.Sc. (1994) from the University of Toronto and a Ph.D. (1999) from Harvard University. She was affiliated with the Institute for Advanced Study (1999–2002) and the Carnegie Institution of Washington (2002–2006) before joining the faculty at the Massachusetts Institute of Technology, where she is Class of 1941 Professor in the Department of Earth, Atmospheric, and Planetary Sciences and the Department of Physics. She is the author of Exoplanet Atmospheres and Exoplanets (both 2010).

Learn more about Seager's fellowship at the MacArthur Foundation website.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Longtime JPL engineer to help lead hunt for exoplanets

5 min read

Alicia Cermak

By Pat Brennan,NASA's Exoplanet Exploration Program

The seeds of Kendra Short’s passion for space were planted early. She remembers being “one of those dorky little fourth graders who made Styrofoam solar system models.” The passion never left her in 27 years at NASA's Jet Propulsion Lab (JPL), serving in critical roles on Mars missions, as well as in Earth science and astrophysics.

Now Short is taking on a new challenge. As the deputy program manager for NASA’s Exoplanet Exploration program, Short will help identify the most promising missions in the search for new worlds throughout our galaxy—and for signs of life among them. Along with program manager Gary Blackwood, she will help steer a path for existing missions, providing oversight and guidance and working to build alliances throughout the scientific community.

Short, who lives in Glendale with her husband and two children and is a fan of cooking and gardening, took a moment to ponder her new role, and the future of exoplanet science.

What drew you to the exoplanet program?

I view it as the next big frontier in space science. We’ve done a lot within our own solar system, and this is the next discovery that could change the way we think about our place in the universe. It could open up entire new frontiers for instruments and remote sensing and discoveries, so it’s a very exciting field, and it’s just at the beginning, just in the early stages. You never know what you’re going to find, and that makes it exciting.

What are the program’s next big missions, or big steps?

Certainly WFIRST (Wide Field Infrared Survey Telescope, expected to launch in the mid 2020s) is one of the most exciting elements of the program’s portfolio. The large missions are interesting—MSL (Mars Science Laboratory, or the Curiosity rover), JWST (James Webb Space Telescope), and now WFIRST. There are always extreme engineering challenges associated with those projects. To be able to navigate those waters and make smart decisions during project implementation is critical to success. That is a challenge I’d like to help with.

What are the program’s high-level goals?

The Exoplanet Exploration Program aims at discovering planets around other stars, characterizing their properties, and identifying candidates that could harbor life.

It’s a new and exciting frontier—we didn’t even know or have any proof there were planets around other stars until just recently. If you think about that, that’s amazing: within our lifetime, to go from speculating it was true to proving it was true, proving how much it was true, maybe being able to characterize those worlds with spectroscopy (analysis of planetary light) and whatever other instruments we can envision. That’s an amazing leap forward. It’s kind of like taking our phones and turning them into mobile computers. It happened so fast and now it’s expected. It blows my mind.

How did you first get interested in space science?

I grew up wanting to be an astronaut. Space, overall, it’s been in my blood since I was a kid. I’ve always worked at JPL in my career; I came right out of college.

What are some of the other projects you’ve worked on?

Within my career at JPL I’ve explored all of the areas of space science that JPL is involved in. I’ve done planetary with Cassini, I’ve done Mars (MSL, MER, Mars Pathfinder), Earth science with SRTM (Shuttle Radar Topography Mission—single pass interferometric measurements of land topography, land height; it flew on a two-and-a-half-week shuttle mission that mapped 80 percent of Earth with synthetic aperture radar), and my most recent project, SWOT (the Surface Water and Ocean Topography mission).

I’ve done planetary, I’ve done Mars, I’ve done Earth science, I’ve done a little bit of astrophysics. I’m kind of coming back around to astrophysics. I’m very excited. I wouldn’t say I set out looking for exoplanets as a career goal, (but) if you look at the astrophysics portfolio, right now, exoplanet activity is a very exciting part of it, in my estimation.

What engineering question intrigues you the most?

The future of large, space-based telescopes, and the engineering technology associated with that, whether it will be segmented reflectors, wavefront sensing and control, extreme stability; those are very different engineering challenges, ones that I think NASA is ready to solve, ready to take it to the next level.

Any advice for young people considering a career in a related field?

Never stop asking questions, never stop trying. That’s the fun of engineering, trying to do something that hasn’t been done before, and not giving up when it doesn’t work the first time. Learn, fix, try again. That’s the whole nature of engineering.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Selects Medium-scale Space Mission Concepts to Study for 2020 Astrophysics Decadal Survey

1 min read

NASA Science Editorial Team

As part of the preparations for the 2020 Decadal Survey, in August 2016 NASA issued a ROSES solicitation (ROSES2016, NNH16ZDA001N, Appendix D.12) for studies of medium-size (“Probes”) mission concepts. On November 15, 2016, 27 compliant proposals were received. The peer review was held in January 2017.

In March 2017, NASA made the following selections:

All the selected proposals were highly rated by the peer-review panels based on merit and other criteria stated in the ROSES solicitation. Selection of the listed proposals follows programmatic criteria as well as taking into account the panels’ guidelines for a diverse portfolio addressing a variety of science questions.

The selected Teams will receive funds for an 18-month comprehensive study. NASA will also provide design lab runs and a final Independent Cost Assessment for the selected studies.

The selection decision document will be posted at https://science.nasa.gov/astrophysics/2020-decadal-survey-planning under Probes Mission Concept Studies.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunters: For Rachel Akeson, Science is in the Genes

4 min read

NASA Science Editorial Team

By Joshua Rodriguez, PlanetQuest

You could say that science runs in Rachel Akeson's family. The daughter of two scientists, she knew she was going to be an astronomer by the time she was a third-grader. Now, in addition to having her hands full with her own young children, Akeson is studying young stars as they develop their own planetary families.

PlanetQuest: What's your role with the Keck Interferometer project?

Rachel Akeson: I'm the project scientist for both the Michelson Science Center at Caltech and for the Keck Interferometer. I try to look after the big science goals for the interferometer, I make sure the decisions about technology and operations will still allow the interferometer to perform then needed operations and try to help the scientists who use the telescope for their studies.

PQ: What's an interferometer?

Akeson uses the Keck Interferometer to look at dust disks around stars similar to the one visualized above.

Akeson: With an interferometer, the idea is to use multiple telescopes to get the resolution of a bigger telescope. You take the light from different telescopes, combine it in a special way, like we do with the two Keck Observatory telescopes on Mauna Kea. Right, now, we're gearing up for an intensive, yearlong study of dust around nearby stars.

PQ: Why look at the dust around stars?

Akeson: Studying the dust can tell us which stars are good exoplanet candidates. That helps us design other planet-finding missions and can help those missions be more efficient by picking which stars are more likely to have planets.

PQ: How do you get a good look at the dust?

Akeson: The dust is very faint compared to the star, so the trick is to null the light of the star with a destructive fringe. When you block the light of the star you can get just the light from the dust.

PQ: How did you get involved with this mission?

Akeson: Well, my parents were both scientists, and I wanted to be an astronomer since third grade. I got a degree in physics from the University of Iowa, got my doctorate at Caltech, then went to the University of California at Berkeley before coming back to Caltech in 1998. I started working at the science center for the SIM PlanetQuest mission and eventually found myself working on the Keck project.

PQ: What's your favorite thing about your current project?

Akeson: My favorite part is that we built something that's actually really useful - and that I get to use the telescope myself. I do my own thesis project research on the side. I study young stars.

PQ: What's interesting about young stars?

In the basement of the Keck Observatory, an intricate system of mirrors on rails is used to equalize the path length of starlight received by the twin telescopes.

Akeson: As the gas and dust that makes up starsin an interstellar cloud collapses and begins to form the a star, there's a disk of material that surrounds the star - this is where planets are made. I study the zone around a star where a habitable planet could form, and I look at that matter that's there, how much of it there is, how warm it is, and how long it will stay around. You can get an idea of how much time there is for a planet to form before the disc disappears. It's something that I've been looking at for 15 years now.

PQ: What do you like to do with your time when you aren't studying the heavens?

Akeson: I love to hike and spend time with my kids - one is almost two, and the other is five years old. We go to the zoo or Huntington Gardens a lot.

PQ: What's your advice to anyone else who's interesteding in being a part of this field?

Akeson: There are all kinds of people working in this area, so you shouldn't get scared off if math isn't your thing. There are lots of different careers, from science journalism to public outreach, that people can be a part of.

PQ: What keeps you interested in planet hunting?

Akeson: For me, it's the idea that the laws of physics apply to everything, even to things in space. Everything in space is so extreme. Things are going on out there that we'd never see on Earth.

JPL, a division of the California Institute of Technology in Pasadena, manages the Keck Interferometer for NASA.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunters: Finding Beauty in the universe

5 min read

NASA Science Editorial Team

By Joshua Rodriguez, PlanetQuest

Beth A. Biller is part of an international team of astronomers trying to tease out images of planets around young stars by removing the distortions caused by Earth's atmosphere.

Extrasolar planets are extremely faint targets to begin with, and an atmospheric effect known as "speckling" has thwarted most previous attempts to observe them directly. Using instruments installed at the Very Large Telescope in Chile, Biller's team has constructed some of the highest contrast images every obtained of substellar objects.

Her work is also helping determine requirements for NASA's Terrestrial Planet Finder, a future mission that will directly observe and characterize habitable planets around nearby stars. Currently a doctoral candidate at the University of Arizona, she presented her research in an oral session at this year's winter meeting of the American Astronomical Society. She is a native of the Washington, D.C., area.

PlanetQuest: Where are you in your career right now?

Beth Biller: Currently I'm at that fun stage of the Ph.D. program where, once I write a book, I'm done. For my thesis, I just finished a major paper on our survey of very nearby, young stars looking for extrasolar planets.

Biller and her colleagues obtained this image of a very cool brown dwarf orbiting a star near our sun using a camera on the Very Large Telescope in Chile. (Credit: Beth Biller and Laird Close, UA Steward Observatory, 2006)

PQ: What are your short- and long-term career goals?

Biller: I'd like a job, short term. I really love research astronomy and want to keep on pursuing it. I'd like to become one of the first comparative exoplanetologists -- someone who classifies different types of planets beyond our solar system. But there are a lot of different options in astronomy.

PQ: What do you love about research?

Biller: The daily grind can be frustrating, but the exciting part is when you discover something new. For example, I discovered a brown dwarf last year. I was like: "I'm looking at a world, and I'm the first person ever to see this place!"

PQ: What is the significance of your research?

Biller: We just completed a 50-star survey. With that many objects, we can really say something cool about the distribution of extrasolar planets. We're looking at giant planets, but not as old as Jupiter - they're bigger, brighter, and puffier.

From an astrobiology sense, it's important to understand the architecture of these early systems, because that can determine where earthlike planets can and cannot form. For instance, we're lucky that Jupiter is where it is in our solar system. A lot of known planetary systems have Jupiter-mass planets at Mercury-like distances. But such a planet can't form that close to a star - it has to form at a Jupiter-like distance, and then migrate inward. However, that inward migration would be disastrous for any proto-Earths that might be forming in that solar system!

PQ: Can you remember what originally sparked your interest in astronomy or science?

Biller: I was always interested in astronomy when I was really little. I kind of drifted away until the end of high school. And then, when I was in high school, the first exoplanets were discovered, and that was a big deal. I was like, I don't know if I can make it in this field, but I want to give it a shot. So I went to college. You have to get into physics pretty early on. It was scary, but it was really fulfilling.

The hardest part was fear of math.

PQ: How did you deal with that?

Biller: I just tried not to freak out too much. When I sat down and really worked through it, I was able to catch up. Now, math is not scary. I'm just used to it.

PQ: What do you like to do in your spare time?

In her spare time, Biller pursues an unusual hobby: belly-dancing. (Credit: Douglas Hester)

Biller: I'm a bellydancer. It's not dance of the seven veils, nothing like that. I do a style called American tribal style. You have a leader, and everyone follows the leaders. It's a cool, improvisatory dance form.

PQ: Do you see any linkages between your two interests -- science and dancing?

Biller: Yes. They're both about beauty in different forms: the beauty of the universe and beauty of movement of the human body.

PQ: Any particular advice to other young people who might be considering a career in science?

Biller: If you think you're an unlikely candidate, but still want to do it, then do it. Don't be intimidated. There are all types of people who are scientists, and it's getting more and more diverse.

PQ: Is there any particular teacher who has inspired or motivated you?

Biller: My first college physics teacher. I was taking mechanics and it was very scary -- again because I was afraid of it. He took me aside, and said, "Hey, don't worry about this, I think you'll do fine in this course as long as you buckle down and work." That was very important. If I hadn't gotten that reassurance, I don't think I would have stayed in the field.

PQ: What has been the most exciting moment for you?

Biller: It was really exciting going to Chile for the commissioning run, when we installed the new instrument on the telescope. It was in the middle of nowhere and it looked like Mars. Very, very empty. Just these four enormous telescopes.

PQ: What kind of music do you like?

Biller: Electronic, gothic, bellydance music. Strange indie stuff.

PQ: Name a favorite movie you've seen recently.

Biller: "Eternal Sunshine of the Spotless Mind." That's totally random, though.

PQ: What's the coolest thing about what you do?

Biller: Just finding new stuff. The idea if you discover a planet, it's a new world. It's a place that maybe in the far, far future people could go to. That's pretty inspiring.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Bright star sets her sights on exoplanets

7 min read

Pat Brennan

By Pat Brennan,NASA's Exoplanet Exploration Program

The main problem in describing the accomplishments of Sophia Sánchez-Maes is: Where to begin? There's the prestigious Jefferson Award for outstanding service “by a young American 25 or under.” Her handshake, at age 16, with President Obama, who said she was “helping to bring the world closer to using algae as a clean, renewable, and even inexhaustible energy source.” Then there's her part in some of the scientific work behind the Mars Curiosity Rover, which is, at the moment, preparing to climb a mountain on the floor of a Martian crater.

At age 18, Sánchez-Maes now takes her next scientific plunge. She’s joining the hunt for extrasolar planets—planets orbiting other stars. During a three-month stint at NASA’s Jet Propulsion Laboratory in Pasadena—her second—she will be helping map out the goals and technology for the next generation of space telescopes. After that, she begins her sophomore year at Yale, where she is pursuing a double major in astrophysics and computer science. A native of New Mexico, Sánchez-Maes said she enjoys mentoring and teaching, and hopes to inspire other young Latinas to pursue careers in science. She shared a few thoughts about her brief but impressive career as she settled into her workspace at JPL:

You’ve been described as a prodigy. What do you think about that?

I don’t know about that. I definitely don’t think of myself as a prodigy. Actually, I’m lucky, and I work hard— on really cool stuff. “Prodigy” says a lot of this came easy. I don’t know that that’s necessarily the case. So many nights staying up late, struggling with a lot of these things. When I was really little, and I was taking violin lessons, I told my mom I wanted to be a prodigy. She said, “Sweetie, that’s not how it works. Now go practice.” A lot of that attitude I carried forward. It’s not something you’re given, so if you’re passionate you have to put in so many hours to make things happen. There was a very “no excuses” attitude around my house.

As you were growing up in New Mexico, how did you become interested in space, in planets?

Whatever project I’ve worked on, I’m able to use my 20/20 hindsight to see this particular little path that got me here. When I was doing algae—I have a photo of myself in the lab with a little bioreactor. It looked like myself as first grader, holding onto a cloned plant [while I was wearing] little goggles. Now it’s exoplanets. In kindergarten, I entered a “My Space Trip” contest. I wrote about touring all these different planets with my aunt and my cousin. It wasn’t very realistic. There were wormholes, black holes, a lot of stuff in the solar system that I now realize isn’t there.

What pointed you in the direction of algae?

New Mexico has a lot of algae fuel startups and plenty of sunshine for it. So people come. But we don’t have so much water. It’s kind of a problem, living in the desert. It’s always challenging for these places. A lot of them are really struggling to produce biofuel. It’s nowhere near what crude oil can give us in terms of the scope of the cost. It was a cool problem; I wanted to see if I could improve some of my skills. I started solving it, I got some friends to start modeling the algae growth process with computers, to figure out a tool these growers could use to optimize the process, and start capitalizing on this beautiful alternative energy source.

We had the support of the Los Alamos National Laboratories and their amazing computing resources. Everyone was saying, “Look at this amazing tool we have. Wow. Awesome. But it’s doomed anyway, because it takes more energy to produce this algal fuel than it contained." It was pretty much worthless. I took my hit, and I started reading up on that problem, too. We're so lucky in that area to have a wonderful agricultural college with agriculture and engineering, the intersection between those two areas. I was able to get a National Science Foundation young scholar fellowship. I started working on this problem. It's so crazy, so amazing. Me, a girl who had never really done chemistry at all, to let me have some free rein in a chemical engineering lab. I was able to show you can bring down the reaction process hundreds of degrees. It really does a lot to decrease the amount of energy to make this (biofuel production) happen.

And you were doing this in high school?

Yeah. So the process is called hydrothermal liquefaction. You pressure-cook everything, and it all becomes fuel. The team over there was so wonderful. Together we were able to kind of get it back in the black. It really went places. I was able to use energy from an extremophile (algae) in Yellowstone. I found it works wonderfully in this process. In addition, it's really hardy. It doesn't need fresh (water); it can stand brackish water. That's a huge sell in New Mexico. It also can stand wastewater. All the contaminants in wastewater that anaerobic bacteria extracts, this algae can do it better. By integrating with wastewater treatment plants, the energy is positive, as opposed to a 33 percent drain on energy. It was amazing to be involved so young. It really taught me the collaboration thing you have in science.

What will you be doing here at JPL?

I'm really excited about the work I get to do here. Right now, my primary project is working on proposals for the next decadal (review), on proposed space telescopes. There's a big one every 10 years or so. The best part about me working on this: This is the telescope that will define the data I get at the height of my career. It's such an opportunity to have a voice in this process, because I'll be doing the science.

Two of those [proposals] are being driven primarily by exoplanets. LUVOIR (Large UV/Optical/Near-infrared telescope) is going to directly image habitable planets. It will do everything HabEx (Habitable Planet Exoplanet Imaging Mission) will do, but it will do lots of other science. HabEx is pretty much exclusively meant to image these exoplanets.

My background is investigating the stellar noise influence on exoplanet detections using the radial velocity method. [Editor's note: Radial velocity is a planet-finding method that infers the presence of planets from the wobbles they cause their parent stars to make]. Right now people are proposing that the radial velocity instrument be included in LUVOIR. What we need is to really study these concepts. My job is to figure out what kind of measurements we could get from space. We need numbers to back up those hunches. As we're imaging these worlds, it's going to be really important to have their masses. That will tell us about the compositions of these worlds. We're not just finding exoplanets anymore; we're trying to characterize them.

I'm also working on the stellar jitter problem with radial velocity measurements. Stars have spots, flares, coronal mass ejections—lots of stuff that can either masquerade as planetary signals, or hide the signals. Identifying the noise will be critical.

You changed course from a mathematics major to astrophysics. Did you catch the space bug?

I think it might have been lying dormant for awhile, but it caught up to me.

When you want to relax and take your mind off things, what do you do?

I like to run. It's a lot of fun for me to go long distance. There are a lot of stages you go through when you're running lots of miles. At first you're very in your head. Everything you're holding onto up there is buzzing around even more. Your mind kind of clears after that. You get sort of focused. It really helps my work, and it helps me get away from my work.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Probing Seven Worlds with NASA’s James Webb Space Telescope

5 min read

With the discovery of seven earth-sized planets around the TRAPPIST-1 star 40 light years away, astronomers are looking to the upcoming James Webb Space Telescope to help us find out if any of these planets could possibly support life.

“If these planets have atmospheres, the James Webb Space Telescope will be the key to unlocking their secrets,” said Doug Hudgins, Exoplanet Program Scientist at NASA Headquarters in Washington. “In the meantime, NASA’s missions like Spitzer, Hubble, and Kepler are following up on these planets.”

“These are the best Earth-sized planets for the James Webb Space Telescope to characterize, perhaps for its whole lifetime,” said Hannah Wakeford, postdoctoral fellow at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. At Goddard, engineers and scientists are currently testing the Webb telescope which will be able to view these planets in the infrared, beyond the capabilities we currently have. “The Webb telescope will increase the information we have about these planets immensely. With the extended wavelength coverage we will be able to see if their atmospheres have water, methane, carbon monoxide/dioxide and/or oxygen.”

When hunting for a potentially life-supporting planet, you need to know more than just the planet’s size or distance from its star. Detecting the relative proportions of these molecules in a planet’s atmosphere could tell researchers whether a planet could support life.

“For thousands of years, people have wondered, are there other planets like Earth out there? Do any support life?” said Sara Seager, astrophysicst and planetary scientist at MIT. “Now we have a bunch of planets that are accessible for further study to try to start to answer these ancient questions.”

Launching in 2018, one of Webb’s main goals is to use spectroscopy, a method of analyzing light by separating it into distinct wavelengths which allows one to identify its chemical components (by their unique wavelength signatures) to determine the atmospheric components of alien worlds. Webb will especially seek chemical biomarkers, like ozone and methane, that can be created from biological processes. Ozone, which protects us from harmful ultraviolet radiation here on Earth, forms when oxygen produced by photosynthetic organisms (like trees and phytoplankton) synthesizes in light. Because ozone is largely dependent on the existence of organisms to form, Webb will look for it in alien atmospheres as a possible indicator of life. It will also be able to look for methane which will help determine a biological source of the oxygen that leads to ozone accumulation.

The discovery of the planets in the TRAPPIST-1 system means that Webb will be able to use its immense capabilities on a relatively nearby system. Researchers recently identified three promising planets in the TRAPPIST-1 system – e, f and g – which orbit in the habitable zone and would make good candidates for Webb to study. Depending upon their atmospheric composition, all three of these Earth-like exoplanets could have the appropriate conditions for supporting liquid water. Because the planets orbit a star that is small, the signal from those planets will be relatively large, and just strong enough for Webb to detect atmospheric features. Shawn Domagal-Goldman, an astrobiologist at NASA’s Goddard Space Flight Center said, “Two weeks ago, I would have told you that Webb can do this in theory, but in practice it would have required a nearly perfect target. Well, we were just handed three nearly perfect targets.”

The number of planets in the system will also enable new research in the field of comparative planetology, which uncovers fundamental planetary processes by comparing different worlds. “This is the first and only system to have seven earth-sized planets, where three are in the habitable zone of the star,” said Wakeford. “It is also the first system bright enough, and small enough, to make it possible for us to look at each of these planets’ atmospheres. The more we can learn about exoplanets, the more we can understand how our own solar system came to be the way it is. With all seven planets Earth-sized, we can look at the different characterisitics that make each of them unique and determine critical connections between a planet’s conditions and origins.”

NASA is exploring the solar system and beyond to better understand the universe and our place in it. We’re looking to answer age-old questions, like how did our universe begin and evolve; how did galaxies, stars, and planets come to be; and are we alone.

The James Webb Space Telescope is the scientific successor to NASA’s Hubble Space Telescope. It will be the most powerful space telescope ever built. Webb is an international project led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

For more information about the Webb telescope visit: www.jwst.nasa.gov or www.nasa.gov/webb

Laura BetzNASA’s Goddard Space Flight Center

Ariel SandbergUniversity of Michigan

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunters: On a Quest for Astronomy's Holy Grail

5 min read

NASA Science Editorial Team

By Joshua Rodriguez / PlanetQuest

It's fitting that Sara Seager is fascinated by stories of explorers visiting uncharted places. From her groundbreaking work on the detection of exoplanet atmospheres to her innovative theories about life on other worlds, Seager has been a pioneer in the vast and unknown world of exoplanets.

Now, like an astronomical Indiana Jones, she's on a quest after the field's holy grail - another Earth-like planet.

In addition to her role as a professor of planetary science and physics at MIT, Seager is also a part of numerous planet hunting committees and projects. She's served on NASA's Exoplanet Task Force and on the Terrestrial Planet Finder science teams. She is currently a participating scientist on the Kepler planet-hunting mission, a co-investigator on the planet-studying EPOXI mission, and is the science team lead on the eXtrasolar Planet Characterizer (XPC) concept study.

PlanetQuest caught up with Seager recently to find out what life is like on astronomy's cutting edge.

PlanetQuest: Do you think that an Earth-like planet will be discovered in your lifetime?

Sara Seager: I like to live in the future, and I'm getting older, so I'm determined to find another Earth-like planet in my lifetime. The super-Earths are interesting, but the difference between them and a real Earth is like the difference between finding your long-lost twin and finding a very, very distant cousin that you have nothing in common with. So I'm working on a concept study for a mission that will look at the very brightest stars in the sky, because those are the only ones that are bright enough for follow-up observations to detect the atmosphere of an Earth-like planet.

Seager is one of the scientists involved with the Kepler planet-hunting mission, scheduled to be launched in 2009.

My idea involves small telescopes in space, each looking at a bright star for signs of a Earth-like planet going in front of the star as seen from Earth, which is called "transiting". I'm convinced that it's going to be successful and that we'll be able to complete the Copernican Revolution.

PQ: You're well-known in scientific circles these days, but how did you get your start in exoplanets?

SS: Well, I was looking for something different to do for my PhD thesis back in 1996, so I decided to write about the properties of hot exoplanet atmospheres - this was one year after the first exoplanets around sun-like stars were discovered in 1995, and no one else had written about this topic. Later, I was the first to propose the detection of exoplanet atmospheres by observing as they transited their host stars. The methods I proposed back then are being used on missions like the Spitzer Space Telescope and the Hubble Space Telescope to detect the composition of exoplanet atmospheres - and they're finding the atoms and molecules that I predicted would be there.

PQ: That's an amazing achievement. What does your work involve these days?

SS: I'm currently a professor of planetary science and physics at MIT - I create models of planet interiors and atmospheres to understand observations of exoplanets. I also study what atmospheres might look like on "Earth cousins" - planets like ours that could have all different kinds of atmospheres, where life could have adapted differently to the conditions on that planet. I'm also working on how we can apply the methods we use to look at the atmospheres of giant planets to smaller, "super-Earth" size planets using the future James Webb Space Telescope.

PQ: What keeps you interested in studying exoplanets?

SS: For me, the hook is the idea of an Earth-like planet, knowing that there's an Earth analog out there. The Kepler mission will be able to tell us if planets like our own orbiting other stars are common, something that will really change the way we look at things. I like to think of finding a true Earth analog as the completion of the Copernican Revolution - Copernicus started a new paradigm when he said that the Earth was not the center of the universe. If we can identify another Earth-like planet, it comes full circle, from thinking that everything revolves around our planet to knowing that there are lots of other Earths out there.

PQ: What's been the most surprising thing you've learned during the course of your career?

Seager is the science team lead for the eXtrasolar Planet Characterizer, a future NASA exoplanet mission concept.

SS: I can think of two surprises: one, any kind of planet is out there, at every semi-major axis. The process of planet formation is random and we've seen planet masses and orbits we never thought could exist. And the second surprise is about the physical characteristics of some planets. For example, how did the "hot Jupiters" get so huge and close to their host stars? Some are bigger than we thought planets could be, too big for us to understand why right now.

PQ: What Earth-bound hobbies do you pursue when you aren't planet hunting?

SS: Well, I have two little kids, so I don't have that much spare time anymore, but I really like canoeing in the Arctic; the northern environment really forces you to push yourself. I like to read, too, books and magazines. My favorite book is "Sleeping Island: The Story of One Man's Travels in the Great Barren Lands of the Canadian North." It's about a Midwest schoolteacher around the 1930s who, every summer, went canoeing in parts of northern Canada that hadn't been mapped yet, just exploring and meeting natives. I like the idea of modern-day-explorers, that sense of adventure about the unknown.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Probing Seven Promising Worlds with NASA's James Webb Space Telescope

5 min read

NASA Science Editorial Team

With the discovery of seven Earth-sized planets around the TRAPPIST-1 star 40 light years away, astronomers are looking to the upcoming James Webb Space Telescope to help us find out if any of these planets could possibly support life.

Sara Seager

MIT Professor

“If these planets have atmospheres, the James Webb Space Telescope will be the key to unlocking their secrets,” said Doug Hudgins, Exoplanet Program Scientist at NASA Headquarters in Washington. “In the meantime, NASA’s missions like Spitzer, Hubble, and Kepler are following up on these planets.”

“These are the best Earth-sized planets for the James Webb Space Telescope to characterize, perhaps for its whole lifetime,” said Hannah Wakeford, postdoctoral fellow at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

At Goddard, engineers and scientists are currently testing the Webb telescope which will be able to view these planets in the infrared, beyond the capabilities we currently have.

“The Webb telescope will increase the information we have about these planets immensely," said Wakeford. "With the extended wavelength coverage we will be able to see if their atmospheres have water, methane, carbon monoxide/dioxide and/or oxygen.”

When hunting for a potentially life-supporting planet, you need to know more than just the planet’s size or distance from its star. Detecting the relative proportions of these molecules in a planet’s atmosphere could tell researchers whether a planet could support life.

“For thousands of years, people have wondered, are there other planets like Earth out there? Do any support life?” said Sara Seager, astrophysicst and planetary scientist at MIT. “Now we have a bunch of planets that are accessible for further study to try to start to answer these ancient questions.”

Launching in 2018, one of Webb’s main goals is to use spectroscopy, a method of analyzing light by separating it into distinct wavelengths which allows one to identify its chemical components (by their unique wavelength signatures) to determine the atmospheric components of alien worlds. Webb will especially seek chemical biomarkers, like ozone and methane, that can be created from biological processes. Ozone, which protects us from harmful ultraviolet radiation here on Earth, forms when oxygen produced by photosynthetic organisms (like trees and phytoplankton) synthesizes in light.

Because ozone is largely dependent on the existence of organisms to form, Webb will look for it in alien atmospheres as a possible indicator of life. It will also be able to look for methane, which will help determine a biological source of the oxygen that leads to ozone accumulation.

The discovery of the planets in the TRAPPIST-1 system means that Webb will be able to use its immense capabilities on a relatively nearby system. Researchers recently identified three promising planets in the TRAPPIST-1 system – e, f and g – which orbit in the habitable zone and would make good candidates Webb to study.

Depending upon their atmospheric composition, all three of these Earth-like exoplanets could have the appropriate conditions for supporting liquid water. Because the planets orbit a star that is small, the signal from those planets will be relatively large, and just strong enough for Webb to detect atmospheric features.

Shawn Domagal-Goldman, an astrobiologist at NASA’s Goddard Space Flight Center said, “Two weeks ago, I would have told you that Webb can do this in theory, but in practice it would have required a nearly perfect target. Well, we were just handed three nearly perfect targets.”

The number of planets in the system will also enable new research in the field of comparative planetology, which uncovers fundamental planetary processes by comparing different worlds.

“This is the first and only system to have seven earth-sized planets, where three are in the habitable zone of the star,” said Wakeford. “It is also the first system bright enough, and small enough, to make it possible for us to look at each of these planets’ atmospheres. The more we can learn about exoplanets, the more we can understand how our own solar system came to be the way it is. With all seven planets Earth-sized, we can look at the different characterisitics that make each of them unique and determine critical connections between a planet’s conditions and origins.”

NASA is exploring the solar system and beyond to better understand the universe and our place in it. We’re looking to answer age-old questions, like how did our universe begin and evolve; how did galaxies, stars, and planets come to be; and are we alone.

The James Webb Space Telescope is the scientific successor to NASA's Hubble Space Telescope. It will be the most powerful space telescope ever built. Webb is an international project led by NASA with its partners, ESA (European Space Agency) and the Canadian Space Agency.

For more information about the Webb telescope, please visit:

www.jwst.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Telescope Reveals Largest Batch of Earth-Size, Habitable-Zone Planets Around Single Star

7 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA's Spitzer Space Telescope has revealed the first known system of seven Earth-size planets around a single star. Three of these planets are firmly located in the habitable zone, the area around the parent star where a rocky planet is most likely to have liquid water.

The discovery sets a new record for greatest number of habitable-zone planets found around a single star outside our solar system. All of these seven planets could have liquid water – key to life as we know it – under the right atmospheric conditions, but the chances are highest with the three in the habitable zone.

“This discovery could be a significant piece in the puzzle of finding habitable environments, places that are conducive to life,” said Thomas Zurbuchen, associate administrator of the agency’s Science Mission Directorate in Washington. “Answering the question ‘are we alone’ is a top science priority and finding so many planets like these for the first time in the habitable zone is a remarkable step forward toward that goal.”

At about 40 light-years (235 trillion miles) from Earth, the system of planets is relatively close to us, in the constellation Aquarius. Because they are located outside of our solar system, these planets are scientifically known as exoplanets.

This exoplanet system is called TRAPPIST-1, named for The Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile. In May 2016, researchers using TRAPPIST announced they had discovered three planets in the system. Assisted by several ground-based telescopes, including the European Southern Observatory's Very Large Telescope, Spitzer confirmed the existence of two of these planets and discovered five additional ones, increasing the number of known planets in the system to seven.

The new results were published Wednesday in the journal Nature, and announced at a news briefing at NASA Headquarters in Washington.

Using Spitzer data, the team precisely measured the sizes of the seven planets and developed first estimates of the masses of six of them, allowing their density to be estimated.

Based on their densities, all of the TRAPPIST-1 planets are likely to be rocky. Further observations will not only help determine whether they are rich in water, but also possibly reveal whether any could have liquid water on their surfaces. The mass of the seventh and farthest exoplanet has not yet been estimated – scientists believe it could be an icy, "snowball-like" world, but further observations are needed.

"The seven wonders of TRAPPIST-1 are the first Earth-size planets that have been found orbiting this kind of star," said Michael Gillon, lead author of the paper and the principal investigator of the TRAPPIST exoplanet survey at the University of Liege, Belgium. "It is also the best target yet for studying the atmospheres of potentially habitable, Earth-size worlds."

In contrast to our sun, the TRAPPIST-1 star – classified as an ultra-cool dwarf – is so cool that liquid water could survive on planets orbiting very close to it, closer than is possible on planets in our solar system. All seven of the TRAPPIST-1 planetary orbits are closer to their host star than Mercury is to our sun. The planets also are very close to each other. If a person was standing on one of the planet's surface, they could gaze up and potentially see geological features or clouds of neighboring worlds, which would sometimes appear larger than the moon in Earth's sky.

The planets may also be tidally locked to their star, which means the same side of the planet is always facing the star, therefore each side is either perpetual day or night. This could mean they have weather patterns totally unlike those on Earth, such as strong winds blowing from the day side to the night side, and extreme temperature changes.

Spitzer, an infrared telescope that trails Earth as it orbits the sun, was well-suited for studying TRAPPIST-1 because the star glows brightest in infrared light, whose wavelengths are longer than the eye can see. In the fall of 2016, Spitzer observed TRAPPIST-1 nearly continuously for 500 hours. Spitzer is uniquely positioned in its orbit to observe enough crossing – transits – of the planets in front of the host star to reveal the complex architecture of the system. Engineers optimized Spitzer's ability to observe transiting planets during Spitzer's "warm mission," which began after the spacecraft's coolant ran out as planned after the first five years of operations.

"This is the most exciting result I have seen in the 14 years of Spitzer operations," said Sean Carey, manager of NASA's Spitzer Science Center at Caltech/IPAC in Pasadena, California. "Spitzer will follow up in the fall to further refine our understanding of these planets so that the James Webb Space Telescope can follow up. More observations of the system are sure to reveal more secrets."

Following up on the Spitzer discovery, NASA's Hubble Space Telescope has initiated the screening of four of the planets, including the three inside the habitable zone. These observations aim at assessing the presence of puffy, hydrogen-dominated atmospheres, typical for gaseous worlds like Neptune, around these planets.

In May 2016, the Hubble team observed the two innermost planets, and found no evidence for such puffy atmospheres. This strengthened the case that the planets closest to the star are rocky in nature.

"The TRAPPIST-1 system provides one of the best opportunities in the next decade to study the atmospheres around Earth-size planets," said Nikole Lewis, co-leader of the Hubble study and astronomer at the Space Telescope Science Institute in Baltimore, Maryland. NASA's planet-hunting Kepler space telescope also is studying the TRAPPIST-1 system, making measurements of the star's minuscule changes in brightness due to transiting planets. Operating as the K2 mission, the spacecraft's observations will allow astronomers to refine the properties of the known planets, as well as search for additional planets in the system. The K2 observations conclude in early March and will be made available on the public archive.

Spitzer, Hubble, and Kepler will help astronomers plan for follow-up studies using NASA's upcoming James Webb Space Telescope, launching in 2018. With much greater sensitivity, Webb will be able to detect the chemical fingerprints of water, methane, oxygen, ozone, and other components of a planet's atmosphere. Webb also will analyze planets' temperatures and surface pressures – key factors in assessing their habitability.

NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate. Science operations are conducted at the Spitzer Science Center, at Caltech, in Pasadena, California. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at Caltech/IPAC. Caltech manages JPL for NASA.

For more information about Spitzer, visit: https://www.nasa.gov/spitzer

For more information on the TRAPPIST-1 system, visit: https://exoplanets.nasa.gov/trappist1

For more information on exoplanets, visit: https://www.nasa.gov/exoplanets

Contacts:

Felicia Chou / Sean PotterHeadquarters, Washington202-358-1726 / 202-358-1536felicia.chou@nasa.gov / sean.potter@nasa.gov

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

In May 2024, a geomagnetic storm hit Earth, sending auroras across the planet's skies in a once-in-a-generation light display. These dazzling sights are possible because of the interaction of coronal mass ejections – explosions of plasma and magnetic field from the Sun – with Earth's magnetic field, which protects us from the radiation the Sun […]

Hubble Space Telescope

Exoplanets

Exoplanet Stories

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanet astronomer searches for a brighter future

4 min read

NASA Science Editorial Team

By Pat Brennan,NASA's Exoplanet Exploration Program

Johnson is a professor of astronomy at the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts

The detection and characterization of planets orbiting other stars is one of today’s most active fields of astronomy, and John Asher Johnson, 40, is among that field’s brightest lights. Using some of the world’s most powerful telescopes, Johnson and his research group detect and observe extrasolar planets, gather data, and design and build instruments used in the hunt for worlds beyond our solar system.

His ultimate goal: a predictive model of planet formation, from swirling dust and gas to planetesimals to fully formed planets.

Johnson also is deeply involved in efforts to increase the representation of African Americans, and other under-represented groups, in the astronomical sciences. To that end, he created the Banneker Institute at Harvard. With its partner, the Aztlán Institute, Banneker conducts 10-week summer programs to prepare talented undergraduates for top graduate programs in astronomy.

Any surprises in your recent research, or with exoplanets in general?

I think the reason to be truly surprised is when you have hard data, that nature should work in some way, and you discover it doesn’t always do that. In the early days of planet detection, we didn’t have any hard data, other than our solar system. People erroneously assumed (other) planetary systems would look like our own. The very first detection, 51 Pegasi, completely threw that notion out.

Every class of planets could be considered a surprise if you’re expecting something to look like our solar system. Nothing does. In that sense, we’re still in a state of constantly being surprised.

How would a “predictive model” of planet formation help in the search for life among the stars?

If we had a completely predictive model for planet formation, we could look at the side effects of the formation process. We could look at water delivery to rocky planets, or the frequency of planets with rocky surfaces and thin atmospheres in the habitable zones of other stars. If we had that model, I think understanding the formation of life, and the precursors of life, would be a really nice secondary effect.

What are some of your biggest discoveries?

Some of the discoveries I’m most proud of– we’ve found a number of really compact systems, small, rocky planets around M-dwarf stars. We had the record-holder for a little while, Kepler-42, KOI 961. That was a Mars-size planet, along with some Earth-size planets. All the planets had an orbital period of less than two days. My group is responsible for what is known about the “Kepler dichotomy.” It reveals that planetary systems either come in nice, neat, circular, co-planar orbits (orbiting in the same plane)– like our solar system, but scaled down– or are in systems with the planets misaligned with respect to one another, misaligned with respect to their stars, in highly eccentric orbits. Some formed in neat, orderly ways, some formed in catastrophic, disorderly ways, or were thrown into disarray at some point in their lives.

Most recently, I was part of a team that found a disintegrating asteroid-size body around a white dwarf star.

How is the astrophysics community doing in terms of inclusion of African-American scientists, and other minorities?

Frankly, we're doing a really horrible job. You can believe that all people are created equal, or you can believe in a meritocracy, but you can't look at the under-representation of people of color and have both be true. Fewer than 1 percent of astronomers are black. We have an order of magnitude to go.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

The Engineer Building a Smaller Telescope to the Stars

4 min read

Pat Brennan

Cube satellites, or CubeSats, might be tiny, but they pack in outsized capabilities. A CubeSat called ASTERIA, smaller than a briefcase, is now being assembled at NASA's Jet Propulsion Laboratory. Launch is expected in the summer of 2017, when ASTERIA will demonstrate observational powers more often seen in its larger brethren– including technologies that could lead to the detection of star-crossing exoplanets.

Whether all goes according to plan is largely in the hands of Matthew W. Smith, 32, project system engineer and technical lead for the mission. Smith took a moment recently to reflect on his scientific role, his areas of interest, and the progress made so far in swelling the ranks of under-represented groups in science and engineering fields.

What is your main job at the moment?

I am currently the project system engineer on a small space telescope called ASTERIA. In that role, I'm the chief engineer of the project and the technical lead for the team. My job is to make sure that the design and implementation fulfill the goals of the mission– to demonstrate technologies that may someday help us find exoplanets using small satellites like CubeSats. We're now in the phase of building the spacecraft and testing the instrument, to make sure it's working properly and will give us the performance we want in space.

Are exoplanets one of your big scientific interests?

I've been interested in exoplanets since I was an undergraduate, and especially in the telescopes and instruments used to find exoplanets. My master's research was on large, segmented telescopes for space use– which have numerous applications, including finding exoplanets. My Ph.D. thesis was related to systems engineering and how to optimize scientific instrumentation. At JPL, I've worked on ground-based instruments for exoplanet detection (such as the Gemini Planet Imager), and proposed space-based missions including Terrestrial Planet Finder and the Space Interferometry Mission. Just prior to ASTERIA, I worked on developing technology for a space-based coronagraph, which is an instrument contained within a telescope that blocks out a star's light so its planets can be seen.

I think this is some of the most interesting work out there, both from a scientific and engineering standpoint. Working on exoplanets raises very fundamental questions about the potential for life elsewhere in the universe, and how to find it. The holy grail of exoplanet research is to find a true Earth analog. That is what we're pushing towards. However in my daily role I'm less of a scientist and more of an engineer, working on the technical challenges needed to do the exciting things I just mentioned. There is a constant push and pull between science and engineering, and that is one of the most interesting aspects of my work.

Do minorities and women have a strong presence in science and engineering, or do we have work to do?

I think JPL is a very diverse and welcoming place that thrives on diversity. And JPL recognizes that diversity often can make teams better– not just diversity for the sake of diversity, but that it adds value by introducing multiple perspectives. NASA as a whole is an agency that embraces diversity as well. But yes, in the national sense, obviously there is still lots of work to do in terms of women and minorities in science. I think there is an awareness now that, yeah, we have a problem with diversity in the sciences; it’s something that definitely needs to be addressed. People are kind of marching toward that goal, whereas maybe that wasn’t always a recognized problem. I think also social media has helped increase outreach in the STEM fields, and is, I hope, showing younger generations from all backgrounds that a career in science or engineering is possible.

In May 2024, a geomagnetic storm hit Earth, sending auroras across the planet’s skies in a once-in-a-generation light display. These dazzling sights are possible because of the interaction of coronal mass ejections – explosions of plasma and magnetic field from the Sun – with Earth’s magnetic field, which protects us from the radiation the Sun […]

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Earth-sized planets: The newest, weirdest generation

9 min read

Alicia Cermak

A bumper crop of Earth-size planets huddled around an ultra-cool, red dwarf star could be little more than chunks of rock blasted by radiation, or cloud-covered worlds as broiling hot as Venus.

Or they could harbor exotic lifeforms, thriving under skies of ruddy twilight.

Scientists are pondering the possibilities after this week's announcement: the discovery of seven worlds orbiting a small, cool star some 40 light-years away, all of them in the ballpark of our home planet in terms of their heft (mass) and size (diameter). Three of the planets reside in the "habitable zone" around their star, TRAPPIST-1, where calculations suggest that conditions might be right for liquid water to exist on their surfaces—though follow-up observations are needed to be sure.

All seven are early ambassadors of a new generation of planet-hunting targets.

Red dwarf stars—also called "M-dwarfs"—outnumber others, including yellow stars like our sun, by a factor of three to one, comprising nearly 75 percent of the stars in our galaxy. They also last far longer. And their planets are proportionally larger compared to the small stars they orbit. That means small, rocky worlds orbiting the nearest red dwarfs will be primary targets for new, powerful telescopes coming online in the years ahead, both in space and on the ground.

"The majority of stars are M-dwarfs, which are faint and small and not very luminous," said Martin Still, program scientist at NASA headquarters in Washington, D.C. "So the majority of places where you would look for planets are around these cool, small stars. We are interested in the nearest stars, and the nearest stars are mostly M-dwarfs."

But these are sure to be perplexing planets, with strange properties that must be teased out by careful observation as well as computer simulations. Finding out whether they can support some form of life, and what kind, likely will keep astrobiologists working overtime, perhaps attempting to recreate in the laboratory some of the conditions on these red-tinged worlds.

"We're definitely all working overtime now," said Nancy Kiang, an astrobiologist at NASA's Goddard Institute for Space Studies in New York City.

Expert opinion on whether red dwarf planets are suitable for life tends to tick back and forth, "like a pendulum," said Shawn Domagal-Goldman, a research space scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

"We've come up with these theoretical reasons why such a planet might struggle to be habitable," he said. "Then we look at those theoretical concerns with a little bit more detail, and find out it's not that big of a concern. Then some other theoretical concern crops up."

At the moment, the pendulum is ticking back toward lifelessness. Recent findings suggest life would have an uphill battle on a planet close to a red dwarf, largely because such stars are extremely active in their early years—shooting off potentially lethal flares and bursts of radiation.

TRAPPIST-1d is one of seven Earth-sized planets in the TRAPPIST-1 system, and one of three in the habitable zone. About 40 light-years from Earth, TRAPPIST-1 is a red dwarf star or M dwarf. While this third planet is at a distance from its star suitable for liquid water, it orbits close enough to its star to endure potentially life-harming solar flares. In this artist's illustration, the rocky planet is shown with water in a thin band along the terminator, dividing the day side and night side.

These youthful tantrums would go on for quite some time. Red dwarfs smolder at much lower energy than our sun, but live much longer, perhaps with lifespans in the trillions of years—longer than the present age of the universe. Our sun is expected to burn out after shining for something on the order of 10 billion years; we're about halfway through its lifespan.

The exact age of the TRAPPIST-1 star is unknown, but scientists believe it is at least 500 million years old, or about one-tenth the age of our 4.5-billion-year-old sun.

Red dwarfs could take their first billion years just to calm down enough to allow any nearby planets to be habitable. And the "habitable zone" around such stars is very close indeed. All seven of the Earth-size planets crowd so close to their star that they complete a single orbit—their "year"—in a matter of days, 1.5 days for the nearest planet and 20 days for the farthest.

That kind of proximity means the planets are probably tidally locked, with one face always turned to the star, the same way our moon presents only one face to Earth. And while red dwarfs are "cool" compared to our sun, they would loom large in the sky of a close, tidally locked planet, perhaps baking the sunward face. The far side, meanwhile, could be trapped in an eternal, frozen night.

The right kind of atmosphere could mitigate such effects, transporting heat to the planet's far side and helping to moderate the climate overall.

A recent study that relied on computer simulations of red dwarf planets, however, delivered more grim news. The flaring tempers of young red dwarfs, with their bursts of high-energy X-rays and ultraviolet emissions, could actually strip oxygen from the atmospheres of nearby planets, according to the study by a team at NASA Goddard led by Vladimir Airapetian.

Other scenarios involve stripping away the atmosphere altogether.

Yet another potentially sterilizing effect, even for M-dwarf planets that manage to hold on to their atmospheres, would result from high-energy radiation triggering a runaway greenhouse effect, Domagal-Goldman said.

"Maybe you would end up in a stable climate that's too hot to support life," he said.

But so little is known about how life gets its start, and how common or rare it might be in the cosmos, that tenacious life on M-dwarf planets remains a distinct possibility.

Although loss of atmosphere from early stellar flaring is a legitimate concern, it is based on complex computer modeling, said Franck Selsis of the University of Bordeaux, one of the authors of the TRAPPIST-1 paper.

Since computer models contain certain assumptions about stars and planets, they may not be complete, Selsis wrote in an e-mail. Models might fail to account for effects from the star on planetary atmospheres that could create a protective magnetic field. Or they might produce atmospheric loss rates so high they are physically implausible.

As for TRAPPIST-1, "The current relative quietness of the star and plausible sources of atmospheric replenishment still make possible for the planets to have atmospheres and surface habitable conditions," said Michaël Gillon, principal investigator of TRAPPIST at the University of Liège, Belgium. "Our only way to go beyond these theoretical speculations is to try detecting and studying thoroughly their atmospheres."

Other scientists also offered possible scenarios on the optimistic side of the M-dwarf habitability equation.

“Maybe the atmosphere can recover, and it’s just fine,” said Tom Barclay, a senior research scientist at the NASA Ames Research Center in Moffett Field, California. Barclay worked on the most prolific planet-finder, NASA’s Kepler space telescope, during both its original mission and its second incarnation, known as K2.

In Barclay’s scenario, lifeforms find a way to adapt to bursts of stellar radiation.

“You have regular events, but life is used to this,” Barclay said. “It just deals with it. We certainly see life on Earth capable of hibernating for very extended periods of time. We see that life goes into a state where it shuts down, sometimes for years or decades. So I think we shouldn’t, probably, rule it out, but we should put a lot of effort into studying whether this is a place where we think life could thrive.”

Future telescopes, including NASA’s James Webb Space Telescope (JWST), to be launched in 2018, could help resolve such questions by closely analyzing the atmospheric gases of the TRAPPIST-1 planets. If one of these instruments were to discover water vapor and, say, a combination of oxygen and methane, it could be a strong indication of a potential life-bearing world.

The Hubble Space Telescope also will be a key player in characterizing the atmospheres of the TRAPPIST-1 planets and has, in fact, already begun a preliminary survey. Both space telescopes are equipped to capture the spectrum of light from the planets, revealing the types of gases that are present.

“We will look at atmospheres effectively in different wavelengths, allowing us to get the composition, temperature, pressure,” said Julien de Wit, a postdoctoral researcher at the Massachusetts Institute of Technology and an author of the new TRAPPIST-1 paper. “This will allow us to constrain habitability.”

Besides, stellar flaring might not be all bad—that is, if M-dwarf planets have a bit of well-timed luck.

“They might start out with dense hydrogen envelopes that get blasted off,” said Victoria Meadows of the University of Washington, the principal investigator for the NASA Astrobiology Institute’s Virtual Planetary Laboratory. “So it’s kind of like a protective skin on the planet.”

The stellar radiation would remove the hydrogen, leaving a potentially habitable world behind.

The planets also might form farther away from the star, moving closer over time.

“They could migrate in from outside, further out in the planetary system, where there is more water, cooler temperatures,” she said. “That would give them more protection against water loss. There are a whole bunch of options.”

Modeling shows, in fact, that densely packed M-dwarf planetary systems—similar to the TRAPPIST-1 system—are more likely to form farther away, then migrate inward, because the inner solar system would lack enough material to form so many planets.

In any case, if such planets possess life at all, simple lifeforms appear to be more likely.

“I’m just talking about slime here,” Meadows said. “It’s far easier to evolve than sentient beings. The majority of life we find out there is likely to be single cell, relatively primitive life. That’s the sort of thing we’d be looking for on planets orbiting these M-dwarfs.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Spitzer Hears Stellar ‘Heartbeat’ From Planetary Companion

4 min read

NASA Science Editorial Team

A planet and a star are having a tumultuous romance that can be detected from 370 light-years away.

NASA's Spitzer Space Telescope, now retired, detected unusual pulsations in the outer shell of a star called HAT-P-2. Scientists' best guess is that a closely orbiting planet, called HAT-P-2b, causes these vibrations each time it gets close to the star in its orbit.

"Just in time for Valentine's Day, we have discovered the first example of a planet that seems to be causing a heartbeat-like behavior in its host star," said Julien de Wit, postdoctoral associate at the Massachusetts Institute of Technology, Cambridge. A study describing the findings was published today in Astrophysical Journal Letters.

The star's pulsations are the most subtle variations of light from any source that Spitzer has ever measured. A similar effect had been observed in binary systems called "heartbeat stars" in the past, but never before between a star and a planet.

Weighing in at about eight times the mass of Jupiter, HAT-P-2b is a relatively massive planet. It's a "hot Jupiter," meaning an exoplanet that is extremely warm and orbits its star tightly. But this hot Jupiter is tiny in relation to its host star, which is about 100 times more massive. That size difference makes the pulsation effect all the more unusual (For comparison, our sun is about 1,000 times more massive than Jupiter).

"It's remarkable that this relatively small planet seems to affect the whole star in a way that we can see from far away," said Heather Knutson, assistant professor of geological and planetary sciences at Caltech in Pasadena, California.

Known to the exoplanet community since 2007, HAT-P-2b was initially interesting to astronomers because of its "eccentric," or elliptical orbit. The planet spends most of its time relatively far from the star, but comes around for a close encounter every 5.6 days. Those are indeed hot dates for this planet, as it receives as much as 10 times the amount of light per unit area at closest approach than at its farthest point in the orbit.

Each time the planet swings around for that close approach, it appears to gives its star a little "kiss" as the gravitational forces of these two bodies interact. The star, in turn, beats like a heart as the planet travels around in its orbit again. For a less lovey-dovey analogy: The planet's gravity hits the star like a bell on closest approach, making it ring throughout the planet's orbit.

"We had intended the observations to provide a detailed look at HAT-P-2b’s atmospheric circulation," said Nikole Lewis, co-author and astronomer at Space Telescope Science Institute, Baltimore. "The discovery of the oscillations was unexpected but adds another piece to the puzzle of how this system evolved."

Spitzer watched the planet-star interactions from the vantage point of our own solar system, in the telescope's Earth-trailing orbit around the sun, for about 350 hours between July 2011 and November 2015. Because of the system's alignment with respect to Earth, Spitzer was able to observe the planet cross directly in front of the star (in a process called a "transit") as well as behind it (called a "secondary eclipse"). These eclipses of the planet allowed scientists to determine that the pulsations originate from the star, not the planet. The point of closest approach occurs between the transit and secondary eclipse.

The planetary system still has scientists stumped. Calculations by co-author Jim Fuller, Caltech postdoctoral scholar, predicted that the pitter-patter of the star's vibrations should be quieter and at a lower frequency than what Spitzer found.

"Our observations suggest that our understanding of planet-star interactions is incomplete," said de Wit. "There's more to learn from studying stars in systems like this one and listening for the stories they tell through their 'heartbeats.'"

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena, California. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

For more information about Spitzer, please visit:

http://spitzer.caltech.edu

http://www.nasa.gov/spitzer

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

NASA-funded Website Lets Public Search for New Nearby Worlds

5 min read

NASA is inviting the public to help search for possible undiscovered worlds in the outer reaches of our solar system and in neighboring interstellar space. A new website, called Backyard Worlds: Planet 9, lets everyone participate in the search by viewing brief movies made from images captured by NASA's Wide-field Infrared Survey Explorer (WISE) mission. The movies highlight objects that have gradually moved across the sky.

"There are just over four light-years between Neptune and Proxima Centauri, the nearest star, and much of this vast territory is unexplored," said lead researcher Marc Kuchner, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "Because there's so little sunlight, even large objects in that region barely shine in visible light. But by looking in the infrared, WISE may have imaged objects we otherwise would have missed."

WISE scanned the entire sky between 2010 and 2011, producing the most comprehensive survey at mid-infrared wavelengths currently available. With the completion of its primary mission, WISE was shut down in 2011. It was then reactivated in 2013 and given a new mission assisting NASA's efforts to identify potentially hazardous near-Earth objects (NEOs), which are asteroids and comets on orbits that bring them into the vicinity of Earth's orbit. The mission was renamed the Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE).

The new website uses the data to search for unknown objects in and beyond our own solar system. In 2016, astronomers at Caltech in Pasadena, California, showed that several distant solar system objects possessed orbital features indicating they were affected by the gravity of an as-yet-undetected planet, which the researchers nicknamed "Planet Nine." If Planet Nine — also known as Planet X — exists and is as bright as some predictions, it could show up in WISE data.

The search also may discover more distant objects like brown dwarfs, sometimes called failed stars, in nearby interstellar space.

"Brown dwarfs form like stars but evolve like planets, and the coldest ones are much like Jupiter," said team member Jackie Faherty, an astronomer at the American Museum of Natural History in New York. "By using Backyard Worlds: Planet 9, the public can help us discover more of these strange rogue worlds."

Unlike more distant objects, those in or closer to the solar system appear to move across the sky at different rates. The best way to discover them is through a systematic search of moving objects in WISE images. While parts of this search can be done by computers, machines are often overwhelmed by image artifacts, especially in crowded parts of the sky. These include brightness spikes associated with star images and blurry blobs caused by light scattered inside WISE's instruments.

Backyard Worlds: Planet 9 relies on human eyes because we easily recognize the important moving objects while ignoring the artifacts. It's a 21st-century version of the technique astronomer Clyde Tombaugh used to find Pluto in 1930, a discovery made 87 years ago this week.

On the website, people around the world can work their way through millions of "flipbooks," which are brief animations showing how small patches of the sky changed over several years. Moving objects flagged by participants will be prioritized by the science team for follow-up observations by professional astronomers. Participants will share credit for their discoveries in any scientific publications that result from the project.

“Backyard Worlds: Planet 9 has the potential to unlock once-in-a-century discoveries, and it’s exciting to think they could be spotted first by a citizen scientist,” said team member Aaron Meisner, a postdoctoral researcher at the University of California, Berkeley, who specializes in analyzing WISE images.

Backyard Worlds: Planet 9 is a collaboration between NASA, UC Berkeley, the American Museum of Natural History in New York, Arizona State University, the Space Telescope Science Institute in Baltimore, and Zooniverse, a collaboration of scientists, software developers and educators who collectively develop and manage citizen science projects on the internet.

NASA’s Jet Propulsion Laboratory in Pasadena, California, manages and operates WISE for NASA’s Science Mission Directorate. The WISE mission was selected competitively under NASA’s Explorers Program managed by the agency’s Goddard Space Flight Center. The science instrument was built by the Space Dynamics Laboratory in Logan, Utah. The spacecraft was built by Ball Aerospace & Technologies Corp. in Boulder, Colorado. Science operations and data processing take place at the Infrared Processing and Analysis Center at Caltech, which manages JPL for NASA.

For more information about Backyard Worlds: Planet 9, visit: http://backyardworlds.org

For more information about NASA’s WISE mission, visit: https://www.nasa.gov/wise

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

JPL rolls out the red carpet for ‘Baby Kepler’

2 min read

Alicia Cermak

Baby Kepler fixed a wide-eyed gaze on the stream of data flowing down from space—a display, part sculpture and part computer readout, in the lobby of the NASA Jet Propulsion Laboratory’s administration building.

Just shy of his first birthday, Kepler—along with his parents, Christine and Jerin Cloutier—had been invited on a tour of JPL by Exoplanet Exploration Program Manager Gary Blackwood. The Cloutiers ran into Blackwood during Astronomy Week in Pasadena in October, and Blackwood was delighted: The Cloutiers said they named their little boy, stylish in his own tiny spacesuit, after both the Kepler Space Telescope and the 17th century astronomer, Johannes Kepler. They spoke of their love for exoplanets.

Three months later, Baby Kepler took his grand (stroller) tour of the lab, hardly fussing during the entire two-hour visit. His father thought the highlight was a personal tour of JPL Mission Control, courtesy of Flight Operations Engineer James McClure.

The Cloutiers, who live in Glendale, also stopped by the von Karman Museum and the Exoplanet Exploration Office, where they met several exoplanet scientists. Kepler’s face lit up when he was placed on the floor amid a crowd of “Celestial Buddies,” plush, personified toys that look like the planets of the solar system. Blackwood and Steve Howell, the former Kepler Space Telescope project scientist who was on hand for the occasion, posed for photos with young Kepler and his buddies. He received his own “Mars” buddy as a parting gift.

But for his mother, Christine, the highlight was watching Kepler’s face as he stared at the data sculpture in the administration building lobby. Signals beaming down from space probes scattered across the solar system are translated, in near-real time, to streams of light raining down through metal rods into the floor of the display; signals from Mission Control back to the space probes are shown as light flowing up through the rods toward the heavens. It’s mesmerizing, even for adults.

Kepler and his parents made a number of new friends that day. And they made a bit of a splash at JPL.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Team Looks to Ancient Earth First to Study Hazy Exoplanets

5 min read

For astronomers trying to understand which distant planets might have habitable conditions, the role of atmospheric haze has been hazy. To help sort it out, a team of researchers has been looking to Earth – specifically Earth during the Archean era, an epic 1-1/2-billion-year period early in our planet's history.

Earth's atmosphere seems to have been quite different then, probably with little available oxygen but high levels of methane, ammonia and other organic chemicals. Geological evidence suggests that haze might have come and gone sporadically from the Archean atmosphere – and researchers aren't quite sure why. The team reasoned that a better understanding of haze formation during the Archean era might help inform studies of hazy earthlike exoplanets.

"We like to say that Archean Earth is the most alien planet we have geochemical data for," said Giada Arney of NASA's Goddard Spaceflight Center in Greenbelt, Maryland, and a member of the NASA Astrobiology Institute's Virtual Planetary Laboratory based at the University of Washington, Seattle. Arney is the lead author of two related papers published by the team.

In the best case, haze in a planet's atmosphere could serve up a smorgasbord of carbon-rich, or organic, molecules that could be transformed by chemical reactions into precursor molecules for life. Haze also might screen out much of the harmful UV radiation that can break down DNA.

In the worst case, haze could become so thick that very little light gets through. In this situation, the surface might get so cold it freezes completely. If a very thick haze occurred on Archean Earth, it might have had a profound effect, because when the era began roughly four billion years ago, the sun was fainter, emitting perhaps 80 percent of the light that it does now.

Arney and her colleagues put together sophisticated computer modeling to look at how haze affected the surface temperature of Archean Earth and, in turn, how the temperature influenced the chemistry in the atmosphere.

The new modeling indicates that as the haze got thicker, less sunlight would have gotten through, inhibiting the types of sunlight-driven chemical reactions needed to form more haze. This would lead to the shutdown of haze-formation chemistry, preventing the planet from undergoing runaway glaciation due to a very thick haze.

The team calls this self-limiting haze, and their work is the first to make the case that this is what occurred on Archean Earth – a finding published in the November 2016 issue of the journal Astrobiology. The researchers concluded that self-limiting haze could have cooled Archean Earth by about 36 degrees Fahrenheit (20 Kelvins) – enough to make a difference but not to freeze the surface completely.

"Our modeling suggests that a planet like hazy Archean Earth orbiting a star like the young sun would be cold," said Shawn Domagal-Goldman, a Goddard scientist and a member of the Virtual Planetary Laboratory. "But we're saying it would be cold like the Yukon in winter, not cold like modern-day Mars."

Such a planet might be considered habitable, even if the mean global temperature is below freezing, as long as there is some liquid water on the surface.

In subsequent modeling, Arney and her colleagues looked at the effects of haze on planets that are like Archean Earth but orbiting several kinds of stars.

“The parent star controls whether a haze is more likely to form, and that haze can have multiple impacts on a planet’s habitability,” said co-author Victoria Meadows, the principal investigator for the Virtual Planetary Laboratory and an astronomy professor at the University of Washington.

It looks as if the Archean Earth hit a sweet spot where the haze served as a sunscreen layer for the planet. If the sun had been a bit warmer, as it is today, the modeling suggests the haze particles would have been larger – a result of temperature feedbacks influencing the chemistry – and would have formed more efficiently, but still would have offered some sun protection.

The same wasn’t true in all cases. The modeling showed that some stars produce so much UV radiation that haze cannot form. Haze did not cool planets orbiting all types of stars equally, either, according to the team’s results. Dim stars, such as M dwarfs, emit most of their energy at wavelengths that pass right through atmospheric haze; in the simulations, these planets experience little cooling from haze, so they benefit from haze’s UV shielding without a major drop in temperature.

For the right kind of star, though, the presence of haze in a planet’s atmosphere could help flag that world as a good candidate for closer study. The team’s simulations indicated that, for some instruments planned for future space telescopes, the spectral signature of haze would appear stronger than the signatures for some atmospheric gases, such as methane. These findings are available in the Astrophysical Journal as of Feb. 8, 2017.

“Haze may turn out to be very helpful as we try to narrow down which exoplanets are the most promising for habitability,” said Arney.

For more information about the NASA Astrobiology Institute, visit https://nai.nasa.gov/

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Scientists Make Huge Dataset of Nearby Stars Available to Public

5 min read

NASA Science Editorial Team

The search for planets beyond our solar system is about to gain some new recruits.

Today, a team that includes MIT and is led by the Carnegie Institution for Science has released the largest collection of observations made with a technique called radial velocity, to be used for hunting exoplanets. The huge dataset, taken over two decades by the W.M. Keck Observatory in Hawaii, is now available to the public, along with an open-source software package to process the data and an online tutorial.

By making the data public and user-friendly, the scientists hope to draw fresh eyes to the observations, which encompass almost 61,000 measurements of more than 1,600 nearby stars.

“This is an amazing catalog, and we realized there just aren’t enough of us on the team to be doing as much science as could come out of this dataset,” says Jennifer Burt, a Torres Postdoctoral Fellow in MIT’s Kavli Institute for Astrophysics and Space Research. “We’re trying to shift toward a more community-oriented idea of how we should do science, so that others can access the data and see something interesting.”

Burt and her colleagues have outlined some details of the newly available dataset in a paper to appear in The Astronomical Journal. After taking a look through the data themselves, the researchers have detected over 100 potential exoplanets, including one orbiting GJ 411, the fourth-closest star to our solar system.

“There seems to be no shortage of exoplanets,” Burt says. “There are a ton of them out there, and there is ton of science to be done.”

The newly available observations were taken by the High Resolution Echelle Spectrometer (HIRES), an instrument mounted on the Keck Observatory’s 10-meter telescope at Mauna Kea in Hawaii. HIRES is designed to split a star’s incoming light into a rainbow of color components. Scientists can then measure the precise intensity of thousands of color channels, or wavelengths, to determine characteristics of the starlight.

Early on, scientists found they could use HIRES’ output to estimate a star’s radial velocity — the very tiny movements a star makes either as a result of its own internal processes or in response to some other, external force. In particular, scientists have found that when a star moves toward and away from Earth in a regular pattern, it can signal the presence of an exoplanet orbiting the star. The planet’s gravity tugs on the star, changing the star’s velocity as the planet moves through its orbit.

“[HIRES] wasn’t specifically optimized to look for exoplanets,” Burt says. “It was designed to look at faint galaxies and quasars. However, even before HIRES was installed, our team worked out a technique for making HIRES an effective exoplanet hunter.”

For two decades, these scientists have pointed HIRES at more than 1,600 “neighborhood” stars, all within a relatively close 100 parsecs, or 325 light years, from Earth. The instrument has recorded almost 61,000 observations, each lasting anywhere from 30 seconds to 20 minutes, depending on how precise the measurements needed to be. With all these data compiled, any given star in the dataset can have several days’, years’, ore even more than a decade’s worth of observations.

“We recently discovered a six-planet system orbiting a star, which is a big number,” Burt says. “We don’t often detect systems with more than three to four planets, but we could successfully map out all six in this system because we had over 18 years of data on the host star.”

Within the newly available dataset, the team has highlighted over 100 stars that are likely to host exoplanets but require closer inspection, either with additional measurements or further analysis of the existing data.

The researchers have, however, confirmed the presence of an exoplanet around GJ 411, which is the fourth-closest star to our solar system and has a mass that is roughly 40 percent that of our sun. The planet has an extremely tight orbit, circling the star in less than 10 days. Burt says that there is a good chance that others, looking through the dataset and combining it with their own observations, may find similarly intriguing candidates.

“We’ve gone from the early days of thinking maybe there are five or 10 other planets out there, to realizing almost every star next to us might have a planet,” Burt says.

HIRES will continue to record observations of nearby stars in the coming years, and the team plans to periodically update the public dataset with those observations.

“This dataset will slowly grow, and you’ll be able to go on and search for whatever star you’re interested in and download all the data we’ve ever taken on it. The dataset includes the date, the velocity we measured, the error on that velocity, and measurements of the star’s activity during that observation,” Burt says. “Nowadays, with access to public analysis software like Systemic, it’s easy to load the data in and start playing with it.”

Then, Burt says, the hunt for exoplanets can really take off.

“I think this opens up possibilities for anyone who wants to do this kind of work, whether you’re an academic or someone in the general public who’s excited about exoplanets,” Burt says. “Because really, who doesn’t want to discover a planet?”

This research was supported, in part, by the National Science Foundation.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Finds Planets of Red Dwarf Stars May Face Oxygen Loss in Habitable Zones

7 min read

The search for life beyond Earth starts in habitable zones, the regions around stars where conditions could potentially allow liquid water – which is essential for life as we know it – to pool on a planet's surface. New NASA research suggests some of these zones might not actually be able to support life due to frequent stellar eruptions – which spew huge amounts of stellar material and radiation out into space – from young red dwarf stars.

Now, an interdisciplinary team of NASA scientists wants to expand how habitable zones are defined, taking into account the impact of stellar activity, which can threaten an exoplanet's atmosphere with oxygen loss. This research was published in The Astrophysical Journal Letters on Feb. 6, 2017.

"If we want to find an exoplanet that can develop and sustain life, we must figure out which stars make the best parents," said Vladimir Airapetian, lead author of the paper and a solar scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "We're coming closer to understanding what kind of parent stars we need."

To determine a star's habitable zone, scientists have traditionally considered how much heat and light the star emits. Stars more massive than our sun produce more heat and light, so the habitable zone must be farther out. Smaller, cooler stars yield close-in habitable zones.

But along with heat and visible light, stars emit X-ray and ultraviolet radiation, and produce stellar eruptions such as flares and coronal mass ejections – collectively called space weather. One possible effect of this radiation is atmospheric erosion, in which high-energy particles drag atmospheric molecules – such as hydrogen and oxygen, the two ingredients for water – out into space. Airapetian and his team's new model for habitable zones now takes this effect into account.

The search for habitable planets often hones in on red dwarfs, as these are the coolest, smallest and most numerous stars in the universe – and therefore relatively amenable to small planet detection.

"On the downside, red dwarfs are also prone to more frequent and powerful stellar eruptions than the sun," said William Danchi, a Goddard astronomer and co-author of the paper. "To assess the habitability of planets around these stars, we need to understand how these various effects balance out."

Another important habitability factor is a star's age, say the scientists, based on observations they've gathered from NASA's Kepler mission. Every day, young stars produce superflares, powerful flares and eruptions at least 10 times more powerful than those observed on the sun. On their older, matured counterparts resembling our middle-aged sun today, such superflares are only observed once every 100 years.

"When we look at young red dwarfs in our galaxy, we see they're much less luminous than our sun today," Airapetian said. "By the classical definition, the habitable zone around red dwarfs must be 10 to 20 times closer-in than Earth is to the sun. Now we know these red dwarf stars generate a lot of X-ray and extreme ultraviolet emissions at the habitable zones of exoplanets through frequent flares and stellar storms."

Superflares cause atmospheric erosion when high-energy X-ray and extreme ultraviolet emissions first break molecules into atoms and then ionize atmospheric gases. During ionization, radiation strikes the atoms and knocks off electrons. Electrons are much lighter than the newly formed ions, so they escape gravity's pull far more readily and race out into space.

Opposites attract, so as more and more negatively charged electrons are generated, they create a powerful charge separation that lures positively charged ions out of the atmosphere in a process called ion escape.

"We know oxygen ion escape happens on Earth at a smaller scale since the sun exhibits only a fraction of the activity of younger stars," said Alex Glocer, a Goddard astrophysicist and co-author of the paper. "To see how this effect scales when you get more high-energy input like you'd see from young stars, we developed a model."

The model estimates the oxygen escape on planets around red dwarfs, assuming they don't compensate with volcanic activity or comet bombardment. Various earlier atmospheric erosion models indicated hydrogen is most vulnerable to ion escape. As the lightest element, hydrogen easily escapes into space, presumably leaving behind an atmosphere rich with heavier elements such as oxygen and nitrogen.

But when the scientists accounted for superflares, their new model indicates the violent storms of young red dwarfs generate enough high-energy radiation to enable the escape of even oxygen and nitrogen – building blocks for life's essential molecules.

"The more X-ray and extreme ultraviolet energy there is, the more electrons are generated and the stronger the ion escape effect becomes," Glocer said. "This effect is very sensitive to the amount of energy the star emits, which means it must play a strong role in determining what is and is not a habitable planet."

Considering oxygen escape alone, the model estimates a young red dwarf could render a close-in exoplanet uninhabitable within a few tens to a hundred million years. The loss of both atmospheric hydrogen and oxygen would reduce and eliminate the planet's water supply before life would have a chance to develop.

"The results of this work could have profound implications for the atmospheric chemistry of these worlds," said Shawn Domagal-Goldman, a Goddard space scientist not involved with the study. "The team's conclusions will impact our ongoing studies of missions that would search for signs of life in the chemical composition of those atmospheres."

Modeling the oxygen loss rate is the first step in the team's efforts to expand the classical definition of habitability into what they call space weather-affected habitable zones. When exoplanets orbit a mature star with a mild space weather environment, the classical definition is sufficient. When the host star exhibits X-ray and extreme ultraviolet levels greater than seven to 10 times the average emissions from our sun, then the new definition applies. The team's future work will include modeling nitrogen escape, which may be comparable to oxygen escape since nitrogen is just slightly lighter than oxygen.

The new habitability model has implications for the recently discovered planet orbiting the red dwarf Proxima Centauri, our nearest stellar neighbor. Airapetian and his team applied their model to the roughly Earth-sized planet, dubbed Proxima b, which orbits Proxima Centauri 20 times closer than Earth is to the sun.

Considering the host star's age and the planet's proximity to its host star, the scientists expect that Proxima b is subjected to torrents of X-ray and extreme ultraviolet radiation from superflares occurring roughly every two hours. They estimate oxygen would escape Proxima b's atmosphere in 10 million years. Additionally, intense magnetic activity and stellar wind – the continuous flow of charged particles from a star – exacerbate already harsh space weather conditions. The scientists concluded that it's quite unlikely Proxima b is habitable.

“We have pessimistic results for planets around young red dwarfs in this study, but we also have a better understanding of which stars have good prospects for habitability,” Airapetian said. “As we learn more about what we need from a host star, it seems more and more that our sun is just one of those perfect parent stars, to have supported life on Earth.”

Related:

By Lina TranNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planets of Red Dwarf Stars May Face Oxygen Loss in Habitable Zones

6 min read

NASA Science Editorial Team

The search for life beyond Earth starts in habitable zones, the regions around stars where conditions could potentially allow liquid water – which is essential for life as we know it – to pool on a planet's surface. New NASA research suggests some of these zones might not actually be able to support life due to frequent stellar eruptions – which spew huge amounts of stellar material and radiation out into space – from young red dwarf stars.

Now, an interdisciplinary team of NASA scientists wants to expand how habitable zones are defined, taking into account the impact of stellar activity, which can threaten an exoplanet's atmosphere with oxygen loss. This research was published in The Astrophysical Journal Letters on Feb. 6, 2017.

"If we want to find an exoplanet that can develop and sustain life, we must figure out which stars make the best parents," said Vladimir Airapetian, lead author of the paper and a solar scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. "We're coming closer to understanding what kind of parent stars we need."

To determine a star's habitable zone, scientists have traditionally considered how much heat and light the star emits. Stars more massive than our sun produce more heat and light, so the habitable zone must be farther out. Smaller, cooler stars yield close-in habitable zones.

But along with heat and visible light, stars emit X-ray and ultraviolet radiation, and produce stellar eruptions such as flares and coronal mass ejections – collectively called space weather. One possible effect of this radiation is atmospheric erosion, in which high-energy particles drag atmospheric molecules – such as hydrogen and oxygen, the two ingredients for water – out into space. Airapetian and his team's new model for habitable zones now takes this effect into account.

The search for habitable planets often hones in on red dwarfs, as these are the coolest, smallest and most numerous stars in the universe – and therefore relatively amenable to small planet detection.

"On the downside, red dwarfs are also prone to more frequent and powerful stellar eruptions than the sun," said William Danchi, a Goddard astronomer and co-author of the paper. "To assess the habitability of planets around these stars, we need to understand how these various effects balance out."

Another important habitability factor is a star's age, say the scientists, based on observations they've gathered from NASA's Kepler mission. Every day, young stars produce superflares, powerful flares and eruptions at least 10 times more powerful than those observed on the sun. On their older, matured counterparts resembling our middle-aged sun today, such superflares are only observed once every 100 years.

"When we look at young red dwarfs in our galaxy, we see they're much less luminous than our sun today," Airapetian said. "By the classical definition, the habitable zone around red dwarfs must be 10 to 20 times closer-in than Earth is to the sun. Now we know these red dwarf stars generate a lot of X-ray and extreme ultraviolet emissions at the habitable zones of exoplanets through frequent flares and stellar storms."

Superflares cause atmospheric erosion when high-energy X-ray and extreme ultraviolet emissions first break molecules into atoms and then ionize atmospheric gases. During ionization, radiation strikes the atoms and knocks off electrons. Electrons are much lighter than the newly formed ions, so they escape gravity's pull far more readily and race out into space.

Opposites attract, so as more and more negatively charged electrons are generated, they create a powerful charge separation that lures positively charged ions out of the atmosphere in a process called ion escape.

“We know oxygen ion escape happens on Earth at a smaller scale since the sun exhibits only a fraction of the activity of younger stars,” said Alex Glocer, a Goddard astrophysicist and co-author of the paper. “To see how this effect scales when you get more high-energy input like you'd see from young stars, we developed a model.”

The model estimates the oxygen escape on planets around red dwarfs, assuming they don't compensate with volcanic activity or comet bombardment. Various earlier atmospheric erosion models indicated hydrogen is most vulnerable to ion escape. As the lightest element, hydrogen easily escapes into space, presumably leaving behind an atmosphere rich with heavier elements such as oxygen and nitrogen.

But when the scientists accounted for superflares, their new model indicates the violent storms of young red dwarfs generate enough high-energy radiation to enable the escape of even oxygen and nitrogen – building blocks for life's essential molecules.

“The more X-ray and extreme ultraviolet energy there is, the more electrons are generated and the stronger the ion escape effect becomes,” Glocer said. “This effect is very sensitive to the amount of energy the star emits, which means it must play a strong role in determining what is and is not a habitable planet.”

Considering oxygen escape alone, the model estimates a young red dwarf could render a close-in exoplanet uninhabitable within a few tens to a hundred million years. The loss of both atmospheric hydrogen and oxygen would reduce and eliminate the planet's water supply before life would have a chance to develop.

“The results of this work could have profound implications for the atmospheric chemistry of these worlds,” said Shawn Domagal-Goldman, a Goddard space scientist not involved with the study. “The team's conclusions will impact our ongoing studies of missions that would search for signs of life in the chemical composition of those atmospheres.”

Modeling the oxygen loss rate is the first step in the team's efforts to expand the classical definition of habitability into what they call space weather-affected habitable zones. When exoplanets orbit a mature star with a mild space weather environment, the classical definition is sufficient. When the host star exhibits X-ray and extreme ultraviolet levels greater than seven to 10 times the average emissions from our sun, then the new definition applies. The team's future work will include modeling nitrogen escape, which may be comparable to oxygen escape since nitrogen is just slightly lighter than oxygen.

The new habitability model has implications for the recently discovered planet orbiting the red dwarf Proxima Centauri, our nearest stellar neighbor. Airapetian and his team applied their model to the roughly Earth-sized planet, dubbed Proxima b, which orbits Proxima Centauri 20 times closer than Earth is to the sun.

Considering the host star's age and the planet's proximity to its host star, the scientists expect that Proxima b is subjected to torrents of X-ray and extreme ultraviolet radiation from superflares occurring roughly every two hours. They estimate oxygen would escape Proxima b's atmosphere in 10 million years. Additionally, intense magnetic activity and stellar wind – the continuous flow of charged particles from a star – exacerbate already harsh space weather conditions. The scientists concluded that it’s quite unlikely Proxima b is habitable.

“We have pessimistic results for planets around young red dwarfs in this study, but we also have a better understanding of which stars have good prospects for habitability,” Airapetian said. “As we learn more about what we need from a host star, it seems more and more that our sun is just one of those perfect parent stars, to have supported life on Earth.”

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Mysterious white dwarf pulsar discovered

3 min read

NASA Science Editorial Team

◆ University of Warwick researchers identify a white dwarf pulsar – a star type which has eluded astronomers for half a century

◆ The star lashes its neighbor with intense radiation beam every two minutes

◆ The research is published in Nature Astronomy

An exotic binary star system 380 light-years away has been identified as an elusive white dwarf pulsar – the first of its kind ever to be discovered in the universe – thanks to research by the University of Warwick.

Professors Tom Marsh and Boris Gänsicke of the University of Warwick's Astrophysics Group, with Dr David Buckley from the South African Astronomical Observatory, have identified the star AR Scorpii (AR Sco) as the first white dwarf version of a pulsar - objects found in the 1960s and associated with very different objects called neutron stars.

The white dwarf pulsar has eluded astronomers for over half a century.

AR Sco contains a rapidly spinning, burnt-out stellar remnant called a white dwarf, which lashes its neighbour – a red dwarf - with powerful beams of electrical particles and radiation, causing the entire system to brighten and fade dramatically twice every two minutes.

The latest research establishes that the lash of energy from AR Sco is a focused 'beam', emitting concentrated radiation in a single direction – much like a particle accelerator – something which is totally unique in the known universe.

AR Sco lies in the constellation Scorpius, 380 light-years from Earth, a close neighbour in astronomical terms. The white dwarf in AR Sco is the size of Earth but 200,000 times more massive, and is in a 3.6 hour orbit with a cool star one third the mass of the sun.

With an electromagnetic field 100 million times more powerful than Earth, and spinning on a period just shy of two minutes, AR Sco produces lighthouse-like beams of radiation and particles, which lash across the face of the cool star, a red dwarf.

As the researchers previously discovered, this powerful light house effect accelerates electrons in the atmosphere of the red dwarf to close to the speed of light, an effect never observed before in similar types of binary stars. The red dwarf is thus powered by the kinetic energy of its spinning neighbour.

The distance between the two stars is around 1.4 million kilometres – which is three times the distance between the Moon and the Earth.

"The new data show that AR Sco's light is highly polarised, showing that the magnetic field controls the emission of the entire system, and a dead ringer for similar behaviour seen from the more traditional neutron star pulsars," said Tom Marsh.

"AR Sco is like a gigantic dynamo: a magnet, size of the Earth, with a field that is ~10.000 stronger than any field we can produce in a laboratory, and it is rotating every two minutes. This generates an enormous electric current in the companion star, which then produces the variations in the light we detect," said Boris Gänsicke.

The latest research, ‘Polarimetric evidence of a white dwarf pulsar in the binary system AR Scorpii’, is published in Nature Astronomy.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Captures ‘Shadow Play’ Caused by Possible Planet

6 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Searching for planets around other stars is a tricky business. They’re so small and faint that it’s hard to spot them. But a possible planet in a nearby stellar system may be betraying its presence in a unique way: by a shadow that is sweeping across the face of a vast pancake-shaped gas-and-dust disk surrounding a young star.

The planet itself is not casting the shadow. But it is doing some heavy lifting by gravitationally pulling on material near the star and warping the inner part of the disk. The twisted, misaligned inner disk is casting its shadow across the surface of the outer disk.

A team of astronomers led by John Debes of the Space Telescope Science Institute in Baltimore, Maryland say this scenario is the most plausible explanation for the shadow they spotted in the stellar system TW Hydrae, located 192 light-years away in the constellation Hydra, also known as the Female Water Snake. The star is roughly 8 million years old and slightly less massive than our sun. Debes’ team uncovered the phenomenon while analyzing 18 years’ worth of archival observations taken by NASA’s Hubble Space Telescope.

“This is the very first disk where we have so many images over such a long period of time, therefore allowing us to see this interesting effect,” Debes said. “That gives us hope that this shadow phenomenon may be fairly common in young stellar systems.”

Debes will present his team’s results Jan. 7 at the winter meeting of the American Astronomical Society in Grapevine, Texas.

Debes’ first clue to the phenomenon was a brightness in the disk that changed with position. Astronomers using Hubble’s Space Telescope Imaging Spectrograph (STIS) first noted this brightness asymmetry in 2005. But they had only one set of observations, and could not make a definitive determination about the nature of the mystery feature.

Searching the archive, Debes’ team put together six images from several different epochs. The observations were made by STIS and by the Hubble's Near Infrared Camera and Multi-Object Spectrometer (NICMOS).

STIS is equipped with a coronagraph that blocks starlight to within about 1 billion miles from the star, allowing Hubble to look as close to the star as Saturn is to our sun. Over time, the structure appeared to move in counter-clockwise fashion around the disk, until, in 2016, it was in the same position as it was in images taken in 2000.

This 16-year period puzzled Debes. He originally thought the feature was part of the disk, but the short period meant that the feature was moving way too fast to be physically in the disk. Under the laws of gravity, disks rotate at glacial speeds. The outermost parts of the TW Hydrae disk would take centuries to complete one rotation.

“The fact that I saw the same motion over 10 billion miles from the star was pretty significant, and told me that I was seeing something that was imprinted on the outer disk rather than something that was happening directly in the disk itself,” Debes said. “The best explanation is that the feature is a shadow moving across the surface of the disk."

Debes concluded that whatever was making the shadow must be deep inside the 41-billion-mile-wide disk, so close to the star it cannot be imaged by Hubble or any other present-day telescope.

The most likely way to create a shadow is to have an inner disk that is tilted relative to the outer disk. In fact, submillimeter observations of TW Hydrae by the Atacama Large Millimeter Array (ALMA) in Chile suggested a possible warp in the inner disk.

But what causes disks to warp? "The most plausible scenario is the gravitational influence of an unseen planet, which is pulling material out of the plane of the disk and twisting the inner disk," Debes explained. "The misaligned disk is inside the planet's orbit."

Given the relatively short 16-year period of the clocklike moving shadow, the planet is estimated to be about 100 million miles from the star—about as close as Earth is from the sun. The planet would be roughly the size of Jupiter to have enough gravity to pull the material up out of the plane of the main disk. The planet's gravitational pull causes the disk to wobble, or precess, around the star, giving the shadow its 16-year rotational period.

Recent observations of TW Hydrae by ALMA in Chile add credence to the presence of a planet. ALMA revealed a gap in the disk roughly 93 million miles from TW Hydrae. A gap is significant, because it could be the signature of an unseen planet clearing away a path in the disk.

This new Hubble study, however, offers a unique way to look for planets hiding in the inner part of the disk and probe what is happening very close to the star, which is not reachable in direct imaging by current telescopes. "What is surprising is that we can learn something about an unseen part of the disk by studying the disk's outer region and by measuring the motion, location, and behavior of a shadow," Debes said. "This study shows us that even these large disks, whose inner regions are unobservable, are still dynamic, or changing in detectable ways which we didn't imagine."

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

For images and more information about TW Hydrae and Hubble, visit:

http://hubblesite.org/news/2017/03

www.nasa.gov/hubble

For additional information, contact:

Felicia ChouNASA Headquarters, Washington, D.C.202-358-0257felicia.chou@nasa.gov

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

John DebesSpace Telescope Science Institute, Baltimore, Maryland410-338-4782debes@stsci.edu

Scientists and engineers tested NASA's LEMS (Lunar Environment Monitoring Station) instrument suite in a "sandbox" of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Can garnet planets be habitable?

4 min read

NASA Science Editorial Team

In results presented at the 2017 American Astronomical Society (AAS) meeting in Grapevine, Texas, astronomer Johanna Teske explained, “our study combines new observations of stars with new models of planetary interiors. We want to better understand the diversity of small, rocky exoplanet composition and structure — how likely are they to have plate tectonics or magnetic fields?”

Earth-sized planets have been found around many stars — but Earth-sized does not necessarily mean Earth-like. Some of these Earth-sized planets have been found orbiting stars with chemical compositions quite different from our Sun, and those differences in chemistry could have important consequences.

Astronomers in the Sloan Digital Sky Survey have made these observations using the APOGEE (Apache Point Observatory Galactic Evolution Experiment) spectrograph on the 2.5m Sloan Foundation Telescope at Apache Point Observatory in New Mexico. This instrument collects light in the near-infrared part of the electromagnetic spectrum and disperses it, like a prism, to reveal signatures of different elements in the atmospheres of stars. A fraction of the almost 200,000 stars surveyed by APOGEE overlap with the sample of stars targeted by the NASA Kepler mission, which was designed to find potentially Earth-like planets. The work presented today focuses on ninety Kepler stars that show evidence of hosting rocky planets, and which have also been surveyed by APOGEE.

In particular, Teske and colleagues presented solar systems around the stars Kepler 102 and Kepler 407. Kepler 102 is slightly less luminous than the Sun and has five known planets; Kepler 407 is a star almost identical in mass to the Sun and hosts at least two planets, one with a mass less than 3 Earth masses.

“Looking at these two exoplanet systems in particular,” Teske explains, “we determined that Kepler 102 is like the Sun, but Kepler 407 has a lot more silicon.”

To understand what a lot more silicon might mean for the planets around Kepler 407, astronomers turned to geophysicists for help. Cayman Unterborn of Arizona State University ran computer models of planet formation. “We took the star compositions found by APOGEE and modeled how the elements condensed into planets in our models. We found that the planet around Kepler 407, which we called ‘Janet,” would likely be rich in the mineral garnet. The planet around Kepler 102, which we called ‘Olive,’ is probably rich in olivine, like Earth.”

That seemingly-small difference in minerals might have major consequences for Janet and Olive. Garnet is a stiffer mineral than olivine, so it flows more slowly. Unterborn explains that this means that a garnet planet like Janet would be much less likely to have long-term plate tectonics. “To sustain plate tectonics over geologic timescales, a planet must have the right mineral composition,” Unterborn says.

Plate tectonics is believed to be essential for life on Earth, because of how volcanoes and ocean ridges recycle elements between Earth’s crust and mantle. This recycling regulates the composition of our atmosphere. Wendy Panero of the School of Earth Sciences at The Ohio State University says that “without these geological processes, life may not have had the chance to evolve on Earth.” Determining the likelihood of such geological processes on other planets will help distinguish which ones are the best targets for future missions searching for signs of life. “If we’re looking for a needle,” Panero says, “why not start in the sewing box?”

The next step in the team's research is to extend this study to all of the stars observed by APOGEE that host small planets. That extension would allow astronomers to map out a wider range of planet compositions and structures to find those most likely to be Earth-like in their mineral content. Teske concludes, "As we've learned more about the Earth, we have learned about how many pieces come together to make it habitable. How often will exoplanets get that lucky?"

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Four-Planet System in Orbit, Directly Imaged and Remarkable

4 min read

NASA Science Editorial Team

By Marc Kaufman, Many Worlds

The era of directly imaging exoplanets has only just begun, but the science and viewing pleasures to come are appealingly apparent.

This evocative movie of four planets more massive than Jupiter orbiting the young star HR 8799 is a composite of sorts, including images taken over seven years at the W.M. Keck observatory in Hawaii.

The movie clearly doesn't show full orbits, which will take many more years to collect. The closest-in planet circles the star in around 40 years; the furthest takes more than 400 years.

But as described by Jason Wang, an astronomy graduate student at the University of California, Berkeley, researchers think that the four planets may well be in resonance with each other.

In this case it's a one-two-four-eight resonance, meaning that each planet has an orbital period in nearly precise ratio with the others in the system.

The black circle in the center of the image is part of the observing and analyzing effort to block the blinding light of the star, and thus make the planets visible.

The images were initially captured by Dr. Christian Marois of the National Research Council of Canada's Herzberg Institute of Astrophysics. The movie animation was put together by Wang, who is part of the Berkeley arm of the Nexus for Exoplanet System Science (NExSS), a NASA-sponsored group formed to encourage interdisciplinary exoplanet science.

The star HR 8799 has already played a pioneering role in the evolution of direct imaging of exoplanets. In 2008, the Marois group announced discovery of three of the four HR 8799 planets using direct imaging for the first time. On the same day that a different team announced the direct imaging of a planet orbiting the star Fomalhaut.

HR 8799 is 129 light-years away in the constellation of Pegasus. By coincidence, it is quite close to the star 51 Pegasi, where the first exoplanet was detected in 1995. It is less than 60 million years old, Wang said, and is almost five times brighter than the sun.

Wang said that the animation is based on eight observations of the planets since 2009. He then used a motion interpolation algorithm to draw the orbit between those points.

Much can be learned from the motion of the planets, however long it may take for them to circle their sun. Based on the Keck observations, astronomers have concluded that the four planets orbit in roughly Keplerian motion around the star — almost circular, but not entirely.

The planets are quite far from each other, which is to be expected due to their enormous size. Because of those large separations, Wang said astronomers will be watching to see if the system is stable or if some of the planets may be ejected from the system.

Although the first three HR 8799 planets were officially discovered in 2008, researchers learned afterwards that the planets had actually already been observed. The “precovery” had been made in 1998 by the NICMOS instrument on the Hubble Space Telescope, but was teased out only after a newly developed image-processing technique was installed.

The fourth HR 8799 planet was found after further observations in 2009–2010. That planet orbits inside the first three planets, but is still fifteen times the distance from its star than Earth to our sun. (The team working with Marois included Quinn Konopacky of the University of California, San Diego, Bruce Macintosh of Stanford University and Travis Barman of the University of Arizona.)

James Graham is leader of the Berkeley NExSS group, and he was struck by some of the connections between what has been found around HR 8799 and what exists in our own solar system.

Read more at the Many Worlds blog.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Microlensing Study Suggests Most Common Outer Planets Likely Neptune-mass

6 min read

A new statistical study of planets found by a technique called gravitational microlensing suggests that Neptune-mass worlds are likely the most common type of planet to form in the icy outer realms of planetary systems. The study provides the first indication of the types of planets waiting to be found far from a host star, where scientists suspect planets form most efficiently.

“We’ve found the apparent sweet spot in the sizes of cold planets. Contrary to some theoretical predictions, we infer from current detections that the most numerous have masses similar to Neptune, and there doesn’t seem to be the expected increase in number at lower masses,” said lead scientist Daisuke Suzuki, a post-doctoral researcher at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and the University of Maryland Baltimore County. “We conclude that Neptune-mass planets in these outer orbits are about 10 times more common than Jupiter-mass planets in Jupiter-like orbits.”

Gravitational microlensing takes advantage of the light-bending effects of massive objects predicted by Einstein’s general theory of relativity. It occurs when a foreground star, the lens, randomly aligns with a distant background star, the source, as seen from Earth. As the lensing star drifts along in its orbit around the galaxy, the alignment shifts over days to weeks, changing the apparent brightness of the source. The precise pattern of these changes provides astronomers with clues about the nature of the lensing star, including any planets it may host.

“We mainly determine the mass ratio of the planet to the host star and their separation,” said team member David Bennett, an astrophysicist at Goddard. “For about 40 percent of microlensing planets, we can determine the mass of the host star and therefore the mass of the planet.”

More than 50 exoplanets have been discovered using microlensing compared to thousands detected by other techniques, such as detecting the motion or dimming of a host star caused by the presence of planets. Because the necessary alignments between stars are rare and occur randomly, astronomers must monitor millions of stars for the tell-tale brightness changes that signal a microlensing event.

However, microlensing holds great potential. It can detect planets hundreds of times more distant than most other methods, allowing astronomers to investigate a broad swath of our Milky Way galaxy. The technique can locate exoplanets at smaller masses and greater distances from their host stars, and it’s sensitive enough to find planets floating through the galaxy on their own, unbound to stars.

NASA’s Kepler and K2 missions have been extraordinarily successful in finding planets that dim their host stars, with more than 2,500 confirmed discoveries to date. This technique is sensitive to close-in planets but not more distant ones. Microlensing surveys are complementary, best probing the outer parts of planetary systems with less sensitivity to planets closer to their stars.

“Combining microlensing with other techniques provides us with a clearer overall picture of the planetary content of our galaxy,” said team member Takahiro Sumi at Osaka University in Japan.

From 2007 to 2012, the Microlensing Observations in Astrophysics (MOA) group, a collaboration between researchers in Japan and New Zealand, issued 3,300 alerts informing the astronomical community about ongoing microlensing events. Suzuki’s team identified 1,474 well-observed microlensing events, with 22 displaying clear planetary signals. This includes four planets that were never previously reported.

To study these events in greater detail, the team included data from the other major microlensing project operating over the same period, the Optical Gravitational Lensing Experiment (OGLE), as well as additional observations from other projects designed to follow up on MOA and OGLE alerts.

From this information, the researchers determined the frequency of planets compared to the mass ratio of the planet and star as well as the distances between them. For a typical planet-hosting star with about 60 percent the sun's mass, the typical microlensing planet is a world between 10 and 40 times Earth's mass. For comparison, Neptune in our own solar system has the equivalent mass of 17 Earths.

The results imply that cold Neptune-mass worlds are likely to be the most common types of planets beyond the so-called snow line, the point where water remained frozen during planetary formation. In the solar system, the snow line is thought to have been located at about 2.7 times Earth's mean distance from the sun, placing it in the middle of the main asteroid belt today.

A paper detailing the findings was published in The Astrophysical Journal on Dec. 13.

"Beyond the snow line, materials that were gaseous closer to the star condense into solid bodies, increasing the amount of material available to start the planet-building process," said Suzuki. "This is where we think planetary formation was most efficient, and it's also the region where microlensing is most sensitive."

NASA's Wide Field Infrared Survey Telescope (WFIRST), slated to launch in the mid-2020s, will conduct an extensive microlensing survey. Astronomers expect it will deliver mass and distance determinations of thousands of planets, completing the work begun by Kepler and providing the first galactic census of planetary properties.

NASA's Ames Research Center manages the Kepler and K2 missions for NASA's Science Mission Directorate. The Jet Propulsion Laboratory (JPL) in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

WFIRST is managed at Goddard, with participation by JPL, the Space Telescope Science Institute in Baltimore, the Infrared Processing and Analysis Center, also in Pasadena, and a science team comprising members from U.S. research institutions across the country.

For more information on how NASA's Kepler is working with ground-based efforts, including the MOA and OGLE groups, to search for planets using microlensing, please visit:

https://www.nasa.gov/feature/ames/kepler/searching-for-far-out-and-wandering-worlds/

By Francis ReddyNASA's Goddard Space Flight Center in Greenbelt, Maryland

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Top 5 Exoplanet Moments of 2016

4 min read

NASA Science Editorial Team

Exoplanet exploration, or the search for planets outside our solar system. It's a field that often sounds mysterious, but seeks to answer an essentially simple question– are we alone in the universe? In 2016, the search for another Earth brought incredible discoveries along the way. We've listed five of the most important discoveries of 2016 as we count down to a new year, and new worlds.

An incredible discovery years in the making, Proxima b is proof that there is a planet around the nearest star to Earth (other than the sun). And the newly discovered, roughly Earth-sized planet orbiting our nearest neighboring star might be habitable. Proxima Centauri is a dim, red star only four light-years away from us. The exoplanet is at a distance from its star that allows temperatures mild enough for liquid water to pool on its surface. Scientists don't know if the planet can support life yet, but are already planning future missions to study it further.

Full story

The other biggest discovery of the year also revealed Earth-sized planets around a red star. Astronomers using the TRAPPIST telescope at ESO’s La Silla Observatory discovered three planets with sizes and temperatures similar to those of Venus and Earth, orbiting an ultra-cool dwarf star just 40 light-years from Earth. TRAPPIST-1b and TRAPPIST-1c may lie within their star's habitable zone, where moderate temperatures could allow for liquid water on the surface. Follow-up observations with the Hubble Space Telescope concluded that the two planets are unlikely to have puffy, hydrogen-dominated atmospheres usually found on gaseous worlds. This leaves open the possibility that both planets have thinner, denser atmospheres like Earth's.

Full story

This year NASA's Kepler mission released the single largest finding of planets to date– 1,284 verified new planets. The announcement more than doubled the number of confirmed planets from Kepler in one sweep. Before the Kepler space telescope launched, we did not know whether exoplanets were rare or common in the galaxy. Now, thanks to the thousands of planets it's found, we can say that Earth-sized planet in the habitable zone around sun-like stars are known to be common.

Full story

After years of prep, NASA is formally starting an astrophysics mission designed to help unlock the secrets of the universe– the Wide Field Infrared Survey Telescope (WFIRST). The telescope was later renamed the Nancy Grace Roman Space Telescope. With a view 100 times bigger than that of NASA's Hubble Space Telescope, NASA Roman will explore the secrets of dark energy and dark matter, and explore the evolution of the cosmos. It also will carry on Kepler's legacy by discovering new worlds outside our solar system and advancing the search for life. The telescope's planned launch date is in the 2027.

Full story

In 2016, observations from NASA's Spitzer Space Telescope led to the first temperature map of a super-Earth planet– a rocky planet nearly two times as big as ours. The map revealed extreme temperature swings from one side of the planet to the other that may indicate the presence of bubbling pools of lava. The fact Spitzer found the night side to be significantly colder than the day side means heat is not being distributed around the planet very well. The data argues against the notion that a thick atmosphere and winds are moving heat around the planet as previously thought. Instead, the findings suggest a planet devoid of a massive atmosphere, and possibly hint at a lava world where the lava would become hardened on the night side and unable to transport heat.

Full story

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

The stars in the big Wyoming skies inspired Aaron Vigil as a child to dream big. Today, he's a mechanical engineer working on the Solar Array Sun Shield (SASS) for the Nancy Grace Roman Space Telescope at Goddard. Name: Aaron VigilTitle: Mechanical EngineerFormal Job Classification: Aerospace Technology, Flight StructuresOrganization: Mechanical Engineering, Engineering and Technology Directorate (Code […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Interstellar: Crossing the Cosmic Void

9 min read

Alicia Cermak

Humanity’s great leap into the space between the stars has, in a sense, already begun. NASA's Voyager 1 probe broke through the sun’s magnetic bubble to touch the interstellar wind. Voyager 2 isn’t far behind. New Horizons shot past Pluto on its way to encounters with more distant dwarf worlds, the rubble at the solar system’s edge.

Closer to home, we’re working on techniques to help us cross greater distances. Astronauts feast on romaine lettuce grown aboard the International Space Station, perhaps a preview of future banquets en route to Mars, or to deep space.

For the moment, sending humans to other stars remains firmly in the realm of science fiction. But while NASA so far has proposed no new missions beyond our solar system, scientists and engineers are sketching out possible technologies that might one day help to get us there.

NASA’s Journey to Mars, a plan aimed at building on robotic missions to send humans to the red planet, could be helping lay the groundwork.

“Propulsion, power, life support, manufacturing, communication, navigation, robotics: the Journey to Mars is going to force us to make advances in every one of these areas,” said Jeffrey Sheehy, NASA’s Space Technology Missions Directorate chief engineer in Washington, D.C. “Those systems are not going to be advanced enough to do an interstellar mission. But Mars is stepping us that much farther into space. It’s a step along the way to the stars.”

Hurling ourselves, "Passengers"-style, just to the nearest star, Proxima Centauri, would require crossing almost inconceivably vast distances. We would need truly exotic technology, such as suspended animation or multi-generational life support. That places in-person visits well out of reach, at least for the near term.

But the possibility of robotic interstellar probes is coming into much sharper focus. Space probe pioneers say the radiation, energy and particle-bathed space between the stars—the so-called interstellar medium—is itself a worthy science destination.

“We need more explorers, more of these local probes into this region, so we can understand better these interface conditions between our sun and the interstellar medium," said Leon Alkalai, an engineering fellow at NASA’s Jet Propulsion Laboratory in Pasadena, California, and co-author of a 2015 report on exploring interstellar space. "Like the ancient mariners, we want to start creating a map.”

Alkalai’s report, “Science and Enabling Technologies for the Exploration of the Interstellar Medium,” maps out the knowns and unknowns of largely uncharted regions, from the dark, distant, dwarf worlds of the Kuiper Belt to the “bow shock”—the turbulent transition thought to separate the sun’s bubble of plasma from the interstellar wind. Drawing on the work of more than 30 specialists during two workshops at the Keck Institute for Space Studies, the report poses pressing questions about the structure, composition and energy flow in this cosmic vastness. And it paints one of the most detailed pictures yet of a possible interstellar probe using present-day technology.

Part of the report focuses on a “Design Reference Mission,” a conceptual starting point that allowed workshop scientists to begin teasing out some of the technical requirements of an interstellar probe. The resulting probe concept was meant to be “daring, challenging, inspirational to the public,” and “a rational first step towards attempting to reach another star,” the report said. It’s the latest in a long line of interstellar probe concepts by NASA scientists stretching back to the 1970s.

In this conceptual scenario, the disk-shaped probe in a bullet-shaped housing is launched as a payload on the Space Launch System, NASA's next big rocket, in the late 2020s. With gravitational boosts from Earth, Jupiter and the sun itself, it could reach interstellar space in just 10 years. By comparison, it took Voyager 1 36 years to reach the heliopause, or the boundary of interstellar space.

The probe would rely on both rockets and electrical power from next-generation radioisotope thermoelectric generators, enhanced versions of the kind now onboard the Mars Curiosity Rover. Such a probe would carry a variety of sensors and a communications antenna. It could investigate the interstellar medium and its boundary with the solar system, and perhaps even conduct a flyby of a Kuiper Belt object, one of the many unknown space bodies that orbit the sun far beyond Pluto.

Future studies could examine the possibility of electric propulsion for the probe, or solar or electric sails.

One of the most extraordinary conceptual spacecraft detailed in the report also would exit the solar system, but only just. And its focus, literally, would be on alien worlds.

This conceptual spacecraft would be parked in near interstellar space to use our sun as a gigantic lens, allowing zoomed-in close-ups of planets orbiting other stars. A space telescope would be lofted to a position far beyond Pluto, some 550 times the distance from Earth to the sun, or farther. It would take advantage of an effect described by Einstein: the power of gravity to bend light rays.

The stream of light from a distant star and its planet would be bent around the edges of the sun, like water flowing around a rock, meeting on the other side at a focal point—where it would be greatly magnified. The telescope would be placed in just the right position to capture these images.

The images would be smeared into a ring around the sun, called an Einstein ring, and the technical challenges would be immense: the distortions would have to be corrected and the fragmentary images reassembled. But if successful, the lens could be powerful enough to reveal surface features of an exoplanet—a planet around another star.

"It would almost be like the Earthrise picture from the moon," Alkalai said, recalling the iconic image sent back by the Apollo 8 astronauts in 1968. "You would see clouds and continents and oceans, that kind of scale of images. From Earth, every image of an exoplanet is a single pixel, so you're looking with a straw at the exoplanet. If you want to image continents on an exoplanet, you need something like the solar gravitational lens."

Once we are ready to take the giant stride to another star, the problem of propulsion takes center stage. Carrying bulky fuel tanks could increase the mass of an interstellar probe beyond the realm of feasibility.

But reaching even one-tenth the speed of light would allow a space probe to arrive at the nearest star in a 50-year time frame, Sheehy said.

"We would never be able to accelerate to that kind of velocity using a chemical reaction," such as those in present-day rockets, he said.

One answer that might just possibly be within reach, he said, involves "beamed energy." A powerful laser array, either on Earth's surface or in orbit, could be used to accelerate space probes equipped with sails to some fraction of the speed of light. NASA's Innovative Advanced Concepts Program (NIAC) recently chose one such project, led by Philip Lubin at the University of California, Santa Barbara, to receive a second grant for further development.

NIAC also recently provided funding for a conceptual project that might warm the hearts of “Passengers” fans. Called “Advanced Torpor Inducing Transfer Habitats for Human Stasis to Mars,” this research effort by John Bradford of Space Works Inc., in Atlanta, investigates how to place astronauts in a deep sleep state with reduced metabolic rates for trips between Earth and Mars. While it isn’t true suspended animation or intended for interstellar travel, such a project highlights the extreme technical difficulties involved in sending fragile human bodies across the reaches of interstellar space.

If our species ever attempts such trips, they could take many decades or even centuries, perhaps requiring some kind of suspension and revival or vessels that can sustain human life for several generations.

“Maybe the people we launch won’t be the people who actually reach Alpha Centauri,” Sheehy said. “It will be their kids. But you’ve got to eat for those 80 years.”

Learning to grow food in space could help, he said, though growing plants from seeds requires “real estate in space. A tomato plant is so big, a head of lettuce is a certain size.”

Another possibility is using 3-D printers that “build 3-D objects up layer by layer. Why couldn’t we build a cell that way? Why couldn’t we build food that way? Could you print a pizza?”

Alkalai also considers human interstellar travel an extremely distant prospect.

“The notion of sending humans to interstellar space is so far out in the sense that people need to have resources on the scale of a planet,” he said. “The only sci-fi story that I like, that might have some scientific basis, is not to build a Star Trek Enterprise but to really hijack an asteroid.

“Imagine a population that would be able to be on a binary asteroid. Then they could use one of them to swing the other one into interstellar space. Then you have resources on the asteroid, a source of iron, carbon, other materials. They could mine that as a source of resources for living, for energy. You would have to imagine something like this designed for many, many generations.”

But the daunting challenges even to sending robotic probes to the stars should be motivating, not discouraging, Sheehy said.

“Anywhere we’ve ever gone as humans, we always learn something, even if it’s just over the next mountain range,” he said. “A lot of times you discover something about yourself on a journey like that. We always find something that surprises us.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Are Star Wars-like Planets Really Out There?

7 min read

NASA Science Editorial Team

In the "Star Wars" universe, ice, ocean and desert planets burst from the darkness as your ship drops out of light speed. But these worlds might be more than just science fiction.

Some of the planets discovered around stars in our own galaxy could be very similar to arid Tatooine, watery Scarif and even frozen Hoth, according to NASA scientists.

Sifting through data on the more than 4,100 confirmed alien worlds, scientists apply sophisticated computer modeling techniques to tease out the colors, light, sunrise and sunsets we might encounter if we could pay them a visit.

Some of these distant worlds are even stranger than those that populate the "Star Wars" films. And others are eerily like the fictional planets from a galaxy far, far away.

A real planet in our galaxy reminded scientists so much of Luke Skywalker’s home planet, they named it “Tatooine.” Officially called Kepler-16b, the Saturn-sized planet is about 200 light-years away in the constellation Cygnus. The reality of its two suns was so startling, George Lucas himself agreed to the astronomers’ nickname for the planet.

“This was the first honest-to-goodness real planetary system where you would see the double sunset as two suns,” said Laurance Doyle, an astrophysicist with the Search for Extraterrestrial Intelligence Institute and Director of the Institute for the Metaphysics of Physics, who discovered the planet using NASA’s Kepler space telescope in 2011.

Each sunset would be unique, because the stars are always changing their configuration. Building a sundial would require calculus. Kepler-16b is now thought to be a gas giant like Saturn. Prospects for life on this unusual world aren't good, as it has a temperature similar to that of dry ice. But the discovery indicates that the movie's iconic double-sunset is anything but science fiction.

Astronomers have discovered that about half of the stars in our Milky Way galaxy are pairs, rather than single stars like our Sun. So while Kepler-16b, aka Tatooine, is probably too cold and gaseous to be home to life, or a hopeful desert farm boy, it’s a good bet that there might be a habitable Tatooine “twin” out there somewhere.

George Lucas has a fondness for desert planets, and at least one NASA scientist thinks he’s on the right track.

“Desert planets are possible. We have one right here in our solar system in Mars. We think desert planets elsewhere could be even more habitable than Mars is,” said Shawn Domagal-Goldman, an astrobiologist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

He likes Lucas’ proliferation of arid worlds because he believes it might reflect the galaxy in which we live.

“The recurring theme of desert worlds in Star Wars is really interesting, because there is some research that shows that these would be likely habitable worlds to find,” said Domagal-Goldman, who is, among other things, a climate scientist.

Desert worlds are not only a very real possibility, but they are probably very common, he said. They could be hot, like Tatooine and Jakku, or cold, like Mars and Jedha in “Rogue One.”

“The lack of water on a desert planet might be what makes it more habitable. Water amplifies changes to climates and can cause planets to end up being really hot like Venus, or really cold like Europa,” said Domagal-Goldman.

There is a world named Hoth in our galaxy — an icy super-Earth discovered in 2006. It reminded scientists so much of the frozen Rebel base they unofficially nicknamed it after the planet that appears in "The Empire Strikes Back." The planet's scientific designation is OGLE 2005-BLG-390L, after the Optical Gravitational Lensing Experiment (OGLE) that found it.

Our galaxy’s Hoth is too cold to support life as we know it. But life may evolve under the ice of a different world, or a moon in our solar system. On Earth, it’s been found inside volcanoes, deep ocean trenches, even the frozen soil of Antarctica.

NASA is currently designing a Europa mission to look for life under the crust of Jupiter’s icy moon Europa. And Saturn’s moon Enceladus also contains an underground ocean that could harbor alien life.

For the scientists who characterize exoplanets, the most important planet to study is Earth—the only known planet with life. And life on Earth began in the ocean.

“We need Earth climate science to help us understand planetary habitability and the potential diversity of life on exoplanets,” said astrobiologist Nancy Kiang, a research scientist at NASA’s Goddard Institute for Space Studies. As an astrobiologist, her job is to model the kind of plant life that might exist on planets around other stars—also known as exoplanets.

We haven’t confirmed the existence of ocean worlds like the perpetually rainy Kamino in “Attack of the Clones,” or worlds with oceans, like the beachy Scarif from “Rogue One.” But we have found frozen ocean worlds in our solar system, in the moons Europa and Enceladus.

We may even be able to glimpse an ocean on an exoplanet in the not-so-distant future.

“Ocean glint can be detected over large distances,” said Victoria Meadows, a professor at the University of Washington and director of the NASA Astrobiology Institute's Virtual Planetary Laboratory.

Such a glint was first observed reflecting from the liquid methane seas on Titan, the largest moon of Saturn.

Both the forest moon of Endor, from “Return of the Jedi,” and Takodana, the home of Han Solo’s favorite cantina in “The Force Awakens,” are green like our home planet. But astrobiologists think that plant life on other worlds could be red, black, or even rainbow-colored.

In 2016, astronomers from the European Southern Observatory announced the discovery of Proxima Centauri b, a planet only four light-years away from Earth, which orbits a tiny red star.

“The star color would be peachy to the human eye,” Meadows said. “And the planet would appear dark purple to light purple, looking at it from a spacecraft.” From the surface of Proxima b, the sky would appear to be periwinkle.

The light from a red star, also known as an M dwarf, is dim and mostly in the infrared spectrum, as opposed to the visible spectrum we see with our Sun. The planet also doesn’t have sunrises or sunsets like Earth: one side always faces its sun.

“If you have photosynthetic organisms, they would always get fixed amounts of light all the time. It would be a permanent sunset around the planet. You would see a gradation of color,” Kiang said.

Just as seaweed changes color from green to dark brown as you dive deeper into the ocean, plants on a red dwarf planet may brilliantly change color from the day side to the night side.

And that could mean rainbow plant life.

In the "Star Wars" universe, Lucas and company envision scores of worlds bustling with intelligent beings. In our galaxy, we know of only one such world so far—Earth. But NASA exoplanet scientists think we have a fighting chance of finding life beyond our solar system.

The Transiting Exoplanet Survey Satellite (TESS) launched in 2018 and NASA's James Webb Space Telescope will attempt to determine what’s in the atmospheres of other planets after its launch. Then, in the next decade, the Nancy Grace Roman Space Telescope will bring us images of exoplanets around sun-like stars.

That’s one step closer to finding life.

“The idea of life on other planets resonates with people on a very personal level,” Doug Hudgins, NASA’s program scientist for exoplanet exploration, said of the "Star Wars" films enduring popularity. “They portray this image of a universe that is teeming with life.”

“We are at our heart explorers," he said. “We want to know what’s out there. Through the imaginings of George Lucas and Gene Roddenberry, we get to feel for a bit of time like we really can go out and explore the stars.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Winds of rubies and sapphires strike the sky of giant planet

3 min read

NASA Science Editorial Team

◆ Weather has been detected on HAT-P-7b – a planet 16x larger than Earth, over 1000 light-years away.

◆

◆ Clouds on the planet could be made of corundum, the mineral which forms rubies and sapphires.

◆ The Kepler Space Telescope measured changes in the light reflected from planet.

Signs of powerful changing winds have been detected on a planet 16 times larger than Earth, over 1000 light-years away – among the first weather systems discovered on a gas giant outside our solar system, according to new research by the University of Warwick.

Dr. David Armstrong in Warwick's Astrophysics Group has discovered that the gas giant HAT-P-7b is affected by large scale changes in the strong winds moving across the planet, likely leading to catastrophic storms.

This discovery was made by monitoring the light being reflected from the atmosphere of HAT-P-7b, and identifying changes in this light, showing that the brightest point of the planet shifts its position.

This shift is caused by an equatorial jet with dramatically variable wind-speeds – at their fastest, pushing vast amounts of cloud across the planet.

The clouds themselves would be visually stunning – likely made of up corundum, the mineral which forms rubies and sapphires.

The planet is probably uninhabitable, due to its likely violent weather systems, and unaccommodating temperatures. One side of the planet always faces the star, because it is tidally locked, and that side remains much hotter than the other – the day side average temperature on HAT-P-7 being 2,860 Kelvin (about 4,688 Fahrenheit).

Thanks to this pioneering research, astrophysicists can now begin to explore how weather systems on other planets outside our solar system change over time.

Dr. Armstrong said, "Using the NASA Kepler satellite we were able to study light reflected from HAT-P-7b's atmosphere, finding that the atmosphere was changing over time. HAT-P-7b is a tidally locked planet, with the same side always facing its star. We expect clouds to form on the cold night side of the planet, but they would evaporate quickly on the hot dayside."

"These results show that strong winds circle the planet, transporting clouds from the night side to the dayside. The winds change speed dramatically, leading to huge cloud formations building up then dying away. This is the first detection of weather on a gas giant planet outside the solar system."

First discovered in 2008, HAT-P-7b is 320 parsecs (over 1,040 light-years) away from us. It is an exoplanet 40 percent larger than Jupiter and 500 times more massive than the Earth– and orbits a star 50 percent more massive, and twice as large, as the sun.

The work was led by the University of Warwick, and performed by a team of scientists from Warwick, Queens University Belfast, Dublin City University and University College London.

The paper, ‘Variability in the Atmosphere of the Hot Jupiter HAT-P-7’, is published in the first issue of Nature Astronomy.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Neptune-mass outer Planets Likely Common Around Other Stars

6 min read

NASA Science Editorial Team

A new statistical study of planets found by a technique called gravitational microlensing suggests that Neptune-mass worlds are likely the most common type of planet to form in the icy outer realms of planetary systems. The study provides the first indication of the types of planets waiting to be found far from a host star, where scientists suspect planets form most efficiently.

"We've found the apparent sweet spot in the sizes of cold planets. Contrary to some theoretical predictions, we infer from current detections that the most numerous have masses similar to Neptune, and there doesn't seem to be the expected increase in number at lower masses," said lead scientist Daisuke Suzuki, a post-doctoral researcher at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and the University of Maryland Baltimore County. "We conclude that Neptune-mass planets in these outer orbits are about 10 times more common than Jupiter-mass planets in Jupiter-like orbits."

The researchers determined the frequency of planets compared to the mass ratio of the planet and star as well as the distances between them. For a typical planet-hosting star with about 60 percent the sun's mass, the typical microlensing planet is a world between 10 and 40 times Earth's mass. For comparison, Neptune in our own solar system has the equivalent mass of 17 Earths.

The results imply that cold Neptune-mass worlds are likely to be the most common types of planets beyond the so-called snow line, the point where water remained frozen during planetary formation. In the solar system, the snow line is thought to have been located at about 2.7 times Earth's mean distance from the sun, placing it in the middle of the main asteroid belt today.

A paper detailing the findings was published in The Astrophysical Journal on Dec. 13.

"Beyond the snow line, materials that were gaseous closer to the star condense into solid bodies, increasing the amount of material available to start the planet-building process," said Suzuki. "This is where we think planetary formation was most efficient, and it's also the region where microlensing is most sensitive."

Gravitational microlensing takes advantage of the light-bending effects of massive objects predicted by Einstein's general theory of relativity. It occurs when a foreground star, the lens, randomly aligns with a distant background star, the source, as seen from Earth. As the lensing star drifts along in its orbit around the galaxy, the alignment shifts over days to weeks, changing the apparent brightness of the source. The precise pattern of these changes provides astronomers with clues about the nature of the lensing star, including any planets it may host.

"We mainly determine the mass ratio of the planet to the host star and their separation," said team member David Bennett, an astrophysicist at Goddard. "For about 40 percent of microlensing planets, we can determine the mass of the host star and therefore the mass of the planet."

More than 50 exoplanets have been discovered using microlensing compared to thousands detected by other techniques, such as detecting the motion or dimming of a host star caused by the presence of planets. Because the necessary alignments between stars are rare and occur randomly, astronomers must monitor millions of stars for the tell-tale brightness changes that signal a microlensing event.

However, microlensing holds great potential. It can detect planets hundreds of times more distant than most other methods, allowing astronomers to investigate a broad swath of our Milky Way galaxy. The technique can locate exoplanets at smaller masses and greater distances from their host stars, and it's sensitive enough to find planets floating through the galaxy on their own, unbound to stars.

NASA's Kepler and K2 missions have been extraordinarily successful in finding planets that dim their host stars, with more than 2,500 confirmed discoveries to date. This technique is sensitive to close-in planets but not more distant ones. Microlensing surveys are complementary, best probing the outer parts of planetary systems with less sensitivity to planets closer to their stars.

"Combining microlensing with other techniques provides us with a clearer overall picture of the planetary content of our galaxy," said team member Takahiro Sumi at Osaka University in Japan.

From 2007 to 2012, the Microlensing Observations in Astrophysics (MOA) group, a collaboration between researchers in Japan and New Zealand, issued 3,300 alerts informing the astronomical community about ongoing microlensing events. Suzuki's team identified 1,474 well-observed microlensing events, with 22 displaying clear planetary signals. This includes four planets that were never previously reported.

To study these events in greater detail, the team included data from the other major microlensing project operating over the same period, the Optical Gravitational Lensing Experiment (OGLE), as well as additional observations from other projects designed to follow up on MOA and OGLE alerts.

NASA's Wide Field Infrared Survey Telescope (WFIRST), slated to launch in the mid-2020s, will conduct an extensive microlensing survey. Astronomers expect it will deliver mass and distance determinations of thousands of planets, completing the work begun by Kepler and providing the first galactic census of planetary properties.

NASA's Ames Research Center manages the Kepler and K2 missions for NASA's Science Mission Directorate. The Jet Propulsion Laboratory (JPL) in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

WFIRST is managed at Goddard, with participation by JPL, the Space Telescope Science Institute in Baltimore, the Infrared Processing and Analysis Center, also in Pasadena, and a science team comprising members from U.S. research institutions across the country.

For more information on how NASA’s Kepler is working with ground-based efforts, including the MOA and OGLE groups, to search for planets using microlensing, please visit:

https://www.nasa.gov/feature/ames/kepler/searching-for-far-out-and-wandering-worlds/

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Building blocks of life's building blocks come from starlight

5 min read

NASA Science Editorial Team

Life exists in a myriad of wondrous forms, but if you break any organism down to its most basic parts, it's all the same stuff: carbon atoms connected to hydrogen, oxygen, nitrogen and other elements. But how these fundamental substances are created in space has been a longstanding mystery.

Now, astronomers better understand how molecules form that are necessary for building other chemicals essential for life. Thanks to data from the European Space Agency's Herschel Space Observatory, scientists have found that ultraviolet light from stars plays a key role in creating these molecules, rather than "shock" events that create turbulence, as was previously thought.

Scientists studied the ingredients of carbon chemistry in the Orion Nebula, the closest star-forming region to Earth that forms massive stars. They mapped the amount, temperature and motions of the carbon-hydrogen molecule (CH, or "methylidyne" to chemists), the carbon-hydrogen positive ion (CH+) and their parent: the carbon ion (C+). An ion is an atom or molecule with an imbalance of protons and electrons, resulting in a net charge.

"On Earth, the sun is the driving source of almost all the life on Earth. Now, we have learned that starlight drives the formation of chemicals that are precursors to chemicals that we need to make life," said Patrick Morris, first author of the paper and researcher at the Infrared Processing and Analysis Center at Caltech in Pasadena.

In the early 1940s, CH and CH+ were two of the first three molecules ever discovered in interstellar space. In examining molecular clouds -- assemblies of gas and dust -- in Orion with Herschel, scientists were surprised to find that CH+ is emitting rather than absorbing light, meaning it is warmer than the background gas. The CH+ molecule needs a lot of energy to form and is extremely reactive, so it gets destroyed when it interacts with the background hydrogen in the cloud. Its warm temperature and high abundance are therefore quite mysterious.

Why, then, is there so much CH+ in molecular clouds such as the Orion Nebula? Many studies have tried to answer this question before, but their observations were limited because few background stars were available for studying. Herschel probes an area of the electromagnetic spectrum -- the far infrared, associated with cold objects -- that no other space telescope has reached before, so it could take into account the entire Orion Nebula instead of individual stars within. The instrument they used to obtain their data, HIFI, is also extremely sensitive to the motion of the gas clouds.

One of the leading theories about the origins of basic hydrocarbons has been that they formed in "shocks," events that create a lot of turbulence, such as exploding supernovae or young stars spitting out material. Areas of molecular clouds that have a lot of turbulence generally create shocks. Like a large wave hitting a boat, shock waves cause vibrations in material they encounter. Those vibrations can knock electrons off atoms, making them ions, which are more likely to combine. But the new study found no correlation between these shocks and CH+ in the Orion Nebula.

Herschel data show that these CH+ molecules were more likely created by the ultraviolet emission of very young stars in the Orion Nebula, which, compared to the sun, are hotter, far more massive and emit much more ultraviolet light. When a molecule absorbs a photon of light, it becomes "excited" and has more energy to react with other particles. In the case of a hydrogen molecule, the hydrogen molecule vibrates, rotates faster or both when hit by an ultraviolet photon.

It has long been known that the Orion Nebula has a lot of hydrogen gas. When ultraviolet light from large stars heats up the surrounding hydrogen molecules, this creates prime conditions for forming hydrocarbons. As the interstellar hydrogen gets warmer, carbon ions that originally formed in stars begin to react with the molecular hydrogen, creating CH+. Eventually the CH+ captures an electron to form the neutral CH molecule.

"This is the initiation of the whole carbon chemistry," said John Pearson, researcher at NASA's Jet Propulsion Laboratory, Pasadena, California, and study co-author. "If you want to form anything more complicated, it goes through that pathway."

Scientists combined Herschel data with models of molecular formation and found that ultraviolet light is the best explanation for how hydrocarbons form in the Orion Nebula.

The findings have implications for the formation of basic hydrocarbons in other galaxies as well. It is known that other galaxies have shocks, but dense regions in which ultraviolet light dominates heating and chemistry may play the key role in creating fundamental hydrocarbon molecules there, too.

"It's still a mystery how certain molecules get excited in the cores of galaxies," Pearson said. "Our study is a clue that ultraviolet light from massive stars could be driving the excitation of molecules there, too."

Herschel is a European Space Agency mission, with science instruments provided by consortia of European institutes and with important participation by NASA. While the observatory stopped making science observations in April 2013, after running out of liquid coolant as expected, scientists continue to analyze its data. NASA's Herschel Project Office is based at NASA's Jet Propulsion Laboratory, Pasadena, California. JPL contributed mission-enabling technology for two of Herschel's three science instruments. The NASA Herschel Science Center, part of IPAC, supports the U.S. astronomical community. Caltech manages JPL for NASA.

More information about Herschel is available at:

http://www.herschel.caltech.edu

http://www.nasa.gov/herschel

http://www.esa.int/SPECIALS/Herschel

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cloudy nights, sunny days on distant hot Jupiters

6 min read

Pat Brennan

The weather forecast for faraway, blistering planets called "hot Jupiters" might go something like this: Cloudy nights and sunny days, with a high of 2,400 degrees Fahrenheit (about 1,300 degrees Celsius, or 1,600 Kelvin).

These mysterious worlds are too far away for us to see clouds in their atmospheres. But a recent study using NASA's Kepler space telescope and computer modeling techniques finds clues to where such clouds might gather and what they're likely made of. The study was published in the Astrophysical Journal and is also available on the arXiv.

Hot Jupiters, among the first of the thousands of exoplanets (planets outside our solar system) discovered in our galaxy so far, orbit their stars so tightly that they are perpetually charbroiled. And while that might discourage galactic vacationers, the study represents a significant advance in understanding the structure of alien atmospheres.

Hot Jupiters are tidally locked, meaning one side of the planet always faces its sun and the other is in permanent darkness. In most cases, the "dayside" would be largely cloud-free and the "nightside" heavily clouded, leaving partly cloudy skies for the zone in between, the study shows.

"The cloud formation is very different from what we know in the solar system," said Vivien Parmentier, a NASA Sagan Fellow and postdoctoral researcher at the University of Arizona, Tucson, who was the lead author of the study.

A "year" on such a planet can be only a few Earth days long, the time the planet takes to whip once around its star. On a "cooler" hot Jupiter, temperatures of, say, 2,400 degrees Fahrenheit might prevail.

But the extreme conditions on hot Jupiters worked to the scientists’ advantage.

"The day-night radiation contrast is, in fact, easy to model," Parmentier said. “[The hot Jupiters] are much easier to model than Jupiter itself."

The scientists first created a variety of idealized hot Jupiters using global circulation models -- simpler versions of the type of computer models used to simulate Earth’s climate.

Then they compared the models to the light Kepler detected from real hot Jupiters. Kepler, which is now operating in its K2 mission, was designed to register the extremely tiny dip in starlight when a planet passes in front of its star, which is called a "transit." But in this case, researchers focused on the planets' "phase curves," or changes in light as the planet passes through phases, like Earth’s moon.

Matching the modeled hot Jupiters to phase curves from real hot Jupiters revealed which curves were caused by the planet’s heat, and which by light reflected by clouds in its atmosphere. By combining Kepler data with computer models, scientists were able to infer global cloud patterns on these distant worlds for the first time.

The new cloud view allowed the team to draw conclusions about wind and temperature differences on the hot Jupiters they studied. Just before the hotter planets passed behind their stars -- in a kind of eclipse -- a blip in the planet’s optical light curve revealed a "hot spot" on the planet’s eastern side.

And on cooler eclipsing planets, a blip was seen just after the planet re-emerged on the other side of the star, this time on the planet’s western side.

The early blip on hotter worlds reveals that powerful winds were pushing the hottest, cloud-free part of the atmosphere, normally found directly beneath its sun, to the east. Meanwhile, on cooler worlds, clouds could bunch up and reflect more light on the "colder," western side of the planet, causing the post-eclipse blip.

"We’re claiming that the west side of the planet’s dayside is more cloudy than the east side," Parmentier said.

While the puzzling pattern has been seen before, this research was the first to study all the hot Jupiters showing this behavior.

This led to another first. By figuring out how clouds are distributed, which is intimately tied to the planet’s overall temperature, scientists were able to determine what the clouds were probably made of.

Hot Jupiters are far too hot for water-vapor clouds like those on Earth. Instead, clouds on these planets are likely formed as exotic vapors condense to form minerals, chemical compounds like aluminum oxide, or even metals, like iron.

The science team found that manganese sulfide clouds probably dominate on "cooler" hot Jupiters, while silicate clouds prevail at higher temperatures. On these planets, the silicates likely "rain out" into the planet’s interior, vanishing from the observable atmosphere.

In other words, a planet’s average temperature, which depends on its distance from its star, governs the kinds of clouds that can form. That leads to different planets forming different types of clouds.

"Cloud composition changes with planet temperature," Parmentier said. "The offsetting light curves tell the tale of cloud composition. It’s super interesting, because cloud composition is very hard to get otherwise."

The new results also show that clouds are not evenly distributed on hot Jupiters, echoing previous findings from NASA’s Spitzer Space Telescope suggesting that different parts of hot Jupiters have vastly different temperatures.

The new findings come as we mark the 21st anniversary of exoplanet hunting. On Oct. 6, 1995, a Swiss team announced the discovery of 51 Pegasi b, a hot Jupiter that was the first planet to be confirmed in orbit around a sun-like star. Parmentier and his team hope their revelations about the clouds on hot Jupiters could bring more detailed understanding of hot Jupiter atmospheres and their chemistry, a major goal of exoplanet atmospheric studies.

NASA Ames manages the Kepler and K2 missions for NASA's Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado at Boulder. This work was performed in part under contract with JPL, funded by NASA through the Sagan Fellowship Program, executed by the NASA Exoplanet Science Institute.

For more information on the Kepler and the K2 mission, visit:

http://www.nasa.gov/kepler

For more information about exoplanets, visit:

https://exoplanets.nasa.gov/

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

Michele JohnsonAmes Research Center, Moffett Field, Calif.650-604-6982michele.johnson@nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Proxima Centauri Might be More Sunlike Than we Thought

4 min read

NASA Science Editorial Team

In August astronomers announced that the nearby star Proxima Centauri hosts an Earth-sized planet (called Proxima b) in its habitable zone. At first glance, Proxima Centauri seems nothing like our sun. It's a small, cool, red dwarf star only one-tenth as massive and one-thousandth as luminous as the sun. However, new research shows that it is sunlike in one surprising way: it has a regular cycle of starspots.

See more: ESO discovers Earth-size planet in habitable zone of nearest star

Starspots (like sunspots) are dark blotches on a star's surface where the temperature is a little cooler than the surrounding area. They are driven by magnetic fields. A star is made of ionized gases called plasma. Magnetic fields can restrict the plasma's flow and create spots. Changes to a star's magnetic field can affect the number and distribution of starspots.

Our sun experiences an 11-year activity cycle. At the solar minimum, the sun is nearly spot-free. At solar maximum, typically more than 100 sunspots cover less than one percent of the sun's surface on average.

The new study finds that Proxima Centauri undergoes a similar cycle lasting seven years from peak to peak. However, its cycle is much more dramatic. At least a full one-fifth of the star's surface is covered in spots at once. Also, some of those spots are much bigger relative to the star's size than the spots on our sun.

"If intelligent aliens were living on Proxima b, they would have a very dramatic view," says lead author Brad Wargelin of the Harvard-Smithsonian Center for Astrophysics (CfA).

See more: Vulcan may not be real, but Spock’s home system is

Astronomers were surprised to detect a stellar activity cycle in Proxima Centauri because its interior is expected to be very different from the sun's. The outer third of the sun experiences a roiling motion called convection, similar to water boiling in a pot, while the sun's interior remains relatively still. There is a difference in the speed of rotation between these two regions. Many astronomers think the shear arising from this difference is responsible for generating the sun's magnetic activity cycle.

In contrast, the interior of a small red dwarf like Proxima Centauri should be convective all the way into the star's core. As a result, it shouldn't experience a regular cycle of activity.

"The existence of a cycle in Proxima Centauri shows that we don't understand how stars' magnetic fields are generated as well as we thought we did," says Smithsonian co-author Jeremy Drake.

The study does not address whether Proxima Centauri's activity cycle would affect the potential habitability of the planet Proxima b. Theory suggests that flares or a stellar wind, both of which are driven by magnetic fields, could scour the planet and strip away any atmosphere. In that case, Proxima b might be like Earth's Moon - located in the habitable zone, but not at all friendly to life.

See more: Earth-like exoplanets may have magnetic fields capable of protecting life

"Direct observations of Proxima b won't happen for a long time. Until then, our best bet is to study the star and then plug that information into theories about star-planet interactions," says co-author Steve Saar.

The team detected the activity cycle using ground-based observations from the All Sky Automated Survey combined with space-based X-ray measurements by several missions, including Swift, Chandra, and XMM-Newton. Their results have been accepted for publication in the Monthly Notices of the Royal Astronomical Society and appear online.

Headquartered in Cambridge, Mass., the Harvard-Smithsonian Center for Astrophysics (CfA) is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Nearby Exo-Earth Family Withstands Extreme Scrutiny

5 min read

NASA Science Editorial Team

When it comes to exoplanets, astronomers have realized that they only know the properties of the planets they discover as well as they know the properties of the stars being orbited. For a planet's size, precisely characterizing the host star can mean the difference in our understanding of whether a distant world is small like Earth or huge like Jupiter.

For astronomers to determine the size of an exoplanet—planets outside the solar system—depends critically on knowing not only the radius of its host star but also whether that star is single or has a close companion. Consider that about half of the stars in the sky are not one but two stars orbiting around each other, this makes knowing the binary property of a star paramount.

One particularly interesting and relatively nearby star, named TRAPPIST-1, recently caught the attention of a team of researchers. They wanted to determine if TRAPPIST-1, which is home to three small, potentially rocky planets—one of which orbits in the temperate habitable zone where liquid water might pool on the surface—was a single star like the sun, or if it had a companion star. If TRAPPIST-1 did have a companion star, the discovered planets will have larger sizes, possibly large enough to be ice giants similar to Neptune.

Steve Howell

NASA

If an exoplanet orbits a star in a binary system but astronomers believe the starlight captured by the telescope is from a single star, the real radius of the planet will be larger than measured. The difference in the measured size of the exoplanet can be small ranging from 10 percent to more than a factor of two in size, depending on the brightness of the companion star in the system.

To confirm or deny the single star nature of TRAPPIST-1, Steve Howell, senior research scientist at NASA's Ames Research Center at Moffett Field, California, led an investigation of the star. Using a specially designed camera, called the Differential Speckle Survey Instrument or DSSI, Howell and his team measured the rapid disturbances in the light emitted by the star caused by the Earth's atmosphere and corrected for them. The resultant high-resolution image revealed that the light coming from the TRAPPIST-1 system is from a single star.

With the confirmation that no other companion star resides in the vicinity of TRAPPIST-1, the research team's result validates not only that transiting planets are responsible for the periodic dips seen in the star's brightness but that they are indeed Earth-size and may likely to be rocky worlds.

"Knowing that a terrestrial-size potentially rocky planet orbits in the habitable zone of a star only 40 light-years from the Earth is an awesome finding," said Howell. "The TRAPPIST-1 system will continue to be studied in great detail as these transiting exoplanets offer one of the best chances to characterize the atmosphere of an alien world."

Mounted on the 8-meter Gemini Observatory South telescope in Chile, the DSSI provided astronomers with the highest resolution images available today from a single ground-based telescope. The nearness of TRAPPIST-1 allowed astronomers to peer deep into the system, looking closer than Mercury's orbit to our sun.

The paper the result is based on is published in the September 13th issue of The Astrophysical Journal Letters.

Interest in the recently-discovered TRAPPIST-1 with its three Earth-size planets is high. Astronomically speaking, at 40 light-years from Earth, the system is a hop, skip and a jump away. The star itself is a dim M-type star, which, relative to most stars, is very small and cool, but making transit detection of small planets easier.

Further detailed measurement of the planetary transits seen in TRAPPIST-1 will begin later this year when NASA's Kepler space telescope in its K2 mission will precisely monitor minute changes in the light emitted from the star for a period of about 75 days.

The space-based observations from the Kepler spacecraft will provide extremely precise measurements of the planet transit shapes allowing for more refined radius and orbital period determination. Noting variations in the mid-time of the transit events can also help astronomers determine the planet masses. Additionally, the new observations will be searched for more transiting planets in the TRAPPIST-1 system.

Speckle interferometry, the imaging technique used by the DSSI, is a powerful asset in the astronomer's toolkit as it provides a unique capability to characterize the environment around distant stars. The technique provides ultra high-resolution images by taking multiple extremely short (40-60 millisecond) exposures of a star to capture fine detail in the received light and “freeze” the turbulence caused by Earth’s atmosphere.

By combining the many thousands of exposures and using mathematical techniques to remove the momentary distortions caused by Earth’s atmosphere, the final result provides a resolution equal to the theoretical limit of what the 8-meter Gemini telescope would produce if no atmosphere were present.

Howell and his team at NASA Ames are currently undertaking the construction of two new speckle interferometric instruments. One of the new instruments will be delivered this fall to the 3.5-meter WIYN telescope located at Kitt Peak National Observatory outside of Tucson, Arizona, where it will be used by the NN_EXPLORE guest observer research program. The other is being developed for the Gemini Observatory North telescope located on Mauna Kea in Hawaii.

NASA Ames manages the Kepler and K2 missions for NASA's Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado at Boulder.

To learn more about the result from the Gemini Observatory, visit:

http://www.gemini.edu/node/12567

For more information on the Kepler and the K2 mission, visit:

http://www.nasa.gov/kepler

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Finds Planet Orbiting Pair of Stars

3 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Two's company, but three might not always be a crowd — at least in space.

Astronomers using NASA's Hubble Space Telescope, and a trick of nature, have confirmed the existence of a planet orbiting two stars in the system OGLE-2007-BLG-349, located 8,000 light-years away towards the center of our galaxy.

The planet orbits roughly 300 million miles from the stellar duo, about the distance from the asteroid belt to our sun. It completes an orbit around both stars roughly every seven years. The two red dwarf stars are a mere 7 million miles apart, or 14 times the diameter of the moon's orbit around Earth.

The Hubble observations represent the first time such a three-body system has been confirmed using the gravitational microlensing technique. Gravitational microlensing occurs when the gravity of a foreground star bends and amplifies the light of a background star that momentarily aligns with it. The particular character of the light magnification can reveal clues to the nature of the foreground star and any associated planets.

The three objects were discovered in 2007 by an international collaboration of five different groups: Microlensing Observations in Astrophysics (MOA), the Optical Gravitational Lensing Experiment (OGLE), the Microlensing Follow-up Network (MicroFUN), the Probing Lensing Anomalies Network (PLANET), and the Robonet Collaboration. These ground-based observations uncovered a star and a planet, but a detailed analysis also revealed a third body that astronomers could not definitively identify.

"The ground-based observations suggested two possible scenarios for the three-body system: a Saturn-mass planet orbiting a close binary star pair or a Saturn-mass and an Earth-mass planet orbiting a single star," explained David Bennett of the NASA Goddard Space Flight Center in Greenbelt, Maryland, the paper's first author.

The sharpness of the Hubble images allowed the research team to separate the background source star and the lensing star from their neighbors in the very crowded star field. The Hubble observations revealed that the starlight from the foreground lens system was too faint to be a single star, but it had the brightness expected for two closely orbiting red dwarf stars, which are fainter and less massive than our sun. "So, the model with two stars and one planet is the only one consistent with the Hubble data," Bennett said.

Bennett's team conducted the follow-up observations with Hubble's Wide Field Planetary Camera 2. "We were helped in the analysis by the almost perfect alignment of the foreground binary stars with the background star, which greatly magnified the light and allowed us to see the signal of the two stars," Bennett explained.

Kepler has discovered 10 other planets orbiting tight binary stars, but these are all much closer to their stars than the one studied by Hubble.

Now that the team has shown that microlensing can successfully detect planets orbiting double-star systems, Hubble could provide an essential role in this new realm in the continued search for exoplanets.

The team's results have been accepted for publication in The Astronomical Journal.

Contact:

Felicia ChouNASA Headquarters, Washington202-358-0257felicia.chou@nasa.gov

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore410-338-4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

David BennettNASA's Goddard Space Flight Center, Greenbelt, Md.301-286-5473david.p.bennett@nasa.gov

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s TESS Mission Will Provide Exciting Exoplanet Targets for Years to Come

5 min read

NASA’s search for planets outside of our solar system has mostly involved very distant, faint stars. NASA’s upcoming Transiting Exoplanet Survey Satellite (TESS), by contrast, will look at the brightest stars in our solar neighborhood.

After TESS launches, it will quickly start discovering new exoplanets that ground-based observatories, the Hubble Space Telescope and, later, the James Webb Space Telescope, will target for follow-up studies. TESS is scheduled to launch no later than June 2018. Astronomers are eagerly anticipating the possibility that, in the near future, all three space missions could be studying the sky at the same time.

“The problem is that we’ve had very few exoplanet targets that are good for follow-up,” said TESS Project Scientist Stephen Rinehart at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “TESS will change that.”

Planets around closer, brighter stars are ideal for follow-up study because they’ll produce stronger signals than planets around more distant stars. These planets have a higher signal-to-noise ratio, which measures the ratio of useful information — the signal — to non-useful information — the noise — that a telescope receives. These signals might also include a chemical sampling of an exoplanet’s atmosphere, which is an exciting prospect for scientists hoping to search for signs of life on distant worlds.

TESS will do the initial roundup of exoplanets, with the potential to identify thousands during its projected two-year mission. One of TESS’ main science goals is to identify 50 rocky worlds, like Earth or Venus, whose masses can be measured.

“The search for exoplanets is a bit like a funnel where you pour in lots of stars,” said TESS Deputy Science Director Sara Seager at the Massachusetts Institute of Technology (MIT), Cambridge. “At the end of the day, you have loads of planets, and from there you need to find the rocky ones.”

The TESS Science Center will help identify and prioritize the TESS Objects of Interest (TOI) for follow-up. TOI are objects that scientists believe could be exoplanets based on TESS data. Ground-based telescopes will confirm which TOI are exoplanets, and from there will help determine which are rocky. The center is a partnership between MIT’s Physics Department and Kavli Institute for Astrophysics and Space Research — where TESS Principle Investigator George Ricker resides — the Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, and NASA’s Ames Research Center in Moffett Field, California.

The main thing space- and ground-based telescopes hope to find out about the TESS targets with follow-up observations is what these exoplanet atmospheres are like. Exoplanet atmosphere exploration is one of the Webb telescope’s four main science goals.

NASA’s Webb telescope and ground-based telescopes will determine the atmospheres of exoplanets using spectroscopy. In this process, telescopes look at the chemical signatures of the light passing through exoplanet atmospheres. This signature can tells scientists what chemicals are in the planetary atmosphere, and how much of each there are. It can also help scientists determine whether a planet could be habitable.

“There are a couple of things we like to see as a potential for habitability – one of them is water, which is probably the single most important, because as far as we know, all life that we’re familiar with depends on water in some way," Rinehart said. "The other is methane, which on our Earth is produced almost entirely biologically. When you start seeing certain combinations of all of these things appearing together – water, methane, ozone, oxygen – it gives you a hint that the chemistry is out of equilibrium. Naturally, planets tend to be chemically stable. The presence of life throws off this balance."

Exoplanets aren't the only science that will come out of the TESS all-sky survey, however. While scientists expect to spot a transit signal that could reveal exoplanets around only about one out of 100 stars, virtually every star in the sky will be monitored carefully and continuously for at least 27 days, resulting in a wide variety of variability to be explored.

The TESS Guest Investigator (GI) Program will allow for deeper investigations of astronomically interesting objects, either through TESS data alone, or by identifying interesting variables for further study with the Webb telescope, Hubble and other ground- and space-based telescopes. The GI Program will look at variable objects, such as flare stars, active galaxies and supernovae, and may even discover optical counterparts to distant transient events, such as gamma-ray bursts. Only the number and type of exciting proposed ideas the program receives limit what TESS will find through the GI Program.

Between the mission's exoplanet survey and the GI Program, TESS will provide the best follow-up targets for many missions to come.

"TESS not only will provide targets for the Webb telescope, but for every telescope we plan to build on the ground and in space over the next two decades," said Mark Clampin, director of the Astrophysics Science Division at Goddard. With such an exciting future, scientists from around the world are watching the progress of the TESS mission, and anxiously awaiting its launch.

Related Links

By Elaine HuntNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

To Boldly Go: How ‘Star Trek’ Inspired NASA’s Planet Hunters

8 min read

Pat Brennan

The 1960s "Star Trek" series, canceled after only three seasons for want of stronger ratings, roared back from oblivion to become one of the world’s most successful film and television franchises. As its 50th anniversary approaches, the show remains a palpable presence within NASA.

Some scientists and engineers are partial to the original series, with its 1960s hairdos, quick-drawing Captain Kirk and soaring musical score. Others prefer the “Next Generation” and its Shakespearean Captain Picard, or fondly recall other "Star Trek" spinoffs such as “Deep Space Nine,” “Voyager” and “Enterprise.”

All of them say various "Star Trek" manifestations, on television or the big screen, made a lasting impression, helping fire their passion for space exploration.

While Mr. Spock's home planet Vulcan (orbited here by the Enterprise) is imaginary, the triple-star system where it's said to orbit--40 Eridani--is real. In the full system view, the orange and blue X's in this visualization indicate the barycenters, or the gravitational centers around which the stars orbit.

Astronomer and astrophysicist at JPL who hunts for planets beyond our solar system using the Spitzer Space Telescope and other instruments.

"Star Trek" is one of the earliest shows I ever remember watching. My brother and I watched it. I’m an Armenian, born in Iran. When I first watched it, it was in Farsi. The Farsi name was "Pishtazane Faza." We called it “Mr. Spock,” or the “Spock show.” Both of us, I think, identified with that character. I think I identified with his scientific bent. It merged well with my scientific interest. What is the logical approach to solving problems, learning about the universe, and so on? That spoke to me greatly. I was 10 years old when I came here [to California]. The resonance was being the outsider. Spock [part human, part Vulcan] was an outsider; he was not even a pure Vulcan. This merged character was what I was—born Armenian in Iran, growing up in the United States. I was this mesh of cultures. He has these two sides to him; for me there were even more sides.

Astrophysicist at NASA’s Goddard Space Flight Center who studies planet formation and is helping conceptualize a possible future space telescope called LUVOIR (Large Ultraviolet / Optical / Infrared surveyor).

Growing up without a TV at home, I didn’t see "Star Trek" til I went away to college at MIT. At my coed fraternity there, we would go to the dining room, put our dinners on plates, and take them to the TV room. A whole gang of us would watch “Star Trek: the Next Generation” together every day. I took to it like a duck to water. Obviously, my captain is Captain Picard, although my favorite series is probably “Deep Space Nine.” For me, it wasn’t only a vision of the diversity of worlds and life that might be out there that drew me in. It was also "Star Trek’s" vision of how humanity itself is changed by the exploration of space and then by meeting others who are genuinely, fundamentally different from ourselves. The "Star Trek" vision is a very optimistic, sunny vision of humanity at peace with itself, and with a greater appreciation for—and a greater value placed on—personal development and satisfaction in your work.

Technology manager for NASA's Exoplanet Exploration Program, based at JPL.

I dedicated my Ph.D. dissertation to several folks, and one of them was to the "Star Trek" series. I dedicated it to "Star Trek," Carl Sagan, the scientists and engineers of Voyager 1 and 2, Isaac Asimov and my father.

When I was a younger man I was fascinated by exploration. All the books I read were biographies of explorers, but mostly sort of the Italian and Spanish explorers of the 15th century and onward. Along that theme, "Star Trek" was all about missions of exploration. It wasn't doing science. They figured, “We'll do the science later. Let's go out and explore, see what we can find.” That just took my interest in exploration to the ultimate level: the exploration of the cosmos.

Professor of planetary science and physics at the Massachusetts Institute of Technology and a JPL affiliate whose research seeks to analyze light from planets orbiting distant stars to learn which gases are present in their atmospheres.

Watching TV and doing math were just totally separate things in my mind. ("Star Trek") didn't really necessarily inspire me, in the sense of, “Wow, I want to go travel to another planet.” I think what it did was really incredible: It was that it made it okay. Even though the TV shows defy logic in traveling faster than light and teleportation and everything—the transporter—it still makes it part of our cultural consciousness: there are planets, probably life out there.

Chief scientist for NASA's Exoplanet Exploration Program, based at JPL.

In the 60s, for the "Star Trek" first run, I was little—five years old. I know I saw it back then because it is in my kindergarten coloring books. One episode, with the planet-killer machine, must have made a big, scary impression on me, because I made drawings of it blasting things. "Star Trek" presents a widely accessible vision of what might be out there in the broader universe. People's interest in the show can be a launching point to discover the real science of astronomy and the real engineering of space travel. A lot of people in aerospace or science are fans of the show, not because we want to act out episodes, but because we'd love to travel/explore/learn about our universe. We'd like to do this not just for ourselves but for the whole world, for all people who are curious about what's out there and how humanity fits in.

Director and chief engineer for NASA's Dawn mission, which orbited the two most massive bodies in the main asteroid belt between Mars and Jupiter; Rayman is based at JPL.

I started watching the "Star Trek" original series when it was on in reruns, when I was a youngster. I was a very avid "Star Trek" fan. I'd already been a very serious space buff; I knew in the fourth grade that I wanted to get a Ph.D. in physics. I only ever wanted to work for NASA. I started writing to JPL when I was nine years old. Two of the missions I worked on at JPL were Deep Space 1 and Dawn, which I'm working on now. Those are NASA's only two planetary missions to use ion propulsion. The first time I ever heard of ion propulsion was in a "Star Trek" episode called “Spock's Brain.”

Before I ever heard of "Star Trek" I was committed to the exploration of space, but "Star Trek" depicted the future I wanted to live in. They get to go to a new planet every week. They have all this wonderful technology. Sure, there was action and adventure, and that appeals to many people, including me. But more strongly appealing was the adventure of exploring the cosmos, at the same time expressing this vision of opportunity for everybody, and peace, and a noble spirit of adventure.

Program manager for NASA's Exoplanet Exploration Program, JPL.

It started real early for me in my household. "Sesame Street" and "Star Trek" were required watching. My mother said this was very important.

I still remember my first episode. It was the Horta [“Devil in the Dark”]. My parents were very interested in the space program, the moon landing, the space age. My mother projected this onto us, but "Star Trek" really gave me a sense of wonder—going to other stars on a spaceship, the stars flying by, that image on the screen. "Star Trek" always spoke to that greater vision, that greater achievement, what mankind could become. And it was set in the future, when many of the troubles of the current day have been worked through. That was the real theme Gene Roddenberry [the creator of "Star Trek"] worked into the episodes.

Project Scientist, NASA K2 Mission (Kepler space telescope), NASA Ames Research Center.

What really struck me about the "Star Trek" shows was that there were a lot of moral issues in them. It was kind of hidden, but not hidden that well. The other thing that struck me is that they would go to planets. They would find lots of planets. That was cool at the time, because we didn't know about exoplanets. They never talked about what kind of star it was, or the orbit, or anything. They never really talked about the habitable zone, things like that. I just always loved science fiction. I liked that it showed the possibilities, let me dream about what I might like to do someday.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Jupiter’s extended family? A billion or more

9 min read

Alicia Cermak

Our galaxy is home to a bewildering variety of Jupiters: hot ones, cold ones, giant versions of our own giant, pint-sized pretenders only half as big around.

Astronomers say that in our galaxy alone, a billion or more Jupiter-like worlds could be orbiting stars other than our sun. And we can use them to gain a better understanding of our solar system and our galactic environment, including the prospects for finding life. We need only turn our instruments and probes to our own backyard.

We just need to see Jupiter as an exoplanet.

An exoplanet unlike any seen in our solar system, WASP-12b is a 'hot Jupiter.' A hot Jupiter is a gas giant like our own Jupiter, but scorching hot because it orbits close to its star. This particular hot Jupiter is egg-shaped because of the pull exerted by the strong gravity of its star, which it orbits in one day.

See more hot Jupiters in 3D

This might be the best chance in all of human history. Juno, a NASA probe the size of a basketball court, hurtled toward a rendezvous with Jupiter on July 4, and began a series of long, looping orbits around the boss hog of our solar system. Juno is expected to capture the clearest, most detailed images of the gas giant ever seen, and with a variety of instruments plumb the secrets below Jupiter’s roiling atmosphere.

It will be a very long time, if ever, before scientists who study exoplanets—planets orbiting other stars—get the chance to watch an interstellar probe coast into orbit around an exo-Jupiter, dozens or hundreds of light-years away. But if they ever do, it’s a safe bet the scene will summon echoes of Juno.

“The only way we’re going to ever be able to understand what we see in those extrasolar planets is by actually understanding our system, our Jupiter itself,” said David Ciardi, an astronomer with NASA’s Exoplanet Science Institute (NExSci) at the California Institute of Technology in Pasadena, Calif.

Juno’s detailed examination of Jupiter could provide insights into the history, and future, of our solar system. The tally of confirmed exoplanets so far includes hundreds in Jupiter’s size-range, and many more that are larger or smaller.

The so-called hot Jupiters acquired their name for a reason: They are in tight orbits around their stars that make them sizzling hot, completing a full revolution—the planet’s entire year—in what would be a few days on Earth. And they’re charbroiled along the way.

But why does our solar system lack a “hot Jupiter?” Or is this, perhaps, the fate awaiting our own Jupiter billions of years from now, as it gradually spirals toward the sun, or as a swollen sun expands to meet it?

Not likely, Ciardi says; such planetary migrations probably occur early in the life of a solar system.

“In order for migration to occur, there needs to be dusty material within the system,” he said. “Enough to produce drag. That phase of migration is long since over for our solar system.”

Jupiter itself might already have migrated from farther out in the solar system, although no one really knows, he said.

If Juno's measurements can help settle the question, they could take us a long way toward understanding Jupiter's influence on the formation of Earth– and, by extension, the formation of other "Earths" that might be scattered among the stars.

"Juno is measuring water vapor in the Jovian atmosphere," said Elisa Quintana, a research scientist at the NASA Ames Research Center in Moffett Field, California. "This allows the mission to measure the abundance of oxygen on Jupiter. Oxygen is thought to be correlated with the initial position from which Jupiter originated."

If Jupiter's formation started with large chunks of ice in its present position, then it would have taken a lot of water ice to carry in the heavier elements which we find in Jupiter. But a Jupiter that formed farther out in the solar system, then migrated inward, could have formed from much colder ice, which would carry in the observed heavier elements with a smaller amount of water. If Jupiter formed more directly from the solar nebula, without ice chunks as a starter, then it should contain less water still. Measuring the water is a key step in understanding how and where Jupiter formed.

More: Finding out what makes hot Jupiters tick

That's how Juno's microwave radiometer, which will measure water vapor, could reveal Jupiter's ancient history.

"If Juno detects a high abundance of oxygen, it could suggest that the planet formed further out," Quintana said.

A probe dropped into Jupiter by the Galileo spacecraft in 1995 found high winds and turbulence, but the expected water seemed to be absent. Scientists think Galileo's one-shot probe just happened to drop into a dry area of the atmosphere, but Juno will survey the entire planet from orbit.

Where Jupiter formed, and when, also could answer questions about the solar system's "giant impact phase," a time of crashes and collisions among early planet-forming bodies that eventually led to the solar system we have today.

Our solar system was extremely accident-prone in its early history -- perhaps not quite like billiard balls caroming around, but with plenty of pileups and fender-benders.

"It definitely was a violent time," Quintana said. "There were collisions going on for tens of millions of years. For example, the idea of how the moon formed is that a proto-Earth and another body collided; the disk of debris from this collision formed the moon. And some people think Mercury, because it has such a huge iron core, was hit by something big that stripped off its mantle; it was left with a large core in proportion to its size."

Part of Quintana's research involves computer modeling of the formation of planets and solar systems. Teasing out Jupiter's structure and composition could greatly enhance such models, she said. Quintana already has modeled our solar system's formation, with Jupiter and without, yielding some surprising findings.

"For a long time, people thought Jupiter was essential to habitability because it might have shielded Earth from the constant influx of impacts [during the solar system's early days] which could have been damaging to habitability," she said. "What we've found in our simulations is that it's almost the opposite. When you add Jupiter, the accretion times are faster and the impacts onto Earth are far more energetic. Planets formed within about 100 million years; the solar system was done growing by that point," Quintana said.

"If you take Jupiter out, you still form Earth, but on timescales of billions of years rather than hundreds of millions. Earth still receives giant impacts, but they're less frequent and have lower impact energies," she said.

Another critical Juno measurement that could shed new light on the dark history of planetary formation is the mission's gravity science experiment. Changes in the frequency of radio transmissions from Juno to NASA's Deep Space Network will help map the giant planet's gravitational field.

Knowing the nature of Jupiter's core could reveal how quickly the planet formed, with implications for how Jupiter might have affected Earth's formation.

And the spacecraft's magnetometers could yield more insight into the deep, internal structure of Jupiter by measuring its magnetic field.

"We don't understand a lot about Jupiter's magnetic field," Ciardi said. "We think it's produced by metallic hydrogen in the deep interior. Jupiter has an incredibly strong magnetic field, much stronger than Earth's."

Mapping Jupiter's magnetic field also might help pin down the plausibility of proposed scenarios for alien life beyond our solar system.

Earth's magnetic field is thought to be important to life because it acts like a protective shield, channeling potentially harmful charged particles and cosmic rays away from the surface.

"If a Jupiter-like planet orbits its star at a distance where liquid water could exist, the Jupiter-like planet itself might not have life, but it might have moons which could potentially harbor life," he said.

An exo-Jupiter’s intense magnetic field could protect such life forms, he said. That conjures visions of Pandora, the moon in the movie "Avatar" inhabited by 10-foot-tall humanoids who ride massive, flying predators through an exotic alien ecosystem.

Juno's findings will be important not only to understanding how exo-Jupiters might influence the formation of exo-Earths, or other kinds of habitable planets. They'll also be essential to the next generation of space telescopes that will hunt for alien worlds. The Transiting Exoplanet Survey Satellite (TESS) will conduct a survey of nearby bright stars for exoplanets beginning in June 2018, or earlier. The James Webb Space Telescope, expected to launch in 2018, and WFIRST (Wide-Field Infrared Survey Telescope), with launch anticipated in the mid 2020s, will attempt to take direct images of giant planets orbiting other stars.

"We're going to be able to image planets and get spectra," or light profiles from exoplanets that will reveal atmospheric gases, Ciardi said. Juno's revelations about Jupiter will help scientists to make sense of these data from distant worlds.

"Studying our solar system is about studying exoplanets," he said. "And studying exoplanets is about studying our solar system. They go together."

To learn more about NASA's Juno mission, visit:

www.nasa.gov/mission_pages/juno

Preston DychesJet Propulsion Laboratory, Pasadena,
Calif.818-354-7013preston.dyches@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s

other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Three Giant Worlds Found Orbiting Twin Suns

4 min read

NASA Science Editorial Team

◆ Three 'Tatooine'-like planets have been discovered orbiting two Sun-like stars.

◆ The planets are large like Jupiter, and may help scientists learn why our solar system is different from others found in the galaxy.

A team of Carnegie scientists has discovered three giant planets in a binary star system composed of stellar "twins" that are also effectively siblings of our sun. One star hosts two planets and the other hosts the third. The system represents the smallest-separation binary in which both stars host planets that has ever been observed. The findings, which may help explain the influence that giant planets like Jupiter have over a solar system’s architecture, have been accepted for publication in The Astronomical Journal.

New discoveries coming from the study of exoplanetary systems will show us where on the continuum of ordinary to unique our own solar system’s layout falls. So far, planet hunters have revealed populations of planets that are very different from what we see in our solar system. The most-common exoplanets detected are so-called super-Earths, which are larger than our planet but smaller than Neptune or Uranus. Given current statistics, Jupiter-sized planets seem fairly rare—having been detected only around a small percentage of stars.

This is of interest because Jupiter’s gravitational pull was likely a huge influence on our solar system’s architecture during its formative period. So the scarcity of Jupiter-like planets could explain why our home system is different from all the others found to date.

The new discovery from the Carnegie team is the first exoplanet detection made based solely on data from the Planet Finder Spectrograph—developed by Carnegie scientists and mounted on the Magellan Clay Telescopes at Carnegie’s Las Campanas Observatory. PFS is able to find large planets with long-duration orbits or orbits that are very elliptical rather than circular, including the new trio of planets discovered in this `”twin’” star study. This special capability comes from the long observing baseline of PFS; it has been taking observations for six years.

Led by Johanna Teske, the team included a number of Carnegie scientists from both the Department of Terrestrial Magnetism in Washington, DC, and the Carnegie Observatories in Pasadena, CA, as well as Steve Vogt of the University of California Santa Cruz.

“We are trying to figure out if giant planets like Jupiter often have long and, or eccentric orbits,” Teske explained. “If this is the case, it would be an important clue to figuring out the process by which our solar system formed, and might help us understand where habitable planets are likely to be found.”

The twin stars studied by the group are called HD 133131A and HD 133131B. The former hosts two moderately eccentric planets, one of which is, at a minimum, about 1.5 times Jupiter’s mass and the other of which is, at a minimum, just over half Jupiter’s mass. The latter hosts one moderately eccentric planet with a mass at least 2.5 times Jupiter’s.

The two stars themselves are separated by only 360 astronomical units (AU). One AU is the distance between the Earth and the sun. This is extremely close for twin stars with detected planets orbiting the individual stars. The next-closest binary system that hosts planets is comprised of two stars that are about 1,000 AU apart.

The system is even more unusual because both stars are “metal poor,” meaning that most of their mass is hydrogen and helium, as opposed to other elements like iron or oxygen. Most stars that host giant planets are "metal rich.” Only six other metal-poor binary star systems with exoplanets have ever been found, making this discovery especially intriguing.

Adding to the intrigue, Teske used very precise analysis to reveal that the stars are not actually identical “twins” as previously thought, but have slightly different chemical compositions, making them more like the stellar equivalent of fraternal twins.

This could indicate that one star swallowed some baby planets early in its life, changing its composition slightly. Alternatively, the gravitational forces of the detected giant planets that remained may have had a strong effect on fully-formed small planets, flinging them in towards the star or out into space.

“The probability of finding a system with all these components was extremely small, so these results will serve as an important benchmark for understanding planet formation, especially in binary systems,” Teske explained.

The other members of Teske’s team were Carnegie’s Stephen Shectman, Matías Díaz, Paul Butler, Jeffrey Crane, and Pamela Arriagada.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Top 10 Star Trek Destinations Chosen by NASA Scientists

7 min read

NASA Science Editorial Team

What would happen if the crew of the Starship Enterprise handed over the controls to NASA scientists and engineers? It turns out many are avid Star Trek fans with lengthy itineraries in mind. We asked a few of them to pick their favorite destinations in the Star Trek universe, to tell us why, and to let us know if they resemble any of the thousands of actual exoplanets—planets orbiting other stars—that have been discovered so far.

What is perhaps the most famous Star Trek planet was placed by creator Gene Roddenberry in a real star system: 40 Eridani. This trinary system of three dwarf stars, about 16 light-years from Earth, could play host to exoplanets; none have been detected there so far. The most massive is 40 Eridani A, chosen as Vulcan's home world. Home to the "pointy eared, green blooded" Vulcans and to Star Trek's iconic Mr. Spock, Vulcan is said to be a hotter, more massive planet than Earth, with stronger gravity and a thinner atmosphere. Desert and mountainous expanses are interspersed with seas. The planet makes an appearance in several Star Trek films and series episodes and (spoiler alert) is destroyed in J.J. Abrams' alternate timeline. An example of a real exoplanet being destroyed—by its own sun, not vengeful aliens—is HD 209458b, a "hot Jupiter" orbiting so close to its star that its atmosphere is being blown away into space, leaving a large, detectable tail.

An icy "M-class" (Star Trek's term for "Earth-like") moon of a much larger planet—a gas giant—that is home to soft-spoken humanoids with blue skin, white hair and stylish antennae. A bit of a dust-up takes place in the original Star Trek series when an Orion poses as an Andorian during an ambassadorial mission ("Journey to Babel"). Definitive "exo-moons" have yet to be discovered, but some could be both icy and habitable. In our solar system, gas giants play host to icy moons, such as Jupiter's Europa or Saturn's Enceladus, that possess subsurface oceans locked inside shells of ice. NASA missions are searching for lifeforms that might exist in these cold, dark habitats.

Another Trek M-class planet known for its engineered tropical climate and its welcoming humanoid population. This earns it a designation as a "pleasure planet" from the United Federation of Planets, of which it is a member. Crew members from the "Next Generation," "Deep Space Nine" and "Enterprise" series all paid visits there. The planet is said to orbit a binary, or double, star system—in Star Trek fan lore, Epsilon Ceti, a real star system some 79 light-years from Earth. While no real planets have yet been discovered around these stars, many exoplanets have been found in orbit around binaries. The first unambiguous such discovery, Kepler-16b found in 2011, is cold, gaseous and Saturn-sized, but still invites comparisons to Tatooine, the double-sunset planet in the competing space franchise Star Wars. A 2014 study suggested that as much as half the stars that play host to exoplanets could be binaries– equaling billions of worlds.

This is another amusement park of a planet—provided someone lets you in on it before you beam down. Unwitting members of the original crew are assailed by strafing aircraft, a jousting knight and a laughing bully named Finnegan ("Shore Leave") before they realize it's all just in good fun—manufactured in underground factories straight from the crew members' imaginations. In real life, astronauts aboard the International Space Station print out plastic tools and containers with their own 3-D printer, and NASA's Jet Propulsion Laboratory in Pasadena, Calif., is among the research centers experimenting with this technology. But the "Shore Leave" planet takes it to a whole new level.

"Star Trek: Into Darkness" finds Captain Kirk and Dr. McCoy fleeing from chalk-skinned aliens through a red jungle. Welcome to planet Nibiru. In the second installment of the latest round of Star

Trek films Kirk interferes, yet again, with a primitive culture, even if it is to save their lives. Red or even black vegetation could cover land surfaces on real exoplanets that orbit cooler, redder stars, an adaptation meant to gather as much light for photosynthesis as possible. Several planets discovered by NASA's Kepler space telescope could fit this profile, orbiting in the "habitable zones" of red dwarf stars—where liquid water can exist on a planetary surface. Perhaps the most famous is Kepler-186f, only 10 percent larger than Earth in diameter, orbiting a star some 500 light-years away. At high noon, the surface of this planet would look something like dusk on Earth.

A star best known in the Star Trek universe as the site of a fierce battle in which a multitude of "Star Trek: Next Generation" ships are defeated by the Borg ("Best of Both Worlds"). But Wolf 359 is a real star, one of the closest to Earth at a distance of 7.8 light-years. Wolf 359 is also a likely observational target for the Kepler space telescope in the upcoming Campaign 14 of its "K2" mission.

Another case of Captain Kirk playing fast and loose with the Prime Directive—that is, the prohibition on interfering with civilizations on other planets ("A Taste of Armageddon"). These two planets are neighbors, sharing a star system. So, of course, they've been at war for centuries. Real exoplanets have shown no signs of interplanetary war, although multiple rocky worlds have been discovered orbiting single stars. One of the latest examples: A cool dwarf star called TRAPPIST-1, orbited by three planets in Earth's size-range; two have a chance of being in the star's habitable zone, with possible Earth-like atmospheres. The Kepler space telescope will further study the star TRAPPIST-1 in the upcoming Campaign 12 of its "K2" mission.

The planets Romulus and Remus are home to the Romulan Empire (ancient Rome, anyone?), although Remus seemed to have gotten the raw end of the deal. Remus is tidally locked, one face always turned to its star, where a lower caste of Romulan society labor in dilithium mines. Reference is made to Remus in the original series as the Enterprise gives chase to a Romulan warship, called a bird of prey ("Balance of Terror"), and in the film "Star Trek: Nemesis." Tidally locked worlds might well be a real thing, with many possible candidates among the thousands of exoplanets discovered with NASA's Kepler space telescope. The habitable portion of the surface of such planets might be confined to a band between the day and night sides called the "terminator zone"—a.k.a. the twilight zone. On these planets, one hemisphere would be seared by its sun, the other plunged permanently…into darkness.

A rocky world lacking an atmosphere, perhaps similar to Mars, that is the site of a Federation mining colony ("Devil in the Dark," original series). While humans must maintain an artificial underground environment to survive, the innards of the planet are a comfortable home to an alien species known as the "Horta." Their rock-like biochemistry is based on silicon, rather than carbon, inspiring us to imagine the many forms life might take in the universe—some that might not be obvious at first.

In the Star Trek universe, Earth is home to Starfleet Headquarters; the real Earth is, at least so far, the only life-bearing world we know. Earth returns again and again in Star Trek series and films, in many guises, from the raucous 1960s, to 1980s San Francisco ("Star Trek: The Voyage Home"), to a troubled 21st century ("Star Trek VIII: First Contact"). Strange Earth analogs also appear, inhabited by centuries-old children ("Miri") or a modern-day Roman Empire worried about TV ratings for its gladiatorial games ("Bread and Circuses"), both in the original series. No true Earth analogs have been discovered among the real exoplanets detected so far. But a new generation of space telescopes, designed to capture direct images of exoplanets in Earth's size range, might one day reveal an alternative "pale blue dot."

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Spitzer Space Telescope begins ‘Beyond’ phase

7 min read

NASA Science Editorial Team

Celebrating the spacecraft's ability to push the boundaries of space science and technology, NASA's Spitzer Space Telescope team has dubbed the next phase of its journey "Beyond."

"Spitzer is operating well beyond the limits that were set for it at the beginning of the mission," said Michael Werner, the project scientist for Spitzer at NASA's Jet Propulsion Laboratory in Pasadena, California. "We never envisioned operating 13 years after launch, and scientists are making discoveries in areas of science we never imagined exploring with the spacecraft."

NASA recently granted the spacecraft a two-and-a-half-year mission extension. This Beyond phase of the Spitzer mission will explore a wide range of topics in astronomy and cosmology, as well as planetary bodies in and out of our solar system.

Because of Spitzer's orbit and age, the Beyond phase presents a variety of new engineering challenges. Spitzer trails Earth in its journey around the sun, but because the spacecraft travels slower than Earth, the distance between Spitzer and Earth has widened over time. As Spitzer gets farther away, its antenna must be pointed at higher angles toward the sun to communicate with Earth, which means that parts of the spacecraft will experience more and more heat. At the same time, Spitzer's solar panels point away from the sun and will receive less sunlight, so the batteries will be under greater stress. To enable this riskier mode of operations, the mission team will have to override some autonomous safety systems.

More: Top 10 Star Trek destinations chosen by NASA scientists

“Balancing these concerns on a heat-sensitive spacecraft will be a delicate dance, but engineers are hard at work preparing for the new challenges in the Beyond phase,” said Mark Effertz, the Spitzer spacecraft chief engineer at Lockheed Martin Space Systems Company, Littleton, Colorado, which built the spacecraft.

Spitzer, which launched on Aug. 25, 2003, has consistently adapted to new scientific and engineering challenges during its mission, and the team expects it will continue to do so during the "Beyond" phase, which begins Oct. 1. The selected research proposals for the Beyond phase, also known as Cycle 13, include a variety of objects that Spitzer wasn't originally planned to address -- such as galaxies in the early universe, the black hole at the center of the Milky Way and exoplanets.

"We never even considered using Spitzer for studying exoplanets when it launched," said Sean Carey of NASA's Spitzer Science Center at Caltech in Pasadena. "It would have seemed ludicrous back then, but now it's an important part of what Spitzer does."

Spitzer has many qualities that make it a valuable asset in exoplanet science, including an extremely accurate star-targeting system and the ability to control unwanted changes in temperature. Its stable environment and ability to observe stars for long periods of time led to the first detection of light from known exoplanets in 2005. More recently, Spitzer’s Infrared Array Camera (IRAC) has been used for finding exoplanets using the "transit" method -- looking for a dip in a star's brightness that corresponds to a planet passing in front of it. This brightness change needs to be measured with exquisite accuracy to detect exoplanets. IRAC scientists have created a special type of observation to make such measurements, using single pixels within the camera.

More: 5 ways to find an exoplanet

Another planet-finding technique that Spitzer uses, but was not designed for, is called microlensing. When a star passes in front of another star, the gravity of the first star can act as a lens, making the light from the more distant star appear brighter. Scientists are using microlensing to look for a blip in that brightening, which could mean that the foreground star has a planet orbiting it. Spitzer and the ground-based Polish Optical Gravitational Lensing Experiment (OGLE) were used together to find one of the most distant planets known outside the solar system, as reported in 2015. This type of investigation is made possible by Spitzer's increasing distance from Earth, and could not have been done early in the mission.

Understanding the early universe is another area where Spitzer has broken ground. IRAC was designed to detect remote galaxies roughly 12 billion light-years away -- so distant that their light has been traveling for roughly 88 percent of the history of the universe. But now, thanks to collaborations between Spitzer and NASA's Hubble Space Telescope, scientists can peer even further into the past. The farthest galaxy ever seen, GN-z11, was characterized in a 2016 study using data from these telescopes. GN-z11 is about 13.4 billion light-years away, meaning its light has been traveling since 400 million years after the big bang.

More: Inventing the Future

"When we designed the IRAC instrument, we didn't know those more distant galaxies existed," said Giovanni Fazio, principal investigator of IRAC, based at the Harvard Smithsonian Center for Astrophysics in Cambridge, Massachusetts. "The combination of the Hubble Space Telescope and Spitzer has been fantastic, with the telescopes working together to determine their distance, stellar mass and age."

Closer to home, Spitzer advanced astronomers' understanding of Saturn when scientists using the observatory discovered the planet's largest ring in 2009. Most of the material in this ring -- consisting of ice and dust -- begins 3.7 million miles (6 million kilometers) from Saturn and extends about 7.4 million miles (12 million kilometers) beyond that. Though the ring doesn't reflect much visible light, making it difficult for Earth-based telescopes to see, Spitzer could detect the infrared glow from the cool dust.

Spitzer reinvented itself in May 2009 with its warm mission, after the depletion of the liquid helium coolant that was chilling its instruments since August 2003. At the conclusion of the "cold mission," Spitzer's Infrared Spectrograph and Multiband Imaging Photometer stopped working, but two of the four cameras in IRAC persisted. Since then, the spacecraft has made numerous discoveries despite operating in warmer conditions (which, at about minus 405 Fahrenheit or 30 Kelvin, is still cold by Earthly standards).

"With the IRAC team and the Spitzer Science Center team working together, we've really learned how to operate the IRAC instrument better than we thought we could," Fazio said. "The telescope is also very stable and in an excellent orbit for observing a large part of the sky."

More: Spitzer confirms closest rocky exoplanet

Spitzer's Beyond mission phase will last until the commissioning phase of NASA's James Webb Space Telescope, currently planned to launch in October 2018. Spitzer is set to identify targets that Webb can later observe more intensely.

"We are very excited to continue Spitzer in its Beyond phase. We fully expect new, exciting discoveries to be made over the next two-and-a-half years," said Suzanne Dodd, project manager for Spitzer, based at JPL.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at Caltech in Pasadena, California. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the

Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

For more information about Spitzer, visit:

http://spitzer.caltech.edu

http://www.nasa.gov/spitzer

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

ESO Discovers Earth-Size Planet in Habitable Zone of Nearest Star

6 min read

Pat Brennan

By Pat BrennanNASA's Exoplanet Exploration Program

A newly discovered, roughly Earth-sized planet orbiting our nearest neighboring star might be habitable, according to a team of astronomers using the European Southern Observatory’s 3.6-meter telescope at La Silla, Chile, along with other telescopes around the world.

The exoplanet is at a distance from its star that allows temperatures mild enough for liquid water to pool on its surface.

A visualization of the nearest exoplanet to Earth, Proxima b. Only 4 light-years away, this world orbits its cool red star every 11 days. Click and drag to move the planet. Click the corner to see full-screen.

"NASA congratulates ESO on the discovery of this intriguing planet that has captured the hopes and the imagination of the world," says Paul Hertz, Astrophysics Division Director at NASA Headquarters, Washington. "We look forward to learning more about the planet, whether it holds ingredients that could make it suitable for life."

The new planet circles Proxima Centauri, the smallest member of a triple star system known to science fiction fans everywhere as Alpha Centauri. Just over 4 light-years away, Proxima is the closest star to Earth, besides our own sun.

"This is really a game-changer in our field," said Olivier Guyon, a planet-hunting affiliate at NASA's Jet Propulsion Laboratory, Pasadena, California, and associate professor at the University of Arizona, Tucson. "The closest star to us has a possible rocky planet in the habitable zone. That's a huge deal. It also boosts the already existing, mounting body of evidence that such planets are near, and that several of them are probably sitting quite close to us. This is extremely exciting."

Olivier Guyon

Astronomer

The science team that made the discovery, led by Guillem Anglada-Escudé of Queen Mary University of London, will publish its findings Aug. 25 in the journal Nature. The team traced subtle wobbles in the star revealing the presence of a star-tugging planet.

They determined that the new planet, dubbed Proxima b, is at least 1.3 times the mass of Earth. It orbits its star far more closely than Mercury orbits our sun, taking only 11 days to complete a single orbit -- a "year" on Proxima b.

The stunning announcement comes with plenty of caveats. While the new planet lies within its star's "habitable zone" -- a distance at which temperatures are right for liquid water -- scientists do not yet know if the planet has an atmosphere.

It also orbits a red-dwarf star, far smaller and cooler than our sun. The planet likely presents only one face to its star, as the moon does to Earth, instead of rotating through our familiar days and nights. And Proxima b could be subject to potentially life-extinguishing stellar flares.

See more: NASA's Hubble Telescope makes first atmospheric study of Earth-sized exoplanets

"That's the worry in terms of habitability," said Scott Gaudi, an astronomy professor at Ohio State University, Columbus, and JPL affiliate credited with numerous exoplanet discoveries. "This thing is being bombarded by a fair amount of high-energy radiation. It's not obvious if it's going to have a magnetic field strong enough to prevent its whole atmosphere from getting blown away. But those are really hard calculations, and I certainly wouldn't put my money either way on that."

Despite the unknowns, the discovery was hailed by NASA exoplanet hunters as a major milestone on the road to finding other possible life-bearing worlds within our stellar neighborhood.

Sara Seager

MIT

"It definitely gives us something to be excited about," said Sara Seager, a planetary science and physics professor at the Massachusetts Institute of Technology, Cambridge, and an exoplanet-hunting pioneer. "I think it will definitely motivate people to get moving."

Statistical surveys of exoplanets – planets orbiting other stars – by NASA's Kepler space telescope have revealed a large proportion of small planets around small stars, she said.

The Kepler data suggest we should expect at least one potentially habitable, Earth-size planet orbiting M-type stars, like Proxima, within 10 light-years of our solar system.

So the latest discovery was "not completely unexpected. We're more lucky than surprised," Seager said. But it "helps buoy our confidence that planets are everywhere."

It's especially encouraging for upcoming space telescopes, which can contribute to the study of the new planet. The James Webb Space Telescope, launching in 2018, may be able to follow-up on this planet with spectroscopy to determine the contents of its atmosphere. NASA's Transiting Exoplanet Survey Satellite (TESS) will find similar planets in the habitable zone in the stellar backyard of our solar system in 2018.

One of TESS's goals is to find planets orbiting nearby M-dwarf stars like Proxima Centauri.

See more: NASA's next planet hunter will look closer to home

"It's great news just to know that M-dwarf planets could be as common as we think they are," Seager said.

Another possible inspiration Proxima b could reignite: the admittedly far-off goal of sending a probe to another solar system.

Bill Borucki, an exoplanet pioneer, said the new discovery might inspire more interstellar research, especially if Proxima b proves to have an atmosphere.

Coming generations of space and ground-based telescopes, including large ground telescopes now under construction, could yield more information about the planet, perhaps inspiring ideas on how to pay it a visit.

See more: Inventing the Future

"It may be that the first time we get really good information is from the newer telescopes that may be coming online in a decade or two," said Borucki, now retired, a former principal investigator for Kepler which has discovered the bulk of the more than 3,300 exoplanets found so far.

"Maybe people will talk about sending a probe to that star system," Borucki said. "I think it does provide some inspiration for an interstellar mission, because now we know there is a planet in the habitable zone, probably around the mass of Earth, around the closest star. I think it does inspire a future effort to go there and check it out."

To read the ESO press release, visit:

www.eso.org/public/news/eso1629/?lang

To learn more about NASA's Exoplanet Program, visit:

http://exoplanets.nasa.gov

To read the paper, visit:

A terrestrial planet candidate in a temperate orbit around Proxima Centauri

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers help focus research in the search for another Earth

1 min read

NASA Science Editorial Team

Using public data collected by NASA's Kepler mission, astronomers have catalogued the planet candidates that may be similar to our third rock from the sun. The tabulation of candidates will help astronomers focus their research efforts in the search for life.

The analysis, led by Stephen Kane, an associate professor of physics and astronomy at San Francisco State University in California, highlights 20 candidates in the Kepler trove that are less than twice the size of Earth and orbit their star in the conservative habitable zone—the range of distances where liquid water could pool on the surface of an orbiting planet. Of these 20 candidates, nine have been previously investigated and determined to be verified planets, including notables like Kepler-62f, Kepler-186f, Kepler-283c, Kepler-296f and Kepler-442b.

The results are presented in a paper accepted by the Astrophysical Journal. To see a listing of the candidates and their properties, visit:

http://arxiv.org/abs/1608.00620

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA’s Hubble Telescope Makes First Atmospheric Study of Earth-Sized Exoplanets

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Using NASA’s Hubble Space Telescope, astronomers have conducted the first search for atmospheres around temperate, Earth-sized planets beyond our solar system and found indications that increase the chances of habitability on two exoplanets.

Specifically, they discovered that the exoplanets TRAPPIST-1b and TRAPPIST-1c, approximately 40 light-years away, are unlikely to have puffy, hydrogen-dominated atmospheres usually found on gaseous worlds.

“The lack of a smothering hydrogen-helium envelope increases the chances for habitability on these planets,” said team member Nikole Lewis of the Space Telescope Science Institute (STScI) in Baltimore. “If they had a significant hydrogen-helium envelope, there is no chance that either one of them could potentially support life because the dense atmosphere would act like a greenhouse.”

Julien de Wit of the Massachusetts Institute of Technology in Cambridge, Massachusetts, led a team of scientists to observe the planets in near-infrared light using Hubble’s Wide Field Camera 3. They used spectroscopy to decode the light and reveal clues to the chemical makeup of an atmosphere. While the content of the atmospheres is unknown and will have to await further observations, the low concentration of hydrogen and helium has scientists excited about the implications.

“These initial Hubble observations are a promising first step in learning more about these nearby worlds, whether they could be rocky like Earth, and whether they could sustain life,” says Geoff Yoder, acting associate administrator for NASA’s Science Mission Directorate in Washington. “This is an exciting time for NASA and exoplanet research.”

The planets orbit a red dwarf star at least 500 million years old, in the constellation of Aquarius. They were discovered in late 2015 through a series of observations by the TRAnsiting Planets and PlanetesImals Small Telescope (TRAPPIST), a Belgian robotic telescope located at ESA’s (European Space Agency’s) La Silla Observatory in Chile.

TRAPPIST-1b completes a circuit around its red dwarf star in 1.5 days and TRAPPIST-1c in 2.4 days. The planets are between 20 and 100 times closer to their star than the Earth is to the sun. Because their star is so much fainter than our sun, researchers think that at least one of the planets, TRAPPIST-1c, may be within the star’s habitable zone, where moderate temperatures could allow for liquid water to pool.

On May 4, astronomers took advantage of a rare simultaneous transit, when both planets crossed the face of their star within minutes of each other, to measure starlight as it filtered through any existing atmosphere. This double-transit, which occurs only every two years, provided a combined signal that offered simultaneous indicators of the atmospheric characters of the planets.

The researchers hope to use Hubble to conduct follow-up observations to search for thinner atmospheres, composed of elements heavier than hydrogen, like those of Earth and Venus.

“With more data, we could perhaps detect methane or see water features in the atmospheres, which would give us estimates of the depth of the atmospheres,” said Hannah Wakeford, the paper’s second author, at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

Observations from future telescopes, including NASA’s James Webb Space Telescope, will help determine the full composition of these atmospheres and hunt for potential biosignatures, such as carbon dioxide and ozone, in addition to water vapor and methane. Webb also will analyze a planet’s temperature and surface pressure – key factors in assessing its habitability.

“These Earth-sized planets are the first worlds that astronomers can study in detail with current and planned telescopes to determine whether they are suitable for life,” said de Wit. “Hubble has the facility to play the central atmospheric pre-screening role to tell astronomers which of these Earth-sized planets are prime candidates for more detailed study with the Webb telescope.”

The results of the study appear in the July 20 issue of the journal Nature.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA. Goddard manages the telescope and STScI conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington.

For imaged and more information about Hubble, visit:

http://www.nasa.gov/hubble

http://hubblesite.org/news/2016/27

Contacts:

Felicia ChouHeadquarters, Washington202-358-0257felicia.chou@nasa.gov

Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore410-338- 4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

NASA’s Next Planet Hunter Will Look Closer to Home

4 min read

As the search for life on distant planets heats up, NASA’s Transiting Exoplanet Survey Satellite (TESS) is bringing this hunt closer to home. Launching in 2017-2018, TESS will identify planets orbiting the brightest stars just outside our solar system using what’s known as the transit method.

When a planet passes in front of, or transits, its parent star, it blocks some of the star’s light. TESS searches for these telltale dips in brightness, which can reveal the planet’s presence and provide additional information about it.

TESS will be able to learn the sizes of the planets it sees and how long it takes them to complete an orbit. These two pieces of information are critical to understanding whether a planet is capable of supporting life. Nearly all other planet classifications will come from follow up observations, by both TESS team ground telescopes as well as ground- and space-based observations, including NASA’s James Webb Space Telescope launching in 2018.

Compared to the Kepler mission, which has searched for exoplanets thousands to tens of thousands of light-years away from Earth towards the constellation Cygnus, TESS will search for exoplanets hundreds of light-years or less in all directions surrounding our solar system.

TESS will survey most of the sky by segmenting it into 26 different segments known as tiles. The spacecraft’s powerful cameras will look continuously at each tile for just over 27 days, measuring visible light from the brightest targets every two minutes. TESS will look at stars classified as twelfth apparent magnitude and brighter, some of which are visible to the naked eye. The higher the apparent magnitude, the fainter the star. For comparison, most people can see stars as faint as sixth magnitude in a clear dark sky and the faintest star in the Big Dipper ranks as third magnitude.

Among the stars TESS will observe, small bright dwarf stars are ideal for planet identification, explained Joshua Pepper, co-chair of the TESS Target Selection Working Group. One of the TESS science goals is to find Earth- and super-Earth-sized planets. These are difficult to discover because of their small size compared to their host stars, but focusing TESS on smaller stars makes finding these small planets much easier. This is because the fraction of the host star’s light that a planet blocks is proportional to the planet’s size.

Scientists expect TESS to observe at least 200,000 stars during the two years of its spaceflight mission, resulting in the discovery of thousands of new exoplanets.

While the search for transiting exoplanets is the primary goal of the mission, TESS will also make observations of other astrophysical objects through the Guest Investigator (GI) Program. Because TESS is conducting a near all-sky survey, it has the capability to perform interesting studies on many different types of astronomical target.

“The goal of the GI Program is to maximize the amount of science that comes out of TESS,” said Padi Boyd, director of the Guest Investigator Program Office at NASA’s Goddard Space Flight Center. “Although TESS was designed to be capable of detecting planets transiting in front of stars, its unique mission characteristics mean that the potential science TESS can do includes far more than just exoplanets.” According to Boyd, the broad range of objects TESS could detect as part of the GI Program include flaring young stars, binary pairs of stars, supernovae in nearby galaxies, and even supermassive black holes in distant active galaxies. “We hope the broader science community will come up with many unique science ideas for TESS, and we hope to encourage broad participation from the larger community,” she said.

With the potential to expand our knowledge of the universe for years to come, researchers are excited about the potential discoveries TESS could bring.

“The cool thing about TESS is that one of these days I’ll be able to go out in the country with my daughter and point to a star and say ‘there’s a planet around that one,’” said TESS Project Scientist Stephen Rinehart.

For more information about TESS, visit: tess.gsfc.nasa.gov/

By Elaine HuntNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Vulcan May Not be Real, but Spock’s Home System is

2 min read

NASA Science Editorial Team

It takes a little imagination to wish some favorite fictional universes into existence. But, for legions of "Star Trek" fans, they don’t have to wish: one star system really exists in our Milky Way galaxy. In Star Trek lore, Vulcan is the home of logic, learning and the deeply beloved first officer Mr. Spock. While Vulcan is fictional, the star system it belongs to–40 Eridani–is very real. It’s located only 16.5 light-years away from Earth and its primary star can be spotted with the naked eye. So how much is science fiction and how much is science fact?

“Could there be an Earth-like planet in this system? We have no way of knowing that now,” said Karl Stapelfeldt, chief scientist of NASA’s Exoplanet Exploration Program. So while Vulcan (as far as we know) doesn’t exist, a fascinating triple sunset would occur on any rocky planet in the system, because 40 Eridani has three stars that circle each other.

See more: Interactive planets

The most massive is 40 Eridani A, a dwarf star that is the mythical Vulcan’s sun. The other two are a pair, orbiting each other at a distance from 40 Eridani A. This binary pair contains a red dwarf (40 Eridani C) and a white dwarf star (40 Eridani B). From the surface of Vulcan, “they would gleam brilliantly in the Vulcan sky,” according to Rodenberry in his 1991 letter to Sky & Telescope magazine.

If you believe in science fiction, Mr. Spock’s dreamt-up world lives in the habitable zone of the largest star, 40 Eridani A. The habitable zone, shown as the area in blue-green, is the distance from a star where liquid water is said to exist. Too far away from its sun and Vulcan would freeze like Pluto; too close and it would sizzle like Mercury. Vulcan is perched on the inner edge, lending the world its imagined desert-like quality (at least, in a timeline where the planet remains undestroyed).

But if there were a planet like Vulcan in the 40 Eridani system, would we be able to see it? Not yet. “We don’t yet have a way to detect it, but NASA is working on the technology to make it possible,” Stapelfeldt said.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Space Snow Visible in Bright Baby Solar System

5 min read

NASA Science Editorial Team

From European Southern Observatory

◆ The Atacama Large Millimeter/submillimeter Array (ALMA) has taken the first ever image of a water snow line within a planet-forming disk.

◆ This line marks where the temperature in the disk surrounding a young star drops sufficiently low for snow to form, which plays a key role in how planets form.

◆ While planet formation is still a mystery, it is believed that within the water snow line rocky planets like Earth form. Outside it, massive gaseous planets like Jupiter can arise.

Young stars are often surrounded by dense, rotating disks of gas and dust, known as protoplanetary disks, from which planets are born. The heat from a typical young solar-type star means that the water within a protoplanetary disk is gaseous up to distances of around 3 AU from the star [1] — less than 3 times the average distance between the Earth and the Sun — or around 450 million kilometers (roughly 280 million miles)[2]. Further out, due to the extremely low pressure, the water molecules transition directly from a gaseous state to form a patina of ice on dust grains and other particles. The region in the protoplanetary disk where water transitions between the gas and solid phases is known as the water snow line [3].

But the star V883 Orionis is unusual. A dramatic increase in its brightness has pushed the water snow line out to a distance of around 40 AU (about 6 billion kilometers or roughly the size of the orbit of the dwarf planet Pluto in our solar system). This huge increase, combined with the resolution of ALMA at long baselines [4], has allowed a team led by Lucas Cieza (Millenium ALMA Disk Nucleus and Universidad Diego Portales, Santiago, Chile) to make the first ever resolved observations of a water snow line in a protoplanetary disk.

The sudden brightening that V883 Orionis experienced is an example of what occurs when large amounts of material from the disk surrounding a young star fall onto its surface. V883 Orionis is only 30 percent more massive than the sun, but thanks to the outburst it is experiencing, it is currently a staggering 400 times more luminous — and much hotter [5].

Lead author Lucas Cieza explains, “The ALMA observations came as a surprise to us. Our observations were designed to look for disk fragmentation leading to planet formation. We saw none of that; instead, we found what looks like a ring at 40 AU. This illustrates well the transformational power of ALMA, which delivers exciting results even if they are not the ones we were looking for.”

The bizarre idea of snow orbiting in space is fundamental to planet formation. The presence of water ice regulates the efficiency of the coagulation of dust grains — the first step in planet formation. Within the snow line, where water is vapourised, smaller, rocky planets like our own are believed to form. Outside the water snow line, the presence of water ice allows the rapid formation of cosmic snowballs, which eventually go on to form massive gaseous planets such as Jupiter.

The discovery that these outbursts may blast the water snow line to about 10 times its typical radius is very significant for the development of good planetary formation models. Such outbursts are believed to be a stage in the evolution of most planetary systems, so this may be the first observation of a common occurrence. In that case, this observation from ALMA could contribute significantly to a better understanding of how planets throughout the Universe formed and evolved.

To read the research paper entitled “Imaging the water snow-line during a protostellar outburst”, by L. Cieza et al., to appear in Nature on July 14, 2016, visit:

http://www.eso.org/public/archives/releases/sciencepapers/eso1626/eso1626a.pdf

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

WASP-12 b: An Egg-shaped Exoplanet

1 min read

NASA Science Editorial Team

The doomed planet WASP-12b is a hot Jupiter that orbits so close to its parent star, it's being torn apart. It takes this alien world only 1.1 days to completely circle its sun.

This artist's concept shows the doomed planet WASP-12b, a hot Jupiter orbiting so close to its parent star, it's being torn apart. It takes this alien world only 1.1 days to completely circle its sun. The star's gravity also pulls material off the planet into a disk around the star. In 10 million years, this alien world could be completely consumed.

Almost two times the size of our Jupiter, WASP-12b is a sizzling gas giant whose temperature is approximately 4,000 degrees Fahrenheit (2,210 degrees Celsius). Gravity causes enormous tidal forces which are stretching the planet into the shape of an egg.

WASP-12b is located roughly 1,200 light-years away in the constellation Auriga. It was discovered in March 2009 via the transit method. It is 1.8 times Jupiter's radius, and 1.4 times Jupiter's mass.

To see more interactive planets, visit:

Strange New Worlds.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers find water clouds in cold Jupiter-like object

4 min read

NASA Science Editorial Team

By Tim Stephens, University of California Santa Cruz

Since its detection in 2014, the brown dwarf known as WISE 0855 has fascinated astronomers. Only 7.2 light-years from Earth, it is the coldest known object outside of our solar system and is just barely visible at infrared wavelengths with the largest ground-based telescopes.

Now, a team led by astronomers at UC Santa Cruz has succeeded in obtaining an infrared spectrum of WISE 0855 using the Gemini North telescope in Hawaii, providing the first details of the object's composition and chemistry. Among the findings is strong evidence for the existence of clouds of water or water ice, the first such clouds detected outside of our solar system.

"We would expect an object that cold to have water clouds, and this is the best evidence that it does," said Andrew Skemer, assistant professor of astronomy and astrophysics at UC Santa Cruz. Skemer is first author of a paper on the new findings to be published in Astrophysical Journal Letters and currently available online.

A brown dwarf is essentially a failed star, having formed the way stars do through the gravitational collapse of a cloud of gas and dust, but without gaining enough mass to spark the nuclear fusion reactions that make stars shine. With about five times the mass of Jupiter, WISE 0855 resembles that gas giant planet in many respects. Its temperature is about 250 degrees Kelvin, or minus 10 degrees Fahrenheit, making it nearly as cold as Jupiter, which is 130 degrees Kelvin.

"WISE 0855 is our first opportunity to study an extrasolar planetary-mass object that is nearly as cold as our own gas giants," Skemer said.

Previous observations of the brown dwarf, published in 2014, provided tentative indications of water clouds based on very limited photometric data. Skemer, a coauthor of the earlier paper, said obtaining a spectrum (which separates the light from an object into its component wavelengths) is the only way to detect an object's molecular composition.

WISE 0855 is too faint for conventional spectroscopy at optical or near-infrared wavelengths, but thermal emission from the deep atmosphere at wavelengths in a narrow window around 5 microns offered an opportunity where spectroscopy would be "challenging but not impossible," he said.

The team used the Gemini-North telescope in Hawaii and the Gemini Near Infrared Spectrograph to observe WISE 0855 over 13 nights for a total of about 14 hours.

"It's five times fainter than any other object detected with ground-based spectroscopy at this wavelength," Skemer said. "Now that we have a spectrum, we can really start thinking about what's going on in this object. Our spectrum shows that WISE 0855 is dominated by water vapor and clouds, with an overall appearance that is strikingly similar to Jupiter."

The researchers developed atmospheric models of the equilibrium chemistry for a brown dwarf at 250 degrees Kelvin and calculated the resulting spectra under different assumptions, including cloudy and cloud-free models. The models predicted a spectrum dominated by features resulting from water vapor, and the cloudy model yielded the best fit to the features in the spectrum of WISE 0855.

Comparing the brown dwarf to Jupiter, the team found that their spectra are strikingly similar with respect to water absorption features. One significant difference is the abundance of phosphine in Jupiter's atmosphere. Phosphine forms in the hot interior of the planet and reacts to form other compounds in the cooler outer atmosphere, so its appearance in the spectrum is evidence of turbulent mixing in Jupiter's atmosphere. The absence of a strong phosphine signal in the spectrum of WISE 0855 implies that it has a less turbulent atmosphere.

"The spectrum allows us to investigate dynamical and chemical properties that have long been studied in Jupiter's atmosphere, but this time on an extrasolar world," Skemer said.

The coauthors of the study include graduate student Caroline Morley and professor of astronomy and astrophysics Jonathan Fortney at UC Santa Cruz; Katelyn Allers at Bucknell University; Thomas Geballe at Gemini Observatory; Mark Marley and Roxana Lupu at NASA Ames Research Center; Jacqueline Faherty at the Carnegie Institution of Washington; and Gordon Bjoraker at NASA Goddard Space Flight Center.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

In new 5-planet system, shades of homegrown giants

1 min read

NASA Science Editorial Team

Interactive visualization of the newly discovered planetary system, which includes several gas giants that orbit a bright, hot F-type star.

A space telescope with a new lease on life has revealed a previously unknown five-planet solar system some 380 light-years away from Earth.

And each of the new planets is a bruiser—two are more than twice the size (by radius) of Earth, one the size of Neptune, one just shy of Saturn-sized and one the size of Jupiter. They were discovered last year using NASA’s Kepler Space Telescope, according to a paper published June 27. Kepler is now in an extended mission, called K2, after a malfunction ended its first mission in 2013, and after engineers found a way to extend the life of the space telescope.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

A surprising planet with three suns

5 min read

NASA Science Editorial Team

From NASA and European Southern Observatory

Luke Skywalker's home planet, Tatooine, in the Star Wars saga, was a strange world with two suns in the sky, but astronomers have now found a planet in an even more exotic system, where an observer would either experience constant daylight or enjoy triple sunrises and sunsets each day, depending on the seasons, which last longer than human lifetimes.

This world has been discovered by a team of astronomers led by the University of Arizona, USA, using direct imaging at ESO’s Very Large Telescope (VLT) in Chile. The planet, HD 131399Ab, is unlike any other known world — its orbit around the brightest of the three stars is by far the widest known within a multi-star system. Such orbits are often unstable, because of the complex and changing gravitational attraction from the other two stars in the system, and planets in stable orbits were thought to be very unlikely.

Located about 320 light-years from Earth in the constellation of Centaurus (The Centaur), HD 131399Ab is about 16 million years old, making it also one of the youngest exoplanets discovered to date, and one of very few directly imaged planets. With a temperature of around 580 degrees Celsius and an estimated mass of four Jupiter masses, it is also one of the coldest and least massive directly-imaged exoplanets.

"HD 131399Ab is one of the few exoplanets that have been directly imaged, and it's the first one in such an interesting dynamical configuration," said Daniel Apai, from the University of Arizona, USA, and one of the co-authors of the new paper.

"For about half of the planet’s orbit, which lasts 550 Earth-years, three stars are visible in the sky; the fainter two are always much closer together, and change in apparent separation from the brightest star throughout the year," adds Kevin Wagner, the paper's first author and discoverer of HD 131399Ab.

Kevin Wagner, who is a PhD student at the University of Arizona, identified the planet among hundreds of candidate planets and led the follow-up observations to verify its nature.

The planet also marks the first discovery of an exoplanet made with the SPHERE instrument on the VLT. SPHERE is sensitive to infrared light, allowing it to detect the heat signatures of young planets, along with sophisticated features correcting for atmospheric disturbances and blocking out the otherwise blinding light of their host stars.

Although repeated and long-term observations will be needed to precisely determine the planet's trajectory among its host stars, observations and simulations seem to suggest the following scenario: the brightest star is estimated to be eighty percent more massive than the Sun and dubbed HD 131399A, which itself is orbited by the less massive stars, B and C, at about 300 au (one au, or astronomical unit, equals the average distance between the Earth and the Sun). All the while, B and C twirl around each other like a spinning dumbbell, separated by a distance roughly equal to that between the Sun and Saturn (10 au).

In this scenario, planet HD 131399Ab travels around the star A in an orbit with a radius of about 80 au, about twice as large as Pluto’s in the Solar System, and brings the planet to about one third of the separation between star A and the B/C star pair. The authors point out that a range of orbital scenarios is possible, and the verdict on the long-term stability of the system will have to wait for planned follow-up observations that will better constrain the planet’s orbit.

"If the planet was further away from the most massive star in the system, it would be kicked out of the system," Apai explained. "Our computer simulations have shown that this type of orbit can be stable, but if you change things around just a little bit, it can become unstable very quickly."

Planets in multi-star systems are of special interest to astronomers and planetary scientists because they provide an example of how the mechanism of planetary formation functions in these more extreme scenarios. While multi-star systems seem exotic to us in our orbit around our solitary star, multi-star systems are in fact just as common as single stars.

"It is not clear how this planet ended up on its wide orbit in this extreme system, and we can't say yet what this means for our broader understanding of the types of planetary systems, but it shows that there is more variety out there than many would have deemed possible," concludes Kevin Wagner. "What we do know is that planets in multi-star systems have been studied far less often, but are potentially just as numerous as planets in single-star systems."

To read the research paper in Science, visit:

http://science.sciencemag.org/content/early/2016/07/06/science.aaf9671

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

‘Electric wind’ can strip potential Earths of oceans, atmospheres

6 min read

wasteigerwald

Venus has an “electric wind” strong enough to remove the components of water from its upper atmosphere, which may have played a significant role in stripping Earth’s twin planet of its oceans, according to new results from ESA’s (European Space Agency) Venus Express mission by NASA-funded researchers.

“It’s amazing, shocking,” said Glyn Collinson, a scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “We never dreamt an electric wind could be so powerful that it can suck oxygen right out of an atmosphere into space.”

Glyn Collinson

NASA’s Goddard Space Flight Center

Collinson is lead author of a paper about this research published June 20, 2016, in the journal Geophysical Research Letters.

Venus is in many ways the most like Earth in terms of its size and gravity, and there’s evidence that it once had oceans worth of water in its distant past. However, with surface temperatures around 860 F (460 C), any oceans would have long since boiled away to steam and Venus is uninhabitable today. Yet Venus’ thick atmosphere, about 100 times the pressure of Earth’s, has 10,000 to 100,000 times less water than Earth’s atmosphere. Something had to remove all that steam, and the current thinking is that much of the early steam dissociated to hydrogen and oxygen: the light hydrogen escaped, while the oxygen oxidized rocks over billions of years. Also the solar wind — a million-mile-per-hour stream of electrically conducting gas blowing from the sun — could have slowly but surely eroded the remainder of an ocean’s worth of oxygen and water from Venus’ upper atmosphere.

“We found that the electric wind, which people thought was just one small cog in a big machine, is in fact this big monster that’s capable of sucking the water from Venus by itself,” said Collinson.

Just as every planet has a gravity field, it is believed that every planet with an atmosphere is also surrounded by a weak electric field. While the force of gravity is trying to hold the atmosphere on the planet, the electric force (the same force that sticks laundry together in a drier and pushes electricity through wires) can help to push the upper layers of the atmosphere off into space. At Venus, the much faster hydrogen escapes easily, but this electric field is so strong that it can accelerate even the heavier electrically charged component of water — oxygen ions — to speeds fast enough to escape the planet’s gravity. When water molecules rise into the upper atmosphere, sunlight breaks the water into hydrogen and oxygen ions, which are then carried away by the electric field.

“If you were unfortunate enough to be an oxygen ion in the upper atmosphere of Venus then you have won a terrible, terrible lottery,” said Collinson, “You and all your ion friends will be dragged off kicking and screaming into space by an invisible hand, and nothing can save you.”

The team discovered Venus’ electric field using the electron spectrometer, a component of the ASPERA-4 instrument, aboard the ESA Venus Express. They were monitoring electrons flowing out of the upper atmosphere when it was noticed that these electrons were not escaping at their expected speeds. The team realized that these electrons had been tugged on by Venus' potent electric field. By measuring the change in speed, the team was able to measure the strength of the field, finding it to be much stronger than anyone had expected, and at least five times more powerful than at Earth.

"We don't really know why it is so much stronger at Venus than Earth," said Collinson, "but, we think it might have something to do with Venus being closer to the sun, and the ultraviolet sunlight being twice as bright. It's a challenging thing to measure and even at Earth to date all we have are upper limits on how strong it might be."

Such information also helps us understand other worlds around the solar system.

"We've been studying the electrons flowing away from Titan [a moon of Saturn] and Mars as well as from Venus, and the ions they drag away to space," said Andrew Coates, who leads the electron spectrometer team at University College London in the U.K. "The new result here shows that the electric field powering this escape is surprisingly strong at Venus compared to the other objects. This will help us understand how this universal process works."

Another planet where the electric wind may play an important role is Mars. NASA's MAVEN mission is currently orbiting Mars to determine what caused the Red Planet to lose much of its atmosphere and water. "We are actively hunting for Mars' electric wind with MAVEN's full arsenal of scientific instruments," said Collinson. "MAVEN is a robotic detective on this four-billion-year-old mystery of where the atmosphere and oceans went, and the electric wind has long been a prime suspect."

Taking the electric wind into account will also help astronomers improve estimates of the size and location of habitable zones around other stars. These are areas where the temperature could allow liquid water to exist on the surface of alien worlds, making them places where life might be found. Some stars emit more ultraviolet light than the sun, so if this creates stronger electric winds in any planets orbiting them, the habitable zone around such stars may be farther away and narrower than thought. "Even a weak electric wind could still play a role in water and atmospheric loss at any planet," said Alex Glocer of NASA Goddard, a co-author on the paper. "It could act like a conveyor belt, moving ions higher in the ionosphere where other effects from the solar wind could carry them away."

ESA's Venus Express was launched on Nov. 9, 2005, to study the complex atmosphere of Venus. The electron spectrometer was built by the Southwest Research Institute in San Antonio, Texas, and is led by University College London. The spacecraft orbited Venus between 2006 and December 2014. After a successful mission that far exceeded its planned life, the spacecraft exhausted its fuel supply and burned up upon entry into Venus' dense atmosphere. The research was funded by NASA's MAVEN (Mars Atmosphere and Volatile Evolution) mission and NASA's Solar System Workings program.

Karen C. FoxNASA's Goddard Space Flight Center, Greenbelt, Md.karen.c.fox@nasa.gov

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

First detection of methyl alcohol in a planet-forming disc

4 min read

NASA Science Editorial Team

The organic molecule methyl alcohol (methanol) has been found by the Atacama Large Millimeter/Submillimeter Array (ALMA) in the TW Hydrae protoplanetary disc, according to the European Southern Observatory. This is the first such detection of the compound in a young planet-forming disc. Methanol is the only complex organic molecule as yet detected in discs that unambiguously derives from an icy form. Its detection helps astronomers understand the chemical processes that occur during the formation of planetary systems and that ultimately lead to the creation of the ingredients for life.

The protoplanetary disc around the young star TW Hydrae is the closest known example to Earth, at a distance of only about 170 light-years. As such it is an ideal target for astronomers to study discs. This system closely resembles what astronomers think the solar system looked like during its formation more than four billion years ago.

The Atacama Large Millimeter/Submillimeter Array (ALMA) is the most powerful observatory in existence for mapping the chemical composition and the distribution of cold gas in nearby discs. These unique capabilities have now been exploited by a group of astronomers led by Catherine Walsh (Leiden Observatory, the Netherlands) to investigate the chemistry of the TW Hydrae protoplanetary disc.

The ALMA observations have revealed the fingerprint of gaseous methyl alcohol, or methanol (CH3OH), in a protoplanetary disc for the first time. Methanol, a derivative of methane, is one of the largest complex organic molecules detected in discs to date. Identifying its presence in pre-planetary objects represents a milestone for understanding how organic molecules are incorporated into nascent planets.

Furthermore, methanol is itself a building block for more complex species of fundamental prebiotic importance, like amino acid compounds. As a result, methanol plays a vital role in the creation of the rich organic chemistry needed for life.

Catherine Walsh, lead author of the study, explained, “Finding methanol in a protoplanetary disc shows the unique capability of ALMA to probe the complex organic ice reservoir in discs and so, for the first time, allows us to look back in time to the origin of chemical complexity in a planet nursery around a young Sun-like star.”

Gaseous methanol in a protoplanetary disc has a unique importance in astrochemistry. While other species detected in space are formed by gas-phase chemistry alone, or by a combination of both gas and solid-phase generation, methanol is a complex organic compound which is formed solely in the ice phase via surface reactions on dust grains.

The sharp vision of ALMA has also allowed astronomers to map the gaseous methanol across the TW Hydrae disc. They discovered a ring-like pattern in addition to significant emission from close to the central star.

The observation of methanol in the gas phase, combined with information about its distribution, implies that methanol formed on the disc’s icy grains, and was subsequently released in gaseous form. This first observation helps to clarify the puzzle of the methanol ice–gas transition, and more generally the chemical processes in astrophysical environments.

Ryan A. Loomis, a co-author of the study, adds, “Methanol in gaseous form in the disc is an unambiguous indicator of rich organic chemical processes at an early stage of star and planet formation. This result has an impact on our understanding of how organic matter accumulates in very young planetary systems.”

This successful first detection of cold gas-phase methanol in a protoplanetary disc means that the production of ice chemistry can now be explored in discs, paving the way to future studies of complex organic chemistry in planetary birthplaces. In the hunt for life-sustaining exoplanets, astronomers now have access to a powerful new tool.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Gluttonous star may hold clues to planet formation

6 min read

NASA Science Editorial Team

In 1936, the young star FU Orionis began gobbling material from its surrounding disk of gas and dust with a sudden voraciousness. During a three-month binge, as matter turned into energy, the star became 100 times brighter, heating the disk around it to temperatures of up to 12,000 degrees Fahrenheit (7,000 Kelvin). FU Orionis is still devouring gas to this day, although not as quickly.

This brightening is the most extreme event of its kind that has been confirmed around a star the size of the sun, and may have implications for how stars and planets form. The intense baking of the star's surrounding disk likely changed its chemistry, permanently altering material that could one day turn into planets.

"By studying FU Orionis, we're seeing the absolute baby years of a solar system," said Joel Green, a project scientist at the Space Telescope Science Institute, Baltimore, Maryland. "Our own sun may have gone through a similar brightening, which would have been a crucial step in the formation of Earth and other planets in our solar system."

Visible light observations of FU Orionis, which is about 1,500 light-years away from Earth in the constellation Orion, have shown astronomers that the star's extreme brightness began slowly fading after its initial 1936 burst. But Green and colleagues wanted to know more about the relationship between the star and surrounding disk. Is the star still gorging on it? Is its composition changing? When will the star's brightness return to pre-outburst levels?

To answer these questions, scientists needed to observe the star’s brightness at infrared wavelengths, which are longer than the human eye can see and provide temperature measurements.

Green and his team compared infrared data obtained in 2016 using the Stratospheric Observatory for Infrared Astronomy, SOFIA, to observations made with NASA's Spitzer Space Telescope in 2004. SOFIA, the world's largest airborne observatory, is jointly operated by NASA and the German Aerospace Center and provides observations at wavelengths no longer attainable by Spitzer. The SOFIA data were taken using the FORCAST instrument (Faint Object infrared Camera for the SOFIA Telescope).

"By combining data from the two telescopes collected over a 12-year interval, we were able to gain a unique perspective on the star's behavior over time," Green said. He presented the results at the American Astronomical Society meeting in San Diego, this week.

Using these infrared observations and other historical data, researchers found that FU Orionis had continued its ravenous snacking after the initial brightening event: The star has eaten the equivalent of 18 Jupiters in the last 80 years.

The recent measurements provided by SOFIA inform researchers that the total amount of visible and infrared light energy coming out of the FU Orionis system decreased by about 13 percent over the 12 years since the Spitzer observations. Researchers determined that this decrease is caused by dimming of the star at short infrared wavelengths, but not at longer wavelengths. That means up to 13 percent of the hottest material of the disk has disappeared, while colder material has stayed intact.

"A decrease in the hottest gas means that the star is eating the innermost part of the disk, but the rest of the disk has essentially not changed in the last 12 years," Green said. "This result is consistent with computer models, but for the first time we are able to confirm the theory with observations."

Astronomers predict, partly based on the new results, that FU Orionis will run out of hot material to nosh on within the next few hundred years. At that point, the star will return to the state it was in before the dramatic 1936 brightening event. Scientists are unsure what the star was like before or what set off the feeding frenzy.

"The material falling into the star is like water from a hose that's slowly being pinched off," Green said. "Eventually the water will stop."

If our sun had a brightening event like FU Orionis did in 1936, this could explain why certain elements are more abundant on Mars than on Earth. A sudden 100-fold brightening would have altered the chemical composition of material close to the star, but not as much farther from it. Because Mars formed farther from the sun, its component material would not have been heated up as much as Earth's was.

At a few hundred thousand years old, FU Orionis is a toddler in the typical lifespan of a star. The 80 years of brightening and fading since 1936 represent only a tiny fraction of the star's life so far, but these changes happened to occur at a time when astronomers could observe.

"It's amazing that an entire protoplanetary disk can change on such a short timescale, within a human lifetime," said Luisa Rebull, study co-author and research scientist at the Infrared Processing and Analysis Center (IPAC), based at Caltech, Pasadena, California.

Green planned to gain more insight into the FU Orionis feeding phenomenon with NASA's James Webb Space Telescope, which launched in 2021. SOFIA has mid-infrared high-resolution spectrometers and far-infrared science instrumentation that complement Webb’s near- and mid-infrared capabilities. Spitzer continued exploring the universe in infrared light, and enabling groundbreaking scientific investigations, until early 2020.

NASA's Jet Propulsion Laboratory, Pasadena, California, manages the Spitzer Space Telescope mission for NASA. Science operations are conducted at the Spitzer Science Center at Caltech. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at IPAC at Caltech. Caltech manages JPL for NASA.

SOFIA is a joint project of NASA and the German Aerospace Center (DLR). The aircraft is based at NASA Armstrong Flight Research Center's facility in Palmdale, California. NASA's Ames Research Center in Moffett Field, California, manages the SOFIA science and mission operations in cooperation with the Universities Space Research Association (USRA) headquartered in Columbia, Maryland, and the German SOFIA Institute (DSI) at the University of Stuttgart.

For more information about Spitzer, visit:

http://www.science.nasa.gov/mission/spitzer or

http://spitzer.caltech.edu

For more information about SOFIA, visit:http://www.science.nasa.gov/mission/sofia

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s

other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Smaller Stars Pack Big X-ray Punch for Would-Be Planets

6 min read

Young stars much less massive than the Sun can unleash a torrent of X-ray radiation that can significantly shorten the lifetime of planet-forming disks surrounding these stars. This result comes from a new study of a group of nearby stars using data from NASA’s Chandra X-ray Observatory and other telescopes.

Researchers found evidence that intense X-ray radiation produced by some of the young stars in the TW Hya association (TWA), which is about 160 light years from Earth, has destroyed disks of dust and gas surrounding them. These disks are where planets form. The stars are only about 8 million years old, compared to the 4.5-billion-year age of the Sun. Astronomers want to learn more about systems this young because they are at a crucial age for the birth and early development of planets.

Another key difference between the Sun and the stars in the study involves their mass. The TWA stars in the new study weigh between about one tenth to one half the mass of the Sun and also emit less light. Until now, it was unclear whether X-ray radiation from such small, faint stars could affect their planet-forming disks of material. These latest findings suggest that a faint star’s X-ray output may play a crucial role in determining the survival time of its disk.

These results mean that astronomers may have to revisit current ideas on the formation process and early lives of planets around these faint stars.

Using X-ray data from NASA’s Chandra X-ray Observatory, the European Space Agency’s XMM-Newton observatory and ROSAT (the ROentgen SATellite), the team looked at the intensity of X-rays produced by a group of stars in the TWA, along with how common their star-forming disks are. They split the stars into two groups to make this comparison. The first group of stars had masses ranging from about one third to one half that of the Sun. The second group contained stars with masses only about one tenth that of the Sun, which included relatively large brown dwarfs, objects that do not have sufficient mass to generate self-sustaining nuclear reactions in their cores.

The researchers found that, relative to their total energy output, the more massive stars in the first group produce more X-rays than the less massive ones in the second. To find out how common planet-forming disks in the groups were, the team used data from NASA’s Wide-Field Infrared Survey Explorer (WISE) and, in some cases, ground-based spectroscopy previously obtained by other teams. They found that all of the stars in the more massive group had already lost their planet-forming disks, but only about half of the stars in the less massive group had lost their disks. This suggests that X-rays from the more massive stars are speeding up the disappearance of their disks, by heating disk material and causing it to “evaporate” into deep space.

A typical star and planet-forming disk from each of these two groups of stars are shown in the illustrations. The illustration above depicts one of the relatively high mass stars, which has a large number of flares and spots. This is a sign of its enhanced X-ray production, which is thinning and destroying the remnants of its planet-forming disk.

Another illustration (below) shows one of the lower mass, fainter stars. Because it is not as active in X-rays, it has retained a thicker disk that represents a more suitable environment to form planets. The planet formation process would cause gaps, not shown in this illustration, to appear in the disk. The streams near the center show how matter from the disk is still falling onto the star. These illustrations, which are not to scale – the stars are actually miniscule in size when compared with their surrounding disks – are accompanied by a Chandra image of two young stars that were included in the new study of the TWA.

In previous studies, astronomers found that 10-million-year-old stars in the Upper Scorpius region, another star-forming group, obeyed the same trend for the increase in the lifetime of disks for lower mass stars. However, the Upper Scorpius work did not incorporate X-ray data that might offer an explanation for this trend, which is one reason why this new study of the 8-million-year-old TWA is important. Another reason is that theoretical models of the evolution of planet-forming disks generally predict that the lifetimes of disks should have very little dependence on the mass of the star. The new results for the "puny" TWA stars point to the need to revisit disk evolution models to account for the range in the X-ray outputs of very low-mass stars.

These results appear in The Astronomical Journal and are available online [link: http://lanl.arxiv.org/abs/1603.09307]. The authors of this paper are Joel Kastner (Rochester Institute of Technology), David Principe (Universidad Diego Portales, Chile), Kristina Punzi (RIT), Beate Stelzer (INAF Palermo, Italy), Uma Gorti (SETI Institute), Ilaria Pascucci (University of Arizona), and Costanza Argiroffi (INAF).

NASA's Marshall Space Flight Center in Huntsville, Alabama, manages the Chandra program for NASA's Science Mission Directorate in Washington. The Smithsonian Astrophysical Observatory in Cambridge, Massachusetts, controls Chandra's science and flight operations.

Read More from NASA's Chandra X-ray Observatory.

For more Chandra images, multimedia and related materials, visit:

https://www.nasa.gov/chandra

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cloudy days on exoplanets may hide atmospheric water

4 min read

NASA Science Editorial Team

Water is a hot topic in the study of exoplanets, including "hot Jupiters," whose masses are similar to that of Jupiter, but which are much closer to their parent star than Jupiter is to the sun. They can reach a scorching 2,000 degrees Fahrenheit (1,100 degrees Celsius), meaning any water they host would take the form of water vapor.

Astronomers have found many hot Jupiters with water in their atmospheres, but others appear to have none. Scientists at NASA's Jet Propulsion Laboratory, Pasadena, California, wanted to find out what the atmospheres of these giant worlds have in common.

Researchers focused on a collection of hot Jupiters studied by NASA's Hubble Space Telescope. They found that the atmospheres of about half of the planets were blocked by clouds or haze.

"The motivation of our study was to see what these planets would be like if they were grouped together, and to see whether they share any atmospheric properties," said Aishwarya Iyer, a JPL intern and master's degree candidate at California State University, Northridge, who led the study.

The new study, published in the June 1 issue of the Astrophysical Journal, suggests that clouds or haze layers could be preventing a substantial amount of atmospheric water from being detected by space telescopes. The clouds themselves are likely not made of water, as the planets in this sample are too hot for water-based clouds.

"Clouds or haze seem to be on almost every planet we studied," Iyer said. "You have to be careful to take clouds or haze into account, or else you could underestimate the amount of water in an exoplanet's atmosphere by a factor of two."

In the study, scientists looked at a set of 19 hot Jupiters previously observed by Hubble. The telescope's Wide Field Camera 3 had detected water vapor in the atmospheres of 10 of these planets, and no water on the other nine. But that information was spread across more than a dozen studies. The methods of analyzing and interpretation varied because the studies were conducted separately. There had not been one overarching analysis of all these planets.

To compare the planets and look for patterns, the JPL team had to standardize the data: Researchers combined the datasets for all 19 hot Jupiters to create an average overall light spectrum for the group of planets. They then compared these data to models of clear, cloud-free atmospheres and those with various cloud thicknesses.

The scientists determined that, for almost every planet they studied, haze or clouds were blocking half of the atmosphere, on average.

"In some of these planets, you can see water peeking its head up above the clouds or haze, and there could still be more water below," Iyer said.

Scientists do not yet know the nature of these clouds or hazes, including what they are they made of.

"Clouds or haze being on almost all these planets is pretty surprising," said Robert Zellem, a postdoctoral fellow at JPL and co-author of the study.

The implications of this result agree with findings published in the Dec. 14, 2015, issue of the journal Nature. The Nature study used data from NASA's Hubble and Spitzer Space Telescopes to suggest that clouds or haze could be hiding undetected water in hot Jupiters. This new study uses exoplanet data from a single instrument on Hubble to uniformly characterize a larger group of hot Jupiters, and is the first to quantify how much of the atmosphere would be shielded as a result of clouds or haze.

The new research could have implications for follow-up studies with future space observatories, such as NASA's James Webb Space Telescope. Exoplanets with thick cloud covers blocking the detection of water and other substances may be less desirable targets for more extensive study.

These results are also important for figuring out how planets form, scientists say.

"Did these planets form in their current positions or migrate toward their host stars from farther out? Understanding the abundances of molecules such as water helps us answer those questions," Zellem said.

"This paper is an exciting step forward for the study of exoplanets and comparing their properties," said Mark Swain, study co-author and group supervisor for the exoplanet discovery and science group at JPL.

Michael Line of the University of California, Santa Cruz, also contributed to the study. Other co-authors from JPL included Gael Roudier, Graca Rocha and John Livingston.

For more information about the Hubble Space Telescope, visit:

www.nasa.gov/hubble

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Cloudy Days on Exoplanets May Hide Atmospheric Water

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Water is a hot topic in the study of exoplanets, including "hot Jupiters," whose masses are similar to that of Jupiter, but which are much closer to their parent star than Jupiter is to the sun. They can reach a scorching 2,000 degrees Fahrenheit (1,100 degrees Celsius), meaning any water they host would take the form of water vapor.

Astronomers have found many hot Jupiters with water in their atmospheres, but others appear to have none. Scientists at NASA's Jet Propulsion Laboratory, Pasadena, California, wanted to find out what the atmospheres of these giant worlds have in common.

Researchers focused on a collection of hot Jupiters studied by NASA's Hubble Space Telescope. They found that the atmospheres of about half of the planets were blocked by clouds or haze.

"The motivation of our study was to see what these planets would be like if they were grouped together, and to see whether they share any atmospheric properties," said Aishwarya Iyer, a JPL intern and master's degree candidate at California State University, Northridge, who led the study.

The new study, published in the June 1 issue of the Astrophysical Journal, suggests that clouds or haze layers could be preventing a substantial amount of atmospheric water from being detected by space telescopes. The clouds themselves are likely not made of water, as the planets in this sample are too hot for water-based clouds.

"Clouds or haze seem to be on almost every planet we studied," Iyer said. "You have to be careful to take clouds or haze into account, or else you could underestimate the amount of water in an exoplanet's atmosphere by a factor of two."

In the study, scientists looked at a set of 19 hot Jupiters previously observed by Hubble. The telescope's Wide Field Camera 3 had detected water vapor in the atmospheres of 10 of these planets, and no water on the other nine. But that information was spread across more than a dozen studies. The methods of analyzing and interpretation varied because the studies were conducted separately. There had not been one overarching analysis of all these planets.

To compare the planets and look for patterns, the JPL team had to standardize the data: Researchers combined the datasets for all 19 hot Jupiters to create an average overall light spectrum for the group of planets. They then compared these data to models of clear, cloud-free atmospheres and those with various cloud thicknesses.

The scientists determined that, for almost every planet they studied, haze or clouds were blocking half of the atmosphere, on average.

"In some of these planets, you can see water peeking its head up above the clouds or haze, and there could still be more water below," Iyer said.

Scientists do not yet know the nature of these clouds or hazes, including what they are they made of.

"Clouds or haze being on almost all these planets is pretty surprising," said Robert Zellem, a postdoctoral fellow at JPL and co-author of the study.

The implications of this result agree with findings published in the Dec. 14, 2015, issue of the journal Nature. The Nature study used data from NASA's Hubble and Spitzer Space Telescopes to suggest that clouds or haze could be hiding undetected water in hot Jupiters. This new study uses exoplanet data from a single instrument on Hubble to uniformly characterize a larger group of hot Jupiters, and is the first to quantify how much of the atmosphere would be shielded as a result of clouds or haze.

The new research could have implications for follow-up studies with future space observatories, such as NASA's James Webb Space Telescope. Exoplanets with thick cloud covers blocking the detection of water and other substances may be less desirable targets for more extensive study.

These results are also important for figuring out how planets form, scientists say.

"Did these planets form in their current positions or migrate toward their host stars from farther out? Understanding the abundances of molecules such as water helps us answer those questions," Zellem said.

"This paper is an exciting step forward for the study of exoplanets and comparing their properties," said Mark Swain, study co-author and group supervisor for the exoplanet discovery and science group at JPL.

Michael Line of the University of California, Santa Cruz, also contributed to the study. Other co-authors from JPL included Gael Roudier, Graca Rocha and John Livingston.

For more information about the Hubble Space Telescope, visit:

www.nasa.gov/hubble

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Giant red stars may heat frozen worlds into habitable planets

3 min read

NASA Science Editorial Team

Searching vast cosmic communities like real estate agents rifling through listings, Cornell astronomers now hunt through time and space for habitable exoplanets – planets beyond our own solar system – looking at planets flourishing in old star, red giant neighborhoods.

Astronomers search for these promising worlds by looking for the “habitable zone,” the region around a star in which water on a planet’s surface is liquid and signs of life can be remotely detected by telescopes.

“When a star ages and brightens, the habitable zone moves outward and you’re basically giving a second wind to a planetary system,” said Ramses M. Ramirez, research associate at Cornell’s Carl Sagan Institute and lead author of the study. “Currently objects in these outer regions are frozen in our own solar system, like Europa and Enceladus – moons orbiting Jupiter and Saturn.”

In their work, Ramirez and Lisa Kaltenegger, associate professor of astronomy and director of the Sagan Institute, have modeled the locations of the habitable zones for aging stars and how long planets can stay in it. Their research, “Habitable Zones of Post-Main Sequence Stars,” was published May 16 in the Astrophysical Journal.

Lisa Kaltenegger

Director of Cornell’s Carl Sagan Institute

All throughout the universe there are stars in varying phases and ages. The oldest detected Kepler planets (exoplanets found using NASA’s Kepler telescope) are about 11 billion years old, and the exoplanetary diversity suggests that around other stars, such initially frozen worlds could be the size of Earth and could provide habitable conditions once the star becomes older. Astronomers usually looked at middle-aged stars like our sun, but to find habitable worlds, one needs to look around stars of all ages, Kaltenegger said.

Dependent upon the mass of the original star, planets and their moons loiter in this red giant habitable zone up to 9 billion years. Earth, for example, has been in our sun’s habitable zone so far for about 4.5 billion years, and it has teemed with changing iterations of life. However, in a few billion years our sun will become a red giant, engulfing Mercury and Venus, turning Earth and Mars into sizzling rocky planets, and warming distant worlds like Jupiter, Saturn and Neptune – and their moons – in a newly established red-giant habitable zone.

“For stars that are like our sun, but older, such thawed planets could stay warm up to half a billion years. That’s no small amount of time,” said Ramirez.

Said Kaltenegger: “In the far future, such worlds could become habitable around small red suns for billions of years, maybe even starting life, just like Earth. That makes me very optimistic for the chances for life in the long run.”

This research was supported by the Simons Foundation and by the Carl Sagan Institute.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing.

Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Dance of the sub-Neptunes: a planetary system in resonance

6 min read

NASA Science Editorial Team

The four planets of the Kepler-223 star system appeared to have little in common with the planets of our own solar system today. But a 2016 study using data from NASA's Kepler space telescope suggests a possible commonality in the distant past. The Kepler-223 planets orbit their star in the same configuration that Jupiter, Saturn, Uranus and Neptune may have had in the early history of our solar system, before migrating to their current locations.

Compare Kepler-223 to our solar system in the Strange New Worlds gallery.

"Exactly how and where planets form is an outstanding question in planetary science," said the study's lead author, Sean Mills, then a graduate student in astronomy and astrophysics at the University of Chicago in Illinois. "Our work essentially tests a model for planet formation for a type of planet we don't have in our solar system."

The puffy, gaseous planets orbiting Kepler-223, all of which are far more massive than Earth, orbit close to their star. "That's why there's a big debate about how they formed, how they got there and why don't we have an analogous planet in our solar system," Mills said.

Mills and his collaborators used data from Kepler (retired in 2018) to analyze how the four planets block their stars' light and change each other's orbits. This information also gave researchers the planets' sizes and masses. The team performed numerical simulations of planetary migration that generate this system's current architecture, similar to the migration suspected for the solar system's gas giants. These calculations are described in the May 11 Advance Online edition of Nature.

The orbital configuration of our own solar system seems to have evolved since its birth 4.6 billion years ago. The four known planets of the much older Kepler-223 system, however, have maintained a single orbital configuration for far longer.

Astronomers call the planets of Kepler-223 "sub-Neptunes." They likely consist of a solid core and an envelope of gas, and they orbit their star in periods ranging from only seven to 19 days. They are the most common type of planets known in the galaxy, even though there is nothing quite like them around our Sun.

Kepler-223's planets also are in resonance, meaning their gravitational influence on each other creates a periodic relationship between their orbits. Planets are in resonance when, for example, every time one of them orbits its sun once, the next one goes around twice. Three of Jupiter's largest moons, where the phenomenon was discovered, display resonances. Kepler-223 is the first time that four planets in an extrasolar system have been confirmed to be in resonance.

"This is the most extreme example of this phenomenon," said study co-author Daniel Fabrycky, then an assistant professor of astronomy and astrophysics at the University of Chicago.

The Kepler-223 system provides alternative scenarios for how planets form and migrate in a planetary system that is different from our own, said study co-author Howard Isaacson, then a research astronomer at the University of California, Berkeley, and member of the California Planet Search Team.

"Data from Kepler and the Keck Telescope were absolutely critical in this regard," Isaacson said. Thanks to observations of Kepler-223 and other exoplanetary systems, "We now know of systems that are unlike our Sun's solar system, with hot Jupiters, planets closer than Mercury or in between the size of Earth and Neptune, none of which we see in our solar system. Other types of planets are very common."

Some stages of planet formation can involve violent processes. But during other stages, planets can evolve from gaseous disks in a smooth, gentle way, which is probably what the sub-Neptune planets of Kepler-223 did, Mills said.

"We think that two planets migrate through this disk, get stuck and then keep migrating together; find a third planet, get stuck, migrate together; find a fourth planet and get stuck," Mills explained.

That process differs completely from the one that scientists believe led to the formation of Mercury, Venus, Earth and Mars, which likely formed in their current orbital locations.

Earth formed from Mars-sized or moon-sized bodies smacking together, Mills said, in a violent and chaotic process. When planets form this way, their final orbital periods are not near a resonance.

But scientists suspect that the solar system's larger, more distant planets of today -- Jupiter, Saturn, Uranus and Neptune -- moved around substantially during their formation. They may have been knocked out of resonances that once resembled those of Kepler-223, possibly after interacting with numerous asteroids and small planets (planetesimals).

"These resonances are extremely fragile," Fabrycky said. "If bodies were flying around and hitting each other, then they would have dislodged the planets from the resonance." But Kepler-223's planets somehow managed to dodge this scattering of cosmic bodies.

NASA's Ames Research Center in Moffett Field, California, managed the Kepler and K2 missions for NASA's Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado at Boulder.

For more information about the Kepler and K2 missions, visit:

http://www.nasa.gov/kepler

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425elizabeth.landau@jpl.nasa.gov

Michele JohnsonNASA Ames Research Center, Moffett Field, Calif.650-604-6982michele.johnson@nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Are We Alone in the Universe? Revisiting the Drake Equation

8 min read

NASA Science Editorial Team

Are humans unique and alone in the vast universe? This question--summed up in the famous Drake equation--has for a half-century been one of the most intractable and uncertain in science.

But a new paper shows that the recent discoveries of exoplanets combined with a broader approach to the question makes it possible to assign a new empirically valid probability to whether any other advanced technological civilizations have ever existed.

And it shows that unless the odds of advanced life evolving on a habitable planet are astonishingly low, then human kind is not the universe's first technological, or advanced, civilization.

The paper, published in Astrobiology, also shows for the first time just what "pessimism" or "optimism" mean when it comes to estimating the likelihood of advanced extraterrestrial life.

"The question of whether advanced civilizations exist elsewhere in the universe has always been vexed with three large uncertainties in the Drake equation," said Adam Frank, professor of physics and astronomy at the University of Rochester and co-author of the paper. "We've known for a long time approximately how many stars exist. We didn't know how many of those stars had planets that could potentially harbor life, how often life might evolve and lead to intelligent beings, and how long any civilizations might last before becoming extinct."

"Of course, we have no idea how likely it is that an intelligent technological species will evolve on a given habitable planet," says Frank. But using our method we can tell exactly how low that probability would have to be for us to be the ONLY civilization the Universe has produced. We call that the pessimism line. If the actual probability is greater than the pessimism line, then a technological species and civilization has likely happened before."

Using this approach, Frank and Sullivan calculate how unlikely advanced life must be if there has never been another example among the universe's ten billion trillion stars, or even among our own Milky Way galaxy's hundred billion.

The result? By applying the new exoplanet data to the universe's 2 x 10 to the 22nd power stars, Frank and Sullivan find that human civilization is likely to be unique in the cosmos only if the odds of a civilization developing on a habitable planet are less than about one in 10 billion trillion, or one part in 10 to the 22nd power.

"One in 10 billion trillion is incredibly small," says Frank. "To me, this implies that other intelligent, technology producing species very likely have evolved before us. Think of it this way. Before our result you'd be considered a pessimist if you imagined the probability of evolving a civilization on a habitable planet were, say, one in a trillion. But even that guess, one chance in a trillion, implies that what has happened here on Earth with humanity has in fact happened about a 10 billion other times over cosmic history!"

For smaller volumes the numbers are less extreme. For example, another technological species likely has evolved on a habitable planet in our own Milky Way galaxy if the odds against it evolving on any one habitable planet are better than one chance in 60 billion.

But if those numbers seem to give ammunition to the “optimists” about the existence of alien civilizations, Sullivan points out that the full Drake equation—which calculates the odds that other civilizations are around today—may give solace to the pessimists.

“Thanks to NASA's Kepler satellite and other searches, we now know that roughly one-fifth of stars have planets in “habitable zones,” where temperatures could support life as we know it. So one of the three big uncertainties has now been constrained.”

Frank said that the third big question--how long civilizations might survive--is still completely unknown. “The fact that humans have had rudimentary technology for roughly ten thousand years doesn’t really tell us if other societies would last that long or perhaps much longer,” he explained.

But Frank and his coauthor, Woodruff Sullivan of the astronomy department and astrobiology program at the University of Washington, found they could eliminate that term altogether by simply expanding the question.

“Rather than asking how many civilizations may exist now, we ask ‘Are we the only technological species that has ever arisen?" said Sullivan. “This shifted focus eliminates the uncertainty of the civilization lifetime question and allows us to address what we call the ‘cosmic archaeological question’—how often in the history of the universe has life evolved to an advanced state?”

That still leaves huge uncertainties in calculating the probability for advanced life to evolve on habitable planets. It's here that Frank and Sullivan flip the question around. Rather than guessing at the odds of advanced life developing, they calculate the odds against it occurring in order for humanity to be the only advanced civilization in the entire history of the observable universe. With that, Frank and Sullivan then calculated the line between a Universe where humanity has been the sole experiment in civilization and one where others have come before us.

In 1961, astrophysicist Frank Drake developed an equation to estimate the number of advanced civilizations likely to exist in the Milky Way galaxy. The Drake equation (top row) has proven to be a durable framework for research, and space technology has advanced scientists' knowledge of several variables. But it is impossible to do anything more than guess at variables such as L, the probably longevity of other advanced civilizations.

In new research, Adam Frank and Woodruff Sullivan offer a new equation (bottom row) to address a slightly different question: What is the number of advanced civilizations likely to have developed over the history of the observable universe? Frank and Sullivan's equation draws on Drake's, but eliminates the need for L.

Their argument hinges upon the recent discovery of how many planets exist and how many of those lie in what scientists call the “habitable zone” – planets in which liquid water, and therefore life, could exist. This allows Frank and Sullivan to define a number they call Nast. Nast is the product of N*, the total number of stars; fp, the fraction of those stars that form planets; and np, the average number of those planets in the habitable zones of their stars.

They then set out what they call the “Archaelogical-form” of the Drake equation, which defines A as the “number of technological species that have ever formed over the history of the observable Universe.”

Their equation, A=Nast*fbt, describes A as the product of Nast – the number of habitable planets in a given volume of the Universe – multiplied by fbt – the likelihood of a technological species arising on one of these planets. The volume considered could be, for example, the entire Universe, or just our Galaxy.

“The universe is more than 13 billion years old,” said Sullivan. “That means that even if there have been a thousand civilizations in our own galaxy, if they live only as long as we have been around—roughly ten thousand years—then all of them are likely already extinct. And others won’t evolve until we are long gone. For us to have much chance of success in finding another "contemporary" active technological civilization, on average they must last much longer than our present lifetime."

"Given the vast distances between stars and the fixed speed of light we might never really be able to have a conversation with another civilization anyway," said Frank. "If they were 20,000 light years away then every exchange would take 40,000 years to go back and forth."

But, as Frank and Sullivan point out, even if there aren't other civilizations in our galaxy to communicate with now, the new result still has a profound scientific and philosophical importance. "From a fundamental perspective the question is 'has it ever happened anywhere before?'" said Frank. Our result is the first time anyone has been able to set any empirical answer for that question and it is astonishingly likely that we are not the only time and place that an advance civilization has evolved."

According to Frank and Sullivan their result has a practical application as well. As humanity faces its crisis in sustainability and climate change we can wonder if other civilization-building species on other planets have gone through a similar bottleneck and made it to the other side. As Frank puts it "We don't even know if it's possible to have a high-tech civilization that lasts more than a few centuries." With Frank and Sullivan's new result, scientists can begin using everything they know about planets and climate to begin modeling the interactions of an energy-intensive species with their home world knowing that a large sample of such cases has already existed in the cosmos. "Our results imply that our evolution has not been unique and has probably happened many times before. The other cases are likely to include many energy intensive civilizations dealing with their feedbacks onto their planets as their civilizations grow. That means we can begin exploring the problem using simulations to get a sense of what leads to long lived civilizations and what doesn't."

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Promising Worlds Found Around Nearby Ultra-cool Dwarf Star

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers using the TRAPPIST telescope at ESO’s La Silla Observatory have discovered three planets with sizes and temperatures similar to those of Venus and Earth, orbiting an ultra-cool dwarf star just 40 light-years from Earth.

Michaël Gillon of the University of Liège in Belgium, leading a team of astronomers including Susan M. Lederer of NASA Johnson Space Center, have used the TRAPPIST telescope to observe the star 2MASS J23062928-0502285, now also known as TRAPPIST-1. They found that this dim and cool star faded slightly at regular intervals, indicating that several objects were passing between the star and the Earth. Detailed analysis showed that three planets are present around the star.

TRAPPIST-1 is an ultra-cool dwarf star — it is much cooler and redder than the Sun and barely larger than Jupiter. Despite being so close to the Earth, this star is too dim and too red to be seen with the naked eye or even visually with a large amateur telescope. It lies in the constellation of Aquarius (The Water Carrier).

Follow-up observations with larger telescopes, including the HAWK-I instrument on ESO’s 8-metre Very Large Telescope in Chile, have shown that the planets orbiting TRAPPIST-1 have sizes very similar to that of Earth. Two of the planets have orbital periods of about 1.5 days and 2.4 days respectively, and the third planet has a less well-determined orbital period in the range 4.5 to 73 days.

"With such short orbital periods, the planets are between 20 and 100 times closer to their star than the Earth to the Sun. The structure of this planetary system is much more similar in scale to the system of Jupiter’s moons than to that of the Solar System," explains Michaël Gillon.

Although they orbit very close to their host dwarf star, the inner two planets only receive four times and twice, respectively, the amount of radiation received by the Earth, because their star is much fainter than the Sun. That puts them closer to the star than the so-called habitable zone for this system, defined as having surface temperatures where liquid water can exist, although it is still possible that they possess potentially habitable regions on their surfaces. The third, outer, planet’s orbit is not yet well known, but it probably receives less radiation than the Earth does, but maybe still enough to lie within the habitable zone. The new results will be published in the journal Nature on 2 May 2016.

NASA’s Hubble Space Telescope and K2, the Kepler spacecraft's second mission, will be observing TRAPPIST-1 and its planets later this year.

Fortuitously, two of these planets are transiting the star on May 4, an event that happens only once every two years as seen from Earth. Astronomers hope to make measurements of the atmospheres of both of these planets and look for evidence of water vapor. The Hubble Space Telescope can characterize the atmospheres of the planets in the TRAPPIST-1 system by observing them as they pass in front of, or transit, their parent star. Hubble astronomers will use spectroscopy to measure starlight as it filters through a planet’s atmosphere.

K2 will observe TRAPPIST-1 as part of their Campaign 12, which is scheduled to take place from Dec. 15 to March 4, 2017. The data are expected to be available at the public archive the end of May 2017.

K2 will observe tens of transits of the two close-in Earth-sized exoplanets during the approximately 80-day campaign. The continuous and multiple observations will allow for measurements of predicted transit timing variations – the gravitational interaction between planets that cause transits to occur slightly earlier or slightly later than predicted. This will provide estimates of the masses of these exoplanets. Using K2’s mass measurements and TRAPPIST's ground-based size measurements, astronomers can calculate or constrain the density of the exoplanets to determine if they could be rocky worlds.

K2’s observations will also help scientists determine the orbital period of the third planet, and help find any additional small transiting objects in the system.

The TRAPPIST-1 system is an ideal target for NASA’s James Webb Space Telescope. Webb’s infrared sensitivity will be able to detect carbon dioxide, methane, water vapor, and other molecules common in the atmospheres of the rocky planets in our own solar system.

"Thanks to several giant telescopes currently under construction, including ESO’s E-ELT and the NASA/ESA/CSA James Webb Space Telescope due to launch for 2018, we will soon be able to study the atmospheric composition of these planets and to explore them first for water, then for traces of biological activity. That's a giant step in the search for life in the Universe," says Julien de Wit, a co-author from the Massachusetts Institute of Technology (MIT) in the USA.

The TRAPPIST survey is a prototype for a more ambitious project called SPECULOOS that will be installed at ESO’s Paranal Observatory.

For more information, please go to:

http://www.eso.org/public/news/eso1615/

As a radio frequency wireless engineer in NASA’s Johnson Space Center Avionic Systems Division in Houston, Melissa Moreno makes an impact in space exploration while proudly sharing her cultural heritage in the NASA community. Moreno works in the Electronic Systems Test Laboratory, developing communication systems critical to Gateway, NASA’s first lunar-orbiting space station. But her […]

Researchers found that long-duration spaceflight affected the mechanical properties of eye tissues, including reducing the stiffness of tissue around the eyeball. A better understanding of these changes could help researchers prevent, diagnose, and treat the vision impairment often seen in crew members. SANSORI, a Canadian Space Agency investigation, examined whether reduced stiffness of eye tissue contributes to […]

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Teachable Moment You Can See! The Transit of Mercury

6 min read

NASA Science Editorial Team

UPDATE - May 9, 2016: These views from the Solar Dynamics Observatory, or SDO, show Mercury passing in front of the sun on May 9, 2016.

By Lyle Tavernier, NASA's Jet Propulsion Laboratory

It only happens about 13 times per century and hasn't happened in nearly a decade, but on Monday, May 9, Mercury will transit the sun. A transit happens when a planet crosses in front of a star. From our perspective on Earth, we only ever see two planets transit the sun: Mercury and Venus. (Transits of Venus are even more rare. The next one won't happen until 2117!) On May 9, as Mercury passes in front of the sun, viewers around Earth (using the proper safety equipment) will be able to see a tiny dark spot moving slowly across the disk of the sun.

CAUTION: Looking directly at the sun can cause permanent vision damage – see below for tips on how to safely view the transit.

In the early 1600s, Johannes Kepler discovered that both Mercury and Venus would transit the sun in 1631. It was fortunate timing: The telescope had been invented just 23 years earlier and the transits wouldn't happen in the same year again until 13425. Kepler didn't survive to see the transits, but French astronomer Pierre Gassendi became the first person to see the transit of Mercury (the transit of Venus wasn't visible from Europe). It was soon understood that transits could be used as an opportunity to measure the apparent diameter – how large a planet appears from Earth – with great accuracy.

In 1677, Edmond Halley observed the transit of Mercury and realized that the parallax shift of the planet – the variation in Mercury's apparent position against the disk of the sun as seen by observers at distant points on Earth – could be used to accurately measure the distance between the sun and Earth, which wasn't known at the time.

Today, radar is used to measure the distance between Earth and the sun with greater precision than can be found using transit observations, but the transit of Mercury still provides scientists with opportunities for scientific investigation in two important areas: exospheres and exoplanets.

Some objects, like the moon and Mercury, were originally thought to have no atmosphere. But scientists have discovered that these bodies are actually surrounded in an ultra-thin atmosphere of gases called an exosphere. Scientists want to better understand the composition and density of the gases that make up Mercury's exosphere and transits make that possible.

"When Mercury is in front of the sun, we can study the exosphere close to the planet," said NASA scientist Rosemary Killen. "Sodium in the exosphere absorbs and re-emits a yellow-orange color from sunlight, and by measuring that absorption, we can learn about the density of gas there."

When Mercury transits the sun, it causes a slight dip in the sun's brightness as it blocks a tiny portion of the sun's light. Scientists discovered they could use that phenomenon to search for planets orbiting distant stars, called exoplanets, that are otherwise obscured from view by the light of the star. When measuring the brightness of far-off stars, a slight recurring dip in the light curve (a graph of light intensity) could indicate an exoplanet orbiting and transiting its star. NASA's Kepler mission has found more than 1,000 exoplanets by looking for this telltale drop in brightness.

Additionally, scientists have begun exploring the exospheres of exoplanets. By observing the spectra of the light that passes through an exosphere – similar to how we study Mercury's exosphere – scientists are beginning to understand the evolution of exoplanet atmospheres as well as the influence of stellar wind and magnetic fields.

Mercury will appear as a tiny dot on the sun's surface and will require a telescope or binoculars with a special solar filter to see. Looking at the sun directly or through a telescope without proper protection can lead to serious and permanent vision damage. Do not look directly at the sun without a solar filter.

The transit of Mercury will begin at 4:12 a.m. PDT, meaning by the time the sun rises on the West Coast, Mercury will have been transiting the sun for nearly two hours. Fortunately, it will take seven and a half hours for Mercury to completely cross the sun's face, so there will be plenty of time for West Coast viewers to witness this event. See the transit map to learn when and where the transit will be visible.

Don't have access to a telescope, binoculars or a solar filter? Visit the Night Sky Network website for the location of events near you where amateur astronomers will have viewing opportunities available.

NASA also will stream a live program on NASA TV and the agency's Facebook page from 7:30 to 8:30 a.m. PDT (10:30 to 11:30 a.m. EDT) -- an informal roundtable during which experts representing planetary, heliophysics and astrophysics will discuss the science behind the Mercury transit. Viewers can ask questions via Facebook and Twitter using #AskNASA.

Here are two ways to turn the transit of Mercury into a lesson for students.

Transit Resources:

Exoplanet Resources:

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

On the Road to Finding Other Earths

2 min read

NASA Science Editorial Team

Scientists are getting closer to finding worlds that resemble our own "blue marble" of a planet. NASA's Kepler mission alone has confirmed more than 1,000 planets outside our solar system– a handful of which are a bit bigger than Earth and orbit in the habitable zones of their stars, where liquid water might exist. Some astronomers think the discovery of Earth's true analogs may be around the corner. What are the next steps to search for life on these potentially habitable worlds?

Scientists and engineers are actively working on two technologies to help with this challenge: the starshade, a giant flower-shaped spacecraft; and coronagraphs, single instruments that fit inside telescopes. Both a starshade and a coronagraph block the light of a star, making it easier for telescopes to pick up the dim light that reflects off planets. This would enable astronomers to take pictures of Earth-like worlds -- and then use other instruments called spectrometers to search the planets' atmospheres for chemical clues about whether life might exist there.

A new JPL "Crazy Engineering" video visits both technologies at NASA's Jet Propulsion Laboratory in Pasadena, California.

"Coronagraphs are like visors in your car– you use them to block the light of the sun so you can see the road," said Nick Siegler, the program chief technologist for NASA's Exoplanet Exploration Program Office at JPL. "Starshades, on the other hand, are separate spacecraft that fly in front of other telescopes, so they are more like driving behind a big truck in front of you to block the light of the sun." Siegler is featured in the Crazy Engineering video.

The starshade would be a large structure about the size of a baseball diamond that deploys in space and flies in front of a space telescope.

Coronagraphs, which use tiny masks to block the light of stars from within a telescope, are also currently in development at JPL, as part of NASA's Wide-Field Infrared Survey Telescope, or WFIRST, mission, led by NASA's Goddard Space Flight Center in Greenbelt, Maryland.

Whitney ClavinJet Propulsion Laboratory, Pasadena,
California818-354-4673whitney.clavin@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hiding in the sunshine: The search for other Earths

6 min read

NASA Science Editorial Team

We humans might not be the only ones to ponder our place in the universe. If intelligent aliens do roam the cosmos, they too might ask a question that has gripped humans for centuries: Are we alone? These aliens might even have giant space telescopes dedicated to studying distant planets and searching for life. Should one of those telescopes capture an image of our blue marble of a planet, evidence of forests and plentiful creatures would jump out as simple chemicals: oxygen, ozone, water and methane.

Many earthlings at NASA are hoping to capture similar chemical clues for Earth-like planets beyond our solar system, also known as exo-Earths, where "exo" is Greek for "external." Researchers are developing new technologies with the goal of building space missions that can capture not only images of these exo-Earths, but also detailed chemical portraits called spectra. Spectra separate light into its component colors in order to reveal secrets of planets' atmospheres, climates and potential habitability.

"Evidence for life is not going to look like little green people – it's going to reveal itself in a spectrum," said Nick Siegler, the chief technologist for NASA's Exoplanet Exploration Program Office at the agency's Jet Propulsion Laboratory in Pasadena, California. The program is helping to develop NASA's plans for future exo-Earth imaging missions.

On the road to this goal, NASA is actively developing coronagraph technology in various laboratories, including JPL. Coronagraphs are instruments introduced in the early 20th century to study our sun. They use special masks to block out light from the circular disk of the sun, so that scientists can study its outer atmosphere, or corona.

Now NASA is developing more sophisticated coronagraphs to block the glaring light of other stars and reveal faint planets that might be orbiting them. Stars far outshine their planets; for example, our sun is 10 billion times brighter than Earth. That's similar to the flood of football stadium lights next to a tiny candle.

"The search for Earth-like planets begins with the suppression of starlight," said Rhonda Morgan of JPL, a coronagraph technologist for the Exoplanet Exploration Program Office. "It's like blocking the sun with a sun visor while driving in order to see the road."

Telescopes on the ground have already used coronagraphs to take pictures of planets, but those planets are easier to photograph because they are large, bright, and orbit far from their host stars. To take a picture of Earth-size planets lying in the habitable zone of sun-like stars – the region where temperatures are just right for possible liquid oceans and lakes – will require a telescope in space. Out in space, the blurring effects of our blustery atmosphere can be avoided.

Several types of coronagraphs are under development for proposed space missions. One mission, led by NASA's Goddard Space Flight Center, Greenbelt, Maryland, is known as WFIRST. WFIRST stands for Wide-Field Infrared Survey Telescope.

Editor’s note: The Wide Field Infrared Survey Telescope (WFIRST) was officially renamed the Nancy Grace Roman Space Telescope on May 20, 2020.

The WFIRST mission would be able to identify chemicals in the atmospheres of exoplanets as small as super-Earths, which are like Earth's bigger cousins, such as Kepler-452b, a recent discovery by NASA's Kepler mission. This would pave the way for future studies of the smaller exo-Earths. The WFIRST mission would also investigate other cosmic mysteries such as dark matter and dark energy.

Engineers and scientists at JPL are busily tinkering with different coronagraph technologies for WFIRST. Ilya Poberezhskiy, who manages the testbeds at JPL, explained two primary coronagraph designs while holding in his hand the tiny, starlight-blocking masks. One of them, the "shaped pupil" mask, is a few centimeters across, while the "hybrid Lyot" mask is a pinprick of a dot, barely visible at only one-tenth of a millimeter in size. Both technologies will fly together on the WFIRST mission as a part of one instrument– the occulting mask coronagraph.

"A wheel-like mechanism will rotate to switch different masks inside the instrument and convert the coronagraph from one mode to another," said Poberezhskiy.

The main challenge for coronagraphs is controlling starlight, which has a tendency to stray. Just putting a circular mask in front of the star doesn't obstruct the light completely; starlight bends around the mask like ocean waves curving around islands in a process called diffraction. Each coronagraph type deals with this challenge differently by using multiple masks as well as mirrors that can deform to sequentially suppress starlight in various stages.

"The starlight likes to walk all over the place, and into the area where you want to image the planet," said Wes Traub, the JPL project scientist for WFIRST. "The goal now is to get more practical with the kind of telescope we will use for WFIRST."

Another challenge in designing coronagraphs is adjusting for a space telescope's tiny vibrations, or jitter. The team at JPL is assessing how their coronagraphs handle jitter by simulating the effects in a vacuum chamber. They built a table-top-size telescope simulator for the tests.

"In space, telescopes experience warping and vibrations that need to be measured and reduced inside the coronagraph," said Poberezhskiy. "Our mock telescope will let us test the WFIRST coronagraph under realistic, space-like conditions."

As WFIRST development moves forward, mission planners are already thinking about a possible next step: a space telescope designed to image true Earth analogs. Such a mission may be more than a decade away, but development of the nuts and bolts of the technology is underway at a feverish pace.

"It's an exciting time for exoplanet research," said Gary Blackwood, manager of the Exoplanet Exploration Program. "This is history in the making."

The hybrid Lyot coronagraph design team is led by John Trauger of JPL. The shaped pupil coronagraph is pioneered by Jeremy Kasdin of Princeton University, New Jersey. A third technology, called a phase-induced amplitude apodization complex mask coronagraph, is being developed by Olivier Guyon of the University of Arizona, Tucson; Brian Kern of JPL' and Ruslan Belikov and Eduardo Bendek of NASA's Ames Research Center, Moffett Field, California.

WFIRST is managed at NASA's Goddard, with participation by JPL, the Space Telescope Science Institute in Baltimore, the Infrared Processing and Analysis Center, also in Pasadena, and a science team comprised of members from U.S. research institutions across the country.

For more information about NASA's Wide Field Infrared Survey Telescope (WFIRST), now known as the Nancy Grace Roman Space Telescope, visit the Roman mission webite.

JPL is managed by the California Institute of Technology for NASA.

Elizabeth LandauJet Propulsion Laboratory, Pasadena, Calif.818-354-6425Elizabeth.landau@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

The stars in the big Wyoming skies inspired Aaron Vigil as a child to dream big. Today, he’s a mechanical engineer working on the Solar Array Sun Shield (SASS) for the Nancy Grace Roman Space Telescope at Goddard. Name: Aaron VigilTitle: Mechanical EngineerFormal Job Classification: Aerospace Technology, Flight StructuresOrganization: Mechanical Engineering, Engineering and Technology Directorate (Code […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunter Breaks Ground with Supernovas

5 min read

NASA Science Editorial Team

By Pat Brennan

The brilliant flash of an exploding star's shockwave – what astronomers call the "shock breakout"– has been captured for the first time in visible light by NASA's planet-hunter, the Kepler space telescope.

An international science team led by Peter Garnavich, an astrophysics professor at the University of Notre Dame in Indiana, analyzed light captured by Kepler every 30 minutes over a three-year period from 500 distant galaxies, searching some 50 trillion stars. They were hunting for signs of massive stellar death explosions known as supernovae.

In 2011, two of these massive stars, called red supergiants, exploded while in Kepler's view. The first behemoth, KSN 2011a, is nearly 300 times the size of our sun and a mere 700 million light-years from Earth. The second, KSN 2011d, is roughly 500 times the size of our sun and around 1.2 billion light-years away.

"To put their size into perspective, Earth's orbit about our sun would fit comfortably within these colossal stars," said Garnavich.

Whether it's a plane crash, car wreck or supernova, capturing images of sudden, catastrophic events is extremely difficult but tremendously helpful in understanding root causes. Just as widespread deployment of mobile cameras has made forensic videos more common, the steady gaze of Kepler allowed astronomers to see, at last, a supernova shockwave as it reached the surface of a star. The shock breakout itself lasts only about 20 minutes, so catching the flash of energy is an investigative milestone for astronomers.

"In order to see something that happens on timescales of minutes, like a shock breakout, you want to have a camera continuously monitoring the sky," said Garnavich. "You don't know when a supernova is going to go off, and Kepler's vigilance allowed us to be a witness as the explosion began."

Supernovae like these – known as Type II – begin when the internal furnace of a star runs out of nuclear fuel, causing its core to collapse as gravity takes over.

The two supernovae matched up well with mathematical models of Type II explosions reinforcing existing theories. But they also revealed what could turn out to be an unexpected variety in the individual details of these cataclysmic stellar events.

While both explosions delivered a similar energetic punch, no shock breakout was seen in the smaller of the supergiants. Scientists think that is likely due to the smaller star being surrounded by gas, perhaps enough to mask the shockwave when it reached the star's surface.

"That is the puzzle of these results," said Garnavich. "You look at two supernovae and see two different things. That's maximum diversity."

Understanding the physics of these violent events allows scientists to better understand how the seeds of chemical complexity and life itself have been scattered in space and time in our Milky Way galaxy.

"All heavy elements in the universe come from supernova explosions. For example, all the silver, nickel, and copper in the earth and even in our bodies came from the explosive death throes of stars," said Steve Howell, project scientist for NASA's Kepler and K2 missions at NASA's Ames Research Center in California's Silicon Valley. "Life exists because of supernovae."

Garnavich is part of a research team known as the Kepler Extragalactic Survey or KEGS. The team is nearly finished mining data from Kepler's primary mission, which ended in 2013 with the failure of reaction wheels that helped keep the spacecraft steady. However, with the reboot of the Kepler spacecraft as NASA's K2 mission, the team is now combing through more data hunting for supernova events in even more galaxies far, far away.

"While Kepler cracked the door open on observing the development of these spectacular events, K2 will push it wide open, observing dozens more supernovae," said Tom Barclay, senior research scientist and director of the Kepler and K2 guest observer office at Ames. "These results are a tantalizing preamble to what's to come from K2!"

In addition to Notre Dame, the KEGS team also includes researchers from the University of Maryland in College Park; the Australian National University in Canberra, Australia; the Space Telescope Science Institute in Baltimore, Maryland; and the University of California, Berkeley.

The research paper reporting this discovery has been accepted for publication in the Astrophysical Journal.

For more information about the Kepler and K2 missions, visit:

http://www.nasa.gov/kepler

Michele JohnsonAmes Research Center, Moffett Field, Calif.650-604-6982michele.johnson@nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Searching for Dark and Distant Worlds

7 min read

NASA Science Editorial Team

Astronomers have made great strides in discovering planets outside of our solar system, termed “exoplanets.” In fact, over the past 20 years more than 5,000 exoplanets have been detected beyond the eight planets that call our solar system home.

The majority of these exoplanets have been found snuggled up to their host star completing an orbit (or year) in hours, days or weeks, while some have been found orbiting as far as Earth is to the sun, taking one-Earth-year to circle. But, what about those worlds that orbit much farther out, such as Jupiter and Saturn, or, in some cases, free-floating exoplanets that are on their own and have no star to call home? In fact, some studies suggest that there may be more free-floating exoplanets than stars in our galaxy.

This week, NASA's K2 mission, the repurposed mission of the Kepler space telescope, and other ground-based observatories have teamed up to kick-off a global experiment in exoplanet observation. Their mission: survey millions of stars toward the center of our Milky Way galaxy in search of distant stars' planetary outposts and exoplanets wandering between the stars.

While today's planet-hunting techniques have favored finding exoplanets near their sun, the outer regions of a planetary system have gone largely unexplored. In the exoplanet detection toolkit, scientists have a technique well suited to search these farthest outreaches and the space in between the stars. This technique is called gravitational microlensing.

For this experiment, astronomers rely on the effect of a familiar fundamental force of nature to help detect the presence of these far out worlds— gravity. The gravity of massive objects such as stars and planets produces a noticeable effect on other nearby objects.

But gravity also influences light, deflecting or warping, the direction of light that passes close to massive objects. This bending effect can make gravity act as a lens, concentrating light from a distant object, just as a magnifying glass can focus the light from the sun. Scientists can take advantage of the warping effect by measuring the light of distant stars, looking for a brightening that might be caused by a massive object, such as a planet, that passes between a telescope and a distant background star. Such a detection could reveal an otherwise hidden exoplanet.

"The chance for the K2 mission to use gravity to help us explore exoplanets is one of the most fantastic astronomical experiments of the decade," said Steve Howell, project scientist for NASA's Kepler and K2 missions at NASA’s Ames Research Center in California's Silicon Valley. "I am happy to be a part of this K2 campaign and look forward to the many discoveries that will be made."

This phenomenon of gravitational microlensing – “micro” because the angle by which the light is deflected is small – is the effect for which scientists will be looking during the next three months. As an exoplanet passes in front of a more distant star, its gravity causes the trajectory of the starlight to bend, and in some cases results in a brief brightening of the background star as seen by the observatory.

The lensing events caused by a free-floating exoplanet last on the order of a day or two, making the continuous gaze of the Kepler spacecraft an invaluable asset for this technique.

"We are seizing the opportunity to use Kepler's uniquely sensitive camera to sniff for planets in a different way," said Geert Barentsen, research scientist at Ames.

The ground-based observatories will record simultaneous measurements of these brief events. From their different vantage points, space and Earth, the measurements can determine the location of the lensing foreground object through a technique called parallax.

“This is a unique opportunity for the K2 mission and ground-based observatories to conduct a dedicated wide-field microlensing survey near the center of our galaxy," said Paul Hertz, director of the astrophysics division in NASA’s Science Mission Directorate at the agency’s headquarters in Washington. "This first-of-its-kind survey serves as a proof of concept for NASA’s Wide-Field Infrared Survey Telescope (WFIRST), which will launch in the 2020s to conduct a larger and deeper microlensing survey. In addition, because the Kepler spacecraft is about 100 million miles from Earth, simultaneous space- and ground-based measurements will use the parallax technique to better characterize the systems producing these light amplifications."

To understand parallax, extend your arm and hold up your thumb. Close one eye and focus on your thumb and then do the same with the other eye. Your thumb appears to move depending on the vantage point. For humans to determine distance and gain depth perception, the vantage points, our eyes, use parallax.

The Kepler spacecraft trails Earth as it orbits the sun and is normally pointed away from Earth during the K2 mission. But this orientation means that the part of the sky being observed by the spacecraft cannot generally be observed from Earth at the same time, since it is mostly in the daytime sky.

To allow simultaneous ground-based observations, flight operations engineers at Ball Aerospace and the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder will perform a maneuver turning the spacecraft around to point the telescope in the forward velocity vector. So, instead of looking towards where it’s been, the spacecraft will look in the direction of where it’s going.

This alignment will yield a viewing opportunity of Earth and the moon as they cross the spacecraft's field of view. On April 14 at 11:50 a.m. PDT (18:50 UT), Kepler will record a full frame image. The result of that image will be released to the public archive in June once the data has been downloaded and processed. Kepler measures the change in brightness of objects and does not resolve color or physical characteristics of an observed object.

To achieve the objectives of this important path-finding research and community exercise in anticipation of WFIRST, approximately two-dozen ground-based observatories on six continents will observe in concert with K2. Each will contribute to various aspects of the experiment and will help explore the distribution of exoplanets across a range of stellar systems and distances.

These results will aid in our understanding of both planetary system architectures as well as the frequency of exoplanets throughout our galaxy.

For a complete list of participating observatories, reference the paper that defines the experiment: Campaign 9 of the K2 mission.

During the roughly 80-day observing period or campaign, astronomers hope to discover over 100 lensing events, ten or more of which may have signatures of exoplanets occupying relatively unexplored regimes of parameter space.

Ames manages the Kepler and K2 missions for NASA’s Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corporation operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

For more information about the Kepler and K2 missions, visit:

https://science.nasa.gov/mission/kepler/

Media contact

Michele JohnsonAmes Research Center, Moffett Field, Calif.650-604-6982michele.johnson@nasa.gov

Disaster and rebirth: a space telescope’s new mission

8 min read

NASA Science Editorial Team

By Pat Brennan and Michele Johnson

The engineers huddled around a telemetry screen, and the mood was tense. They were watching streams of data from a crippled spacecraft more than 50 million miles away – so far that even at the speed of light, it took nearly nine minutes for a signal to travel to the spacecraft and back.

It was late August 2013, and the group of about five employees at Ball Aerospace in Boulder, Colorado, was waiting for NASA’s Kepler space telescope to reveal whether it would live or die. A severe malfunction had robbed the planet-hunting Kepler of its ability to stay pointed at a target without drifting off course.

The engineers had devised a remarkable solution: using the pressure of sunlight to stabilize the spacecraft so it could continue to do science. Now, there was nothing more they could do but wait for the spacecraft to reveal its fate.

“You’re not watching it unfold in real time,” said Dustin Putnam, Ball’s attitude control lead for Kepler. “You’re watching it as it unfolded a few minutes ago, because of the time the data takes to get back from the spacecraft.”

Finally, the team received the confirmation from the spacecraft they had been waiting for. The room broke out in cheers. The fix worked! Kepler, with a new lease on life, was given a new mission as K2. But the biggest surprise was yet to come. A space telescope with a distinguished history of discovering distant exoplanets – planets orbiting other stars – was about to outdo even itself, racking up hundreds more discoveries and helping to usher in entirely new opportunities in astrophysics research.

“Many of us believed that the spacecraft would be saved, but this was perhaps more blind faith than insight,” said Tom Barclay, senior research scientist and director of the Kepler and K2 guest observer office at NASA’s Ames Research Center in California's Silicon Valley. "The Ball team devised an ingenious solution allowing the Kepler space telescope to shine again."

A little more than two years after the tense moment for the Ball engineers, K2 has delivered on its promise with a breadth of discoveries. Continuing the exoplanet-hunting legacy, K2 has discovered more than three dozen exoplanets and with more than 250 candidates awaiting confirmation. A handful of these worlds are near-Earth-sized and orbit stars that are bright and relatively nearby compared with Kepler discoveries, allowing scientists to perform follow-up studies. In fact, these exoplanets are likely future targets for the Hubble Space Telescope and the forthcoming James Webb Space Telescope (JWST), with the potential to study these planets’ atmospheres in search of signatures indicative of life.

K2 also has astronomers rethinking long-held planetary formation theory, and the commonly understood lonely "hot Jupiter" paradigm. The unexpected discovery of a star with a close-in Jupiter-sized planet sandwiched between two smaller companion planets now has theorists back at their computers reworking the models, and has sent astronomers back to their telescopes in search of other hot Jupiter companions.

“It remains a mystery how a giant planet can form far out and migrate inward leaving havoc in its wake and still have nearby planetary companions,” said Barclay.

Like its predecessor, K2 searches for planetary transits – the tiny, telltale dip in the brightness of a star as a planet crosses in front – and for the first time caught the rubble from a destroyed exoplanet transiting across the remains of a dead star known as a white dwarf. Exoplanets have long been thought to orbit these remnant stars, but not until K2 has the theory been confirmed.

K2 has fixed its gaze on regions of the sky with densely packed clusters of stars which has revealed the first transiting exoplanet in such an area, popularly known as the Hyades star cluster. Clusters are exciting places to find exoplanets because stars in a cluster all form around the same time, giving them all the same "born-on" date. This helps scientists understand the evolution of planetary systems.

The repurposed spacecraft boasts discoveries beyond the realm of exoplanets. Mature stars – about the age of our sun and older – largely populated the original single Kepler field of view. In contrast, many K2 fields see stars still in the process of forming. In these early days, planets also are assembled and by looking at the timescales of star formation, scientists gain insight into how our own planet formed.

Studies of one star-forming region, called Upper Scorpius, compared the size of young stars observed by K2 with computational models. The result demonstrated fundamental imperfections in the models. While the reason for these discrepancies is still under debate, it likely shows that magnetic fields in stars do not arise as researchers expect.

Looking in the ecliptic – the orbital path traveled around the sun by the planets of our solar system and the location of the zodiac – K2 also is well equipped to observe small bodies within our own solar system such as comets, asteroids, dwarf planets, ice giants and moons. Last year, for instance, K2 observed Neptune in a dance with its two moons, Triton and Nereid. This was followed by observations of Pluto and Uranus.

“K2 can’t help but observe the dynamics of our planetary system, " said Barclay. "We all know that planets follow laws of motion but with K2 we can see it happen.”

These initial accomplishments have come in the first year and a half since K2 began in May 2014, and have been carried off without a hitch. The spacecraft continues to perform nominally.

In April, K2 will take part in a global experiment in exoplanet observation with a special observing period or campaign, Campaign 9. In this campaign, both K2 and astronomers at ground-based observatories on five continents will simultaneously monitor the same region of sky towards the center of our galaxy to search for small planets, such as the size of Earth, orbiting very far from their host star or, in some cases, orbiting no star at all.

For this experiment, scientists will use gravitational microlensing – the phenomenon that occurs when the gravity of a foreground object, such as a planet, focuses and magnifies the light from a distant background star. This detection method will allow scientists to find and determine the mass of planets that orbit at great distances, like Jupiter and Neptune do our sun.

What could turn out to be one of the most important legacies of K2 has little to do with the mechanics of the telescope, now operating on two wheels and with an assist from the sun.

The Kepler mission was organized along traditional lines of scientific discovery: a targeted set of objectives carefully chosen by the science team to answer a specific question on behalf of NASA – how common or rare are "Earths" around other suns?

K2’s modified mission involves a whole new approach-- engaging the scientific community at large and opening up the spacecraft's capabilities to a broader audience.

"The new approach of letting the community decide the most compelling science targets we're going to look at has been one of the most exciting aspects," said Steve Howell, the Kepler and K2 project scientist at Ames. "Because of that, the breadth of our science is vast, including star clusters, young stars, supernovae, white dwarfs, very bright stars, active galaxies and, of course, exoplanets."

In the new paradigm, the K2 team laid out some broad scientific objectives for the mission and planned to operate the spacecraft on behalf of the community.

Kepler's field of view surveyed just one patch of sky in the northern hemisphere. The K2 ecliptic field of view provides greater opportunities for Earth-based observatories in both the northern and southern hemispheres, allowing the whole world to participate.

With more than two years of fuel remaining, the spacecraft's scientific future continues to look unexpectedly bright.

For more information about the Kepler and K2 missions, visit:

http://www.nasa.gov/kepler

Michele JohnsonAmes Research Center, Moffett Field,
Calif.650-604-6982michele.johnson@nasa.go

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Directly Measures Rotation of Cloudy ‘Super-Jupiter’

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers using NASA's Hubble Space Telescope have measured the rotation rate of an extreme exoplanet by observing the varied brightness in its atmosphere. This is the first measurement of the rotation of a massive exoplanet using direct imaging.

"The result is very exciting," said Daniel Apai of the University of Arizona in Tucson, leader of the Hubble investigation. "It gives us a unique technique to explore the atmospheres of exoplanets and to measure their rotation rates."

The planet, called 2M1207b, is about four times more massive than Jupiter and is dubbed a "super-Jupiter." It is a companion to a failed star known as a brown dwarf, orbiting the object at a distance of 5 billion miles. By contrast, Jupiter is approximately 500 million miles from the sun. The brown dwarf is known as 2M1207. The system resides 170 light-years away from Earth.

Hubble's image stability, high resolution, and high-contrast imaging capabilities allowed astronomers to precisely measure the planet's brightness changes as it spins. The researchers attribute the brightness variation to complex clouds patterns in the planet's atmosphere. The new Hubble measurements not only verify the presence of these clouds, but also show that the cloud layers are patchy and colorless.

Astronomers first observed the massive exoplanet 10 years ago with Hubble. The observations revealed that the exoplanet's atmosphere is hot enough to have "rain" clouds made of silicates: vaporized rock that cools down to form tiny particles with sizes similar to those in cigarette smoke. Deeper into the atmosphere, iron droplets are forming and falling like rain, eventually evaporating as they enter the lower levels of the atmosphere.

"So at higher altitudes it rains glass, and at lower altitudes it rains iron," said Yifan Zhou of the University of Arizona, lead author on the research paper. "The atmospheric temperatures are between about 2,200 to 2,600 degrees Fahrenheit."

The super-Jupiter is so hot that it appears brightest in infrared light. Astronomers used Hubble's Wide Field Camera 3 to analyze the exoplanet in infrared light to explore the object's cloud cover and measure its rotation rate. The planet is hot because it is only about 10 million years old and is still contracting and cooling. For comparison, Jupiter in our solar system is about 4.5 billion years old.

The planet, however, will not maintain these sizzling temperatures. Over the next few billion years, the object will cool and fade dramatically. As its temperature decreases, the iron and silicate clouds will also form lower and lower in the atmosphere and will eventually disappear from view.

Zhou and his team have also determined that the super-Jupiter completes one rotation approximately every 10 hours, spinning at about the same fast rate as Jupiter.

This super-Jupiter is only about five to seven times less massive than its brown-dwarf host. By contrast, our sun is about 1,000 times more massive than Jupiter. "So this is a very good clue that the 2M1207 system we studied formed differently than our own solar system," Zhou explained. The planets orbiting our sun formed inside a circumstellar disk through accretion. But the super-Jupiter and its companion may have formed throughout the gravitational collapse of a pair of separate disks.

"Our study demonstrates that Hubble and its successor, NASA's James Webb Space Telescope, will be able to derive cloud maps for exoplanets, based on the light we receive from them," Apai said. Indeed, this super-Jupiter is an ideal target for the Webb telescope, an infrared space observatory scheduled to launch in 2018. Webb will help astronomers better determine the exoplanet's atmospheric composition and derive detailed maps from brightness changes with the new technique demonstrated with the Hubble observations.

Results from this study will appear in the Feb. 11, 2016, edition of The Astrophysical Journal.

Contacts:Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4493 / 410-338-4514dweaver@stsci.edu / villard@stsci.edu

As a radio frequency wireless engineer in NASA’s Johnson Space Center Avionic Systems Division in Houston, Melissa Moreno makes an impact in space exploration while proudly sharing her cultural heritage in the NASA community. Moreno works in the Electronic Systems Test Laboratory, developing communication systems critical to Gateway, NASA’s first lunar-orbiting space station. But her […]

Researchers found that long-duration spaceflight affected the mechanical properties of eye tissues, including reducing the stiffness of tissue around the eyeball. A better understanding of these changes could help researchers prevent, diagnose, and treat the vision impairment often seen in crew members. SANSORI, a Canadian Space Agency investigation, examined whether reduced stiffness of eye tissue contributes to […]

On Sept. 30, 1994, space shuttle Endeavour took to the skies on its 7th trip into space. During the 11-day mission, the STS-68 crew of Commander Michael A. Baker, Pilot Terrence “Terry” W. Wilcutt, and Mission Specialists Steven L. Smith, Daniel W. Bursch, Peter J.K. “Jeff” Wisoff, and Payload Commander Thomas “Tom” D. Jones operated […]

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Life or illusion? Avoiding ‘false positives’ in the search for living worlds

4 min read

NASA Science Editorial Team

By Peter Kelley, University of Washington

Is it life, or merely the illusion of life?

Research from the University of Washington-based Virtual Planetary Laboratory published in Astrophysical Journal Lettersin 2016 can help astronomers better identify — and thus rule out — “false positives” in the search for life beyond Earth.

Powerful devices such as the James Webb Space Telescope, launched in 2021, can help astronomers look for possible signs of life on a handful of faraway worlds by searching for, among other things, evidence of oxygen — a “biosignature” — in their atmospheres. This is done by transit spectroscopy, or studying the spectral features of light visible through a planet’s atmosphere when it transits or passes in front of its host star.

“We wanted to determine if there was something we could observe that gave away these ‘false positive’ cases among exoplanets,” said lead author Edward Schwieterman, then a doctoral student in astronomy. “We call them ‘biosignature impostors’ in the paper.

“The potential discovery of life beyond our solar system is of such a huge magnitude and consequence, we really need to be sure we’ve got it right — that when we interpret the light from these exoplanets we know exactly what we’re looking for, and what could fool us.”

Here on Earth, oxygen is produced almost exclusively by photosynthesis — plants and algae converting the sun’s rays into energy to sustain life. And so Earth’s oxygen biosignature is indeed evidence of life. But that may not be universally true.

Previous research from the Virtual Planetary Laboratory has found that some worlds can create oxygen “abiotically,” or by nonliving means. This is more likely in the case of planets orbiting low-mass stars, which are smaller and dimmer than our sun and the most common in the universe.

The first abiotic method they identified results when the star’s ultraviolet light splits apart carbon dioxide (CO2) molecules, freeing some of the oxygen atoms to form into O2, the kind of oxygen present in Earth’s atmosphere.

The giveaway that this particular oxygen biosignature might not indicate life came when the researchers, through computer modeling, found that the process produces not only oxygen but also significant and potentially detectable amounts of carbon monoxide. “So if we saw carbon dioxide and carbon monoxide together in the atmosphere of a rocky planet, we would know to be very suspicious that future oxygen detections would mean life,” Schwieterman said.

The team also found an indicator for abiotic oxygen resulting from starlight similarly breaking down atmospheric water, H2O, allowing hydrogen to escape and leaving vast quantities of oxygen — far more than the Earth has ever had in its atmosphere.

In such cases, Schwieterman said, oxygen molecules collide with each other frequently, producing short-lived pairs of oxygen molecules that become O4 molecules, with their own unique signature.

“Certain O4 features are potentially detectable in transit spectroscopy, and many more could be seen in reflected light,” Schwieterman said. “Seeing a large O4 signature could tip you off that this atmosphere has far too much oxygen to be biologically produced.”

“With these strategies in hand, we can more quickly move on to more promising targets that may have true oxygen biosignatures,” he said.

“It’s one thing to detect a biosignature gas, but another thing to be able to interpret what you are looking at, said Victoria Meadows, then UW professor of astronomy and principal investigator of the Virtual Planetary Laboratory. “This research is important because biosignature impostors may be more common for planets orbiting low-mass stars, which will be the first places we look for life outside our solar system in the coming decade.”

Schwieterman’s other co-authors are Rory Barnes, Giada Arney, Rodrigo Luger, Shawn Domagal-Goldman, Drake Deming and Chester Harman.

The research was funded by the NASA Astrobiology Institute.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Veteran Astronomer Joins JPL Exoplanet Team

7 min read

NASA Science Editorial Team

From Pat Brennan, JPL

Like many a planet-struck high-school student, Dr. Karl Stapelfeldt watched the Voyager spacecraft make their historic Jupiter flybys in 1979—and first became aware of NASA’s Jet Propulsion Laboratory. He even wrote a letter from his home in Florida asking how to get a job there.

And Stapelfeldt did make his way to JPL, first as a graduate student researcher and later as an employee working on a variety of projects: The WFPC2 camera for the Hubble Space Telescope, NASA’s Spitzer Space Telescope, and a proposed mission called the Terrestrial Planet Finder. Now, after a four-year stint at the Goddard Spaceflight Center in Greenbelt, Maryland, where he was chief of the Exoplanets and Stellar Astrophysics Laboratory, Stapelfeldt is returning to JPL.

A specialist in direct imaging of extrasolar planets—that is, planets circling stars other than our sun—Stapelfeldt will become the chief scientist for NASA’s Exoplanet Exploration Program, an arm of the NASA Astrophysics Division, helping to design state-of-the-art instruments for future space missions.

His timing couldn’t be better. JPL scientists are working on a new generation of space telescopes that should, in the years ahead, capture actual images of planets orbiting distant stars.

Stapelfeldtbrings expertise and a long list of goals and ideas to his new position. Hetook a few moments recently to talk about the big picture and provide a previewof coming attractions.

Q. What are the goals of NASA’s Exoplanet program for the next decade?

A. For a long time the program'sgoal has been to fly missions that can discover Earth-like planets around otherstars, and measure the properties of their atmospheres. Such planets might havewater on their surfaces, they might be habitable, perhaps even have life. Let'sfind out! The program manages NASA's current exoplanet-related projects anddevelops the technologies needed for future missions to observe the mostaccessible targets, the stars in the sun’s immediate neighborhood.

Thefirst exoplanet was only found 20 years ago, and since then we have detectedrelatively few exoplanets by way of direct imaging. To the layperson the mostnatural way to discover something is to actually see it. But for the most part,the exoplanets discovered so far are only known indirectly by the wobble oftheir host star, or dimming of the star as the planet passes in front. Theindirect methods have been great—they’ve told us so many amazing things—butimaging is still our ultimate goal. It has the potential to find Earth-sizedplanets around stars like the sun, and measure their (atmospheric) spectra veryclearly.

Inthe next 10 years a major first step is going to happen. We’ve been trying formore than a decade to get an imaging mission going. The first one will be theWFIRST (Wide-field Infrared Survey Telescope) mission that is starting now, andwill be launched by the mid 2020s. That mission will carry an exoplanet imageron it, for the first time flying a dedicated instrument for this purpose. Withthe WFIRST instrument we intend to show that our approach to the problem willwork in flight, and also get a taste of the science results that can come fromit. So in the mid 2020s we should be seeing the reflected spectrum ofJupiter-like exoplanets, or even down at Neptune size—though not at Neptune’sdistance from the sun.

Q. What is the next bigstep after that?

A. The WFIRST mission isnot going to get us the goal I mentioned before: imaging Earth-like planets,and finding out if they are habitable and if they have water and possibly life.To accomplish that we need, really, a major new observatory. NASA is about tostart a series of major mission studies, two of which will explore our optionsfor that observatory. The Exoplanet Exploration Program Office here willsupport those studies. Eventually the 2020 Decadal Survey of Astronomy andAstrophysics will evaluate those studies and hopefully recommend one of them togo forward.

Thenew observatory may be designed to block the starlight using the WFIRSTapproach of an instrument held inside the telescope—a coronagraph— oralternatively use a different approach to blocking starlight, a starshadefloating far in the distance along the sight line to the target star. Thesemethods would be developed to the level where we could see a planet 10 billiontimes fainter than the target star.

Q. What is your visionfor the program?

A. We need achievable andaffordable options for space missions that can make progress in this problem,and get the whole national science community lined up behind them.

Thisis really the intersection of astrophysics and planetary science. We're usingthe tools of astronomers—telescopes and their attached instruments—to extendplanetary science to other solar systems. We want to get planetary scientistsand astronomers together in this enterprise.

Ihope to catalyze Goddard and JPL cooperation on this common goal. And followingthe precedent of Hubble, get other countries to join with us to achieve thesechallenging goals. I'd like to see an international effort.

Thepublic is very excited by this problem of exoplanets. We see imaginary worldsall the time in science fiction. The missions we will be developing can take usfrom imagination to knowing what's really out there. Exoplanet science combineskey scientific questions with the public's general enthusiasm for exploration.

Q. How did you first getinterested in science and astronomy?

A. I was like many littlekids affected by what I saw on television, both the reality of the Apolloprogram and the visions in science fiction. Both were inspiring. I havekindergarten drawings that show what was in my mind at the time. My dad got mea telescope at the right age and I just read all I could about this stuff.

I'vealways been interested in where planetary science and astrophysics cometogether. During my graduate years, we didn't know of any exoplanets. The nextbest thing at that time was circumstellar disk material in orbit around a star—gasand dust clouds that might form a planetary system, or might be leftover fromforming it. I started in my research career studying them.

Q. What science questionintrigues you the most?

A. I would like to be ableto understand the complete evolution of a planetary system, just as a geologistwould like to see every stage in the evolution of a continent or a mountain.Knowing the processes that govern the formation, maturation, and eventualdestruction of planetary systems is a prerequisite for understanding theprevalence of life in the universe.

Q. Any advice to youngpeople considering a career in science or astronomy?

A. I think it's one of themore rewarding things one could do. You're pursuing knowledge for its own sake,especially in astronomy. It's not one of the more practical things. The kind ofsatisfaction you get out of it is not really connected to financial reward; it'sunderstanding our place in the universe.

Awhole bunch of NASA folks 40 years ago worked hard to make the Hubble telescopea reality, to get it started. I was lucky to be in position for the payoff fromtheir efforts—to enjoy using that machine when it began operating on-orbit. Sofor young people, the message is that NASA right now is working to define yourtelescope, the telescope you will use when you are a researcher. So go tocollege and graduate school and become that researcher, so that you can takethis machine and do great things with it.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers find the largest solar system in the galaxy

4 min read

NASA Science Editorial Team

From the Royal Astronomical Society

A team of astronomers in the UK, USA and Australia have found a lonely planet, until now thought to be a free floating or lonely planet, in a huge orbit around its star. Incredibly the object, designated as 2MASS J2126, is about 1 trillion (1 million million) kilometers from the star, or about 7000 times the distance from the Earth to the sun. The researchers report the discovery in a paper in Monthly Notices of the Royal Astronomical Society.

In the last five years a number of free floating planets have been found. These are gas giant worlds like Jupiter that lack the mass for the nuclear reactions that make stars shine, so cool and fade over time. Measuring the temperatures of these objects is relatively straightforward, but it depends on both mass and age. This means astronomers need to find out how old they are, before they can find out if they are lightweight enough to be planets or if they are heavier 'failed stars' known as brown dwarfs.

US-based researchers found 2MASS J2126 in an infrared sky survey, flagging it as a possible young and hence low mass object. In 2014, Canadian researchers identified 2MASS J2126 as a possible member of a 45-million-year-old group of stars and brown dwarfs known as the Tucana Horologium Association. This made it young and low enough in mass to be classified as a free-floating planet.

In the same region of the sky, TYC 9486-927-1 is a star that had been identified as being young, but not as a member of any known group of young stars. Until now no one had suggested that TYC 9486-927-1 and 2MASS J2126 were in some way linked.

Lead author Dr. Niall Deacon of the University of Hertfordshire has spent the last few years searching for young stars with companions in wide orbits. As part of the work, his team looked through lists of known young stars, brown dwarfs and free-floating planets to see if any of them could be related. They found that TYC 9486-927-1 and 2MASS J2126 are moving through space together and are both about 104 light-years from the sun, implying that they are associated.

"This is the widest planet system found so far and both the members of it have been known for eight years," said Dr. Deacon. "But nobody had made the link between the objects before. The planet is not quite as lonely as we first thought, but it's certainly in a very long distance relationship."

When they looked in more detail, the team were not able to confirm that TYC 9486-927-1 and 2MASS J2126 are members of any known group of young stars.

"Membership in a group of young stars is great for establishing an age," said study co-author Josh Schlieder of the NASA Ames Research Center. "But when we can't use that we need to resort to other methods."

The team then looked at the spectrum – the dispersed light – of the star to measure the strength of a feature caused by the element lithium. This is destroyed early on in a star's life so the more lithium it has, the younger it is. TYC 9486-927-1 has stronger signatures of lithium than a group of 45 million year old stars (the Tucana Horologium Association) but weaker signatures than a group of 10-million-year-old stars, implying an age between the two.

Based on this age the team was able to estimate the mass of 2MASS J2126, finding it to be between 11.6 to 15 times the mass of Jupiter. This placed it on the boundary between planets and brown dwarfs. It means that 2MASS J2126 has a similar mass, age and temperature to one of the first planets directly imaged around another star, beta Pictoris b.

"Compared to beta Pictoris b, 2MASS J2126 is more than 700 times further away from its host star," Dr. Simon Murphy of the Australian National University, also a study co-author, "But how such a wide planetary system forms and survives remains an open question."

2MASS J2126 is around 7000 Earth-sun distances or 1 trillion kilometers away from its parent star, giving it the widest orbit of any planet found around another star. At such an enormous distance it takes roughly 900,000 years to complete one orbit, meaning it has completed less than 50 orbits over its lifetime. There is little prospect of any life on an exotic world like this, but any inhabitants would see their 'sun' as no more than a bright star, and might not even imagine they were connected to it at all.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Combing the galaxy for habitable worlds

7 min read

NASA Science Editorial Team

From Adam Hadhazy, Caltech

Promising new calibration tools, called laser frequency combs, could allow astronomers to take a major step in discovering and characterizing Earth-like planets around other stars. These devices generate evenly spaced lines of light, much like the teeth on a comb for styling hair or the tick marks on a ruler—hence their nickname of "optical rulers." The tick marks serve as stable reference points when making precision measurements such as those of the small shifts in starlight caused by planets pulling gravitationally on their parent stars.

Yet today's commercially available combs have a significant drawback. Because their tick marks are so finely spaced, the light output of these combs must be filtered to produce useful reference lines. This extra step adds complexity to the system and requires costly additional equipment.

To resolve these kinds of issues, Caltech researchers looked to a kind of comb not previously deployed for astronomy. The novel comb produces easily resolvable lines, without any need for filtering. Furthermore, the Caltech comb is built from off-the-shelf components developed by the telecommunications industry.

"We have demonstrated an alternative approach that is simple, reliable, and relatively inexpensive," says paper coauthor Kerry Vahala, the Ted and Ginger Jenkins Professor of Information Science and Technology and Applied Physics as well as the executive officer for Applied Physics and Materials Science in Caltech's Division of Engineering and Applied Science. The kind of frequency comb used by the researchers previously has been studied in the Vahala group in a different application, the generation of high-stability microwaves.

"We believe members of the astronomical community could greatly benefit in their exoplanet hunting and characterization studies with this new laser frequency comb instrument," says Xu Yi, a graduate student in Vahala's lab and the lead author of a paper describing the work published in the January 27, 2016, issue of the journal Nature Communications.

Scientists first began widely using laser frequency combs as precision rulers in the late 1990s in fields like metrology and spectroscopy; for their work, the technology's developers (John L. Hall of JILA and the National Institute of Standards and Technology (NIST) and Theodor Hänsch of the Max Planck Institute of Quantum Optics and Ludwig Maximilians University Munich) were awarded half of the Nobel Prize in Physics in 2005. In astronomy, the combs are starting to be utilized in the radial velocity, or "wobble" method, the earliest and among the most successful methods for identifying exoplanets.

The "wobble" refers to the periodic changes in a star's motion, accompanied by starlight shifts owing to the Doppler effect, that are induced by the gravitational pull of an exop

lanet orbiting around the star. The magnitude of the shift in the starlight's wavelength—on the order of quadrillionths of a meter—together with the period of the wobble can be used to determine an exoplanet's mass and orbital distance from its star. These details are critical for assessing habitability parameters such as surface temperature and the eccentricity of the exoplanet's orbit. With exoplanets that pass directly in front of (or "transit") their host star, allowing their radius to be determined directly, it is even possible to determine the bulk composition—for example, if the planet is built up primarily of gas, ice, or rock.

In recent years, so-called mode-locked laser combs have proven useful in this task. These lasers generate a periodic stream of ultrashort light pulses to create the comb. With such combs, however, approximately 49 out of every 50 tick marks must be blocked out. This requires temperature- and vibration-insensitive filtering equipment.

The new electro-optical comb that the Caltech team studied relies on microwave modulation of a continuous laser source, rather than a pulsed laser. It produces comb lines spaced by tens of gigahertz. These lines have from 10 to 100 times wider spacing than the tick marks of pulsed laser combs.

To see how well a prototype would work in the field, the researchers took their comb to Mauna Kea in Hawaii. In September 2014, the instrument was tested at the NASA Infrared Telescope Facility (IRTF); in March 2015, it was tested with the Near Infrared Spectrometer on the W. M. Keck Observatory's Keck II telescope with the assistance of UCLA astronomer Mike Fitzgerald and UCLA graduate student Emily Martin, coauthors on the paper. The researchers found that their simplified comb (the entire electro-optical comb apparatus requires only half of the space available on a standard 19-inch instrumentation rack) provided steady calibration at room temperature for more than five days at IRTF. The comb also operated flawlessly during the second test—despite having been disassembled, stored for six months, and reassembled.

"From a technological maturity point of view, the frequency comb we have developed is already basically ready to go and could be installed at many telescopes," says paper coauthor Scott Diddams of NIST.

The Caltech comb produces spectral lines in the infrared, making it ideal for studying red dwarf stars, the most common stars in the Milky Way. Red dwarf stars are brightest in infrared wavelengths. Because red dwarfs are small, cool, and dim, planets orbiting these types of stars are easier to detect and analyze than those orbiting hotter sun-like stars. NASA's Kepler space observatory has shown that almost all red dwarf stars host planets in the range of one to four times the size of Earth, with up to 25 percent of these planets located in the temperate, or "habitable," zone around their host stars. Thus, many astronomers predict that red dwarfs provide the best chance for the first discovery of a world capable of supporting life.

"Our goal is to make these laser frequency combs simple and sturdy enough that you can slap them onto every telescope, and you don't have to think about them anymore," says paper coauthor Charles Beichman, senior faculty associate in astronomy and the executive director of the NASA ExoPlanet Science Institute at Caltech. "Having these combs routinely available as a modest add-on to current and future instrumentation really will expand our ability to find potentially habitable planets, particularly around very cool red dwarf stars," he says.

The research team is planning to double the frequency of the prototype comb's light output—now centered around 1,550 nanometers, in the infrared—to reach into the visible light range. Doing so would allow the comb also to calibrate spectra from sun-like stars, whose light output is at shorter, visible wavelengths, and thus seek out planets that are Earth's "twins."

Other authors of the paper are Jiang Li, a visitor in applied physics and materials science, graduate students Peter Gao and Michael Bottom, and scientific research assistant Elise Furlan, all from Caltech; Stephanie Leifer, Jagmit Sandhu, Gautam Vasisht, and Pin Chen of JPL; Peter Plavchan, formerly at Caltech and now a professor at Missouri State University; G. Ycas of NIST; Jonathan Gagne of the University of Montréal; and Greg Doppmann of the Keck Observatory.

The paper is titled "Demonstration of a near-IR line-referenced electro-optical laser frequency comb for precision radial velocity measurements in astronomy." The research performed at Caltech and JPL was funded through the President's and Director's Fund Program, and the work at NIST was funded by the National Science Foundation.

Yet today's commercially available combs have a significant drawback. Because their tick marks are so finely spaced, the light output of these combs must be filtered to produce useful reference lines. This extra step adds complexity to the system and requires costly additional equipment. - See more at: http://www.caltech.edu/news/new-calibration-tool-will-help-astronomers-look-habitable-exoplanets-49624#sthash.uwb9Otf3.dpuf

Promising new calibration tools, called laser frequency combs, could allow astronomers to take a major step in discovering and characterizing earthlike planets around other stars. These devices generate evenly spaced lines of light, much like the teeth on a comb for styling hair or the tick marks on a ruler—hence their nickname of "optical rulers." The tick marks serve as stable reference points when making precision measurements such as those of the small shifts in starlight caused by planets pulling gravitationally on their parent stars. - See more at: http://www.caltech.edu/news/new-calibration-tool-will-help-astronomers-look-habitable-exoplanets-49624#sthash.uwb9Otf3.dpuf

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Far Beyond Pluto, a Possible Planet Nine Awaits Discovery

10 min read

NASA Science Editorial Team

From Kimm Fesenmaier, Caltech

Caltech researchers have found evidence of a giant planet tracing a bizarre, highly elongated orbit in the outer solar system. The object, which the researchers have nicknamed Planet Nine, has a mass about 10 times that of Earth and orbits about 20 times farther from the sun on average than does Neptune (which orbits the sun at an average distance of 2.8 billion miles, or 4.5 billion km). In fact, it would take this new planet between 10,000 and 20,000 years to make just one full orbit around the sun.

The researchers, Konstantin Batygin and Mike Brown, discovered the planet's existence through mathematical modeling and computer simulations but have not yet observed the object directly.

"This would be a real ninth planet," says Brown, the Richard and Barbara Rosenberg Professor of Planetary Astronomy at Caltech. "There have only been two true planets discovered since ancient times, and this would be a third. It's a pretty substantial chunk of our solar system that's still out there to be found, which is pretty exciting."

Brown notes that the putative ninth planet – at 5,000 times the mass of Pluto – is sufficiently large that there should be no debate about whether it is a true planet. Unlike the class of smaller objects now known as dwarf planets, Planet Nine gravitationally dominates its neighborhood of the solar system. In fact, it dominates a region larger than any of the other known planets – a fact that Brown says makes it "the most planet-y of the planets in the whole solar system."

Batygin and Brown describe their work in the current issue of the Astronomical Journal and show how Planet Nine helps explain a number of mysterious features of the field of icy objects and debris beyond Neptune known as the Kuiper Belt.

"Although we were initially quite skeptical that this planet could exist, as we continued to investigate its orbit and what it would mean for the outer solar system, we become increasingly convinced that it is out there," said Batygin, an assistant professor of planetary science. "For the first time in over 150 years, there is solid evidence that the solar system's planetary census is incomplete."

The road to the theoretical discovery was not straightforward. In 2014, a former postdoc of Brown's, Chad Trujillo, and his colleague Scott Sheppard published a paper noting that 13 of the most distant objects in the Kuiper Belt are similar with respect to an obscure orbital feature. To explain that similarity, they suggested the possible presence of a small planet. Brown thought the planet solution was unlikely, but his interest was piqued.

He took the problem down the hall to Batygin, and the two started what became a year-and-a-half-long collaboration to investigate the distant objects. As an observer and a theorist, respectively, the researchers approached the work from very different perspectives – Brown as someone who looks at the sky and tries to anchor everything in the context of what can be seen, and Batygin as someone who puts himself within the context of dynamics, considering how things might work from a physics standpoint. Those differences allowed the researchers to challenge each other's ideas and to consider new possibilities. "I would bring in some of these observational aspects; he would come back with arguments from theory, and we would push each other. I don't think the discovery would have happened without that back and forth," said Brown. "It was perhaps the most fun year of working on a problem in the solar system that I've ever had."

Fairly quickly Batygin and Brown realized that the six most distant objects from Trujillo and Shepherd's original collection all follow elliptical orbits that point in the same direction in physical space. That is particularly surprising because the outermost points of their orbits move around the solar system, and they travel at different rates.

"It's almost like having six hands on a clock all moving at different rates, and when you happen to look up, they're all in exactly the same place," said Brown. The odds of having that happen are something like 1 in 100, he said. But on top of that, the orbits of the six objects are also all tilted in the same way – pointing about 30 degrees downward in the same direction relative to the plane of the eight known planets. The probability of that happening is about 0.007 percent. "Basically it shouldn't happen randomly," Brown says. "So we thought something else must be shaping these orbits."

The first possibility they investigated was that perhaps there are enough distant Kuiper Belt objects – some of which have not yet been discovered – to exert the gravity needed to keep that subpopulation clustered together. The researchers quickly ruled this out when it turned out that such a scenario would require the Kuiper Belt to have about 100 times the mass it has today.

That left them with the idea of a planet. Their first instinct was to run simulations involving a planet in a distant orbit that encircled the orbits of the six Kuiper Belt objects, acting like a giant lasso to wrangle them into their alignment. Batygin said that almost works but does not provide the observed eccentricities precisely. "Close, but no cigar," he said.

Then, effectively by accident, Batygin and Brown noticed that if they ran their simulations with a massive planet in an anti-aligned orbit – an orbit in which the planet's closest approach to the sun, or perihelion, is 180 degrees across from the perihelion of all the other objects and known planets – the distant Kuiper Belt objects in the simulation assumed the alignment that is actually observed.

"Your natural response is 'This orbital geometry can't be right. This can't be stable over the long term because, after all, this would cause the planet and these objects to meet and eventually collide,'" said Batygin. But through a mechanism known as mean-motion resonance, the anti-aligned orbit of the ninth planet actually prevents the Kuiper Belt objects from colliding with it and keeps them aligned. As orbiting objects approach each other they exchange energy. So, for example, for every four orbits Planet Nine makes, a distant Kuiper Belt object might complete nine orbits. They never collide. Instead, like a parent maintaining the arc of a child on a swing with periodic pushes, Planet Nine nudges the orbits of distant Kuiper Belt objects such that their configuration with relation to the planet is preserved.

"Still, I was very skeptical," said Batygin. "I had never seen anything like this in celestial mechanics."

But little by little, as the researchers investigated additional features and consequences of the model, they became persuaded. "A good theory should not only explain things that you set out to explain. It should hopefully explain things that you didn't set out to explain and make predictions that are testable," said Batygin.

And indeed, Planet Nine's existence helps explain more than just the alignment of the distant Kuiper Belt objects. It also provides an explanation for the mysterious orbits that two of them trace. The first of those objects, dubbed Sedna, was discovered by Brown in 2003. Unlike standard-variety Kuiper Belt objects, which get gravitationally "kicked out" by Neptune and then return back to it, Sedna never gets very close to Neptune. A second object like Sedna, known as 2012 VP113, was announced by Trujillo and Shepherd in 2014. Batygin and Brown found that the presence of Planet Nine in its proposed orbit naturally produces Sedna-like objects by taking a standard Kuiper Belt object and slowly pulling it away into an orbit less connected to Neptune.

But the real kicker for the researchers was the fact that their simulations also predicted that there would be objects in the Kuiper Belt on orbits inclined perpendicularly to the plane of the planets. Batygin kept finding evidence for these in his simulations and took them to Brown. "Suddenly I realized, there are objects like that," recalled Brown. In the last three years, observers have identified four objects tracing orbits roughly along one perpendicular line from Neptune, and one object along another. "We plotted up the positions of those objects and their orbits, and they matched the simulations exactly," Brown said. "When we found that, my jaw sort of hit the floor."

Said Batygin, "When the simulation aligned the distant Kuiper Belt objects and created objects like Sedna, we thought this is kind of awesome – you kill two birds with one stone. But with the existence of the planet also explaining these perpendicular orbits, not only do you kill two birds, you also take down a bird that you didn't realize was sitting in a nearby tree."

Where did Planet Nine come from and how did it end up in the outer solar system? Scientists have long believed that the early solar system began with four planetary cores that went on to grab all of the gas around them, forming the four gas planets – Jupiter, Saturn, Uranus, and Neptune. Over time, collisions and ejections shaped them and moved them out to their present locations. "But there is no reason that there could not have been five cores, rather than four," Brown said. Planet Nine could represent that fifth core, and if it got too close to Jupiter or Saturn, it could have been ejected into its distant, eccentric orbit.

Batygin and Brown continue to refine their simulations and learn more about the planet's orbit and its influence on the distant solar system. Meanwhile, Brown and other colleagues have begun searching the skies for Planet Nine. Only the planet's rough orbit is known, not the precise location of the planet on that elliptical path. If the planet happens to be close to its perihelion, Brown said, astronomers should be able to spot it in images captured by previous surveys. If it is in the most distant part of its orbit, the world's largest telescopes – such as the twin 10-meter telescopes at the W. M. Keck Observatory and the Subaru Telescope, all on Mauna Kea in Hawaii – will be needed to see it. If, however, Planet Nine is now located anywhere in between, many telescopes have a shot at finding it.

"I would love to find it," said Brown. "But I'd also be perfectly happy if someone else found it. That is why we're publishing this paper. We hope that other people are going to get inspired and start searching."

In terms of understanding more about the solar system's context in the rest of the universe, Batygin said that, in a couple of ways, this ninth planet that seems like such an oddball to us would actually make our solar system more similar to the other planetary systems that astronomers are finding around other stars. First, most of the planets around other Sun-like stars have no single orbital range – that is, some of them orbit extremely close to their host stars, while others follow exceptionally distant orbits. Second, the most common planets around other stars range between 1 and 10 Earth masses.

"One of the most startling discoveries about other planetary systems has been that the most common type of planet out there has a mass between that of Earth and that of Neptune," said Batygin. "Until now, we've thought that the solar system was lacking in this most common type of planet. Maybe we're more normal after all."

Brown – well known for the significant role he played in Pluto's demotion from a planet to a dwarf planet – added, "All those people who are mad that Pluto is no longer a planet can be thrilled to know that there is a real planet out there still to be found. Now we can go and find this planet and make the solar system have nine planets once again."

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Fantastic Alien Civilizations and Where to Find Them

4 min read

NASA Science Editorial Team

From Harvard-Smithsonian Center for Astrophysics

Globular star clusters are extraordinary in almost every way. They're densely packed, holding a million stars in a ball only about 100 light-years across on average. They're old, dating back almost to the birth of the Milky Way. And according to new research, they also could be extraordinarily good places to look for space-faring civilizations.

"A globular cluster might be the first place in which intelligent life is identified in our galaxy," says lead author Rosanne DiStefano of the Harvard-Smithsonian Center for Astrophysics (CfA).

DiStefano presented this research today in a press conference at a meeting of the American Astronomical Society.

Our Milky Way galaxy hosts about 150 globular clusters, most of them orbiting in the galactic outskirts. They formed about 10 billion years ago on average. As a result, their stars contain fewer of the heavy elements needed to construct planets, since those elements (like iron and silicon) must be created in earlier generations of stars. Some scientists have argued that this makes globular cluster stars less likely to host planets. In fact, only one planet has been found in a globular cluster to date.

However, DiStefano and her colleague Alak Ray (Tata Institute of Fundamental Research, Mumbai) argue that this view is too pessimistic. Exoplanets have been found around stars only one-tenth as metal-rich as our Sun. And while Jupiter-sized planets are found preferentially around stars containing higher levels of heavy elements, research finds that smaller, Earth-sized planets show no such preference.

"It's premature to say there are no planets in globular clusters," states Ray.

Another concern is that a globular cluster's crowded environment would threaten any planets that do form. A neighboring star could wander too close and gravitationally disrupt a planetary system, flinging worlds into icy interstellar space.

However, a star's habitable zone - the distance at which a planet would be warm enough for liquid water - varies depending on the star. While brighter stars have more distant habitable zones, planets orbiting dimmer stars would have to huddle much closer. Brighter stars also live shorter lives, and since globular clusters are old, those stars have died out. The predominant stars in globular clusters are faint, long-lived red dwarfs. Any potentially habitable planets they host would orbit nearby and be relatively safe from stellar interactions.

"Once planets form, they can survive for long periods of time, even longer than the current age of the universe," explains DiStefano.

So if habitable planets can form in globular clusters and survive for billions of years, what are the consequences for life should it evolve? Life would have ample time to become increasingly complex, and even potentially develop intelligence.

Such a civilization would enjoy a very different environment than our own. The nearest star to our solar system is four light-years, or 24 trillion miles, away. In contrast, the nearest star within a globular cluster could be about 20 times closer - just one trillion miles away. This would make interstellar communication and exploration significantly easier.

"We call it the 'globular cluster opportunity,'" says DiStefano. "Sending a broadcast between the stars wouldn't take any longer than a letter from the U.S. to Europe in the 18th century."

"Interstellar travel would take less time too. The Voyager probes are 100 billion miles from Earth, or one-tenth as far as it would take to reach the closest star if we lived in a globular cluster. That means sending an interstellar probe is something a civilization at our technological level could do in a globular cluster," she adds.

The closest globular cluster to Earth is still several thousand light-years away, making it difficult to find planets, particularly in a cluster’s crowded core. But it could be possible to detect transiting planets on the outskirts of globular clusters. Astronomers might even spot free-floating planets through gravitational lensing, in which the planet’s gravity magnifies light from a background star.

A more intriguing idea might be to target globular clusters with SETI search methods, looking for radio or laser broadcasts. The concept has a long history: In 1974 astronomer Frank Drake used the Arecibo radio telescope to broadcast the first deliberate message from Earth to outer space. It was directed at the globular cluster Messier 13 (M13).

Headquartered in Cambridge, Mass., the Harvard-Smithsonian Center for Astrophysics (CfA) is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanets are renamed after heroes and legends

3 min read

NASA Science Editorial Team

From the International Astronomical Union

The votes are in — the names of 19 ExoWorlds (14 stars and 31 exoplanets orbiting them) have been chosen by public vote in the NameExoWorlds contest, and accepted by the IAU. Reflecting the truly international interest in astronomy, over half a million votes from 182 countries and territories contributed to the new official designations of the alien worlds.

Although people have been naming celestial objects for millennia, the International Astronomical Union (IAU) is the authority responsible for assigning official names to celestial bodies. The NameExoWorlds contest provided the first opportunity for the public to name exoplanets, and their stars. The winning names are to be used freely in parallel with the existing scientific nomenclature, with due credit to the clubs or organizations that proposed them.

With voting concluding on Oct 31, 2015, a total of 573,242 votes from the public have contributed to the naming of 31 exoplanets and 14 host stars. Proposers of the winning names are to be awarded a plaque commemorating their contribution to astronomy and they will be given the exciting opportunity to name a minor planet.

The public voted on the 274 proposed ExoWorld names submitted by a wide variety of astronomy organizations from 45 countries all over the world — these included amateur astronomy groups, schools, universities and planetariums. The successful entries were received from across the globe — four were received from North America (USA, Canada), one from Latin America and the Caribbean (Mexico), two from the Middle East & Africa (Morocco, Syria), six from Europe (France, Italy, Netherlands, Spain, Switzerland), and six from Asia–Pacific (Australia, Japan, Thailand).

Image credit: IAU

The IAU Executive Committee Working Group on the Public Naming of Planets and Planetary Satellites validated all the individual cases of the winning names from the vote, as stipulated in the guidelines, and made appropriate modifications to the original proposals where necessary, in full agreement with the proposers.

However, after extensive deliberation, the Committee decided to annul the vote for one particular ExoWorld — tau Boötis — as the winning name was judged not to conform with the IAU rules for naming exoplanets. To this end, the IAU will organize a new contest to decide the name of tau Boötis in the future.

The newly adopted names take the form of different mythological figures from a wide variety of cultures from across history, as well as famous scientists, fictional characters, ancient cities and words selected from bygone languages.

Download the complete list of results here: http://nameexoworlds.iau.org/names

Image credit: IAU

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Missing Water Mystery Solved in Comprehensive Survey of Exoplanets

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

A survey of 10 hot, Jupiter-sized exoplanets conducted with NASA's Hubble and Spitzer space telescopes has led a team to solve a long-standing mystery -- why some of these worlds seem to have less water than expected. The findings offer new insights into the wide range of planetary atmospheres in our galaxy and how planets are assembled.

Of the nearly 2,000 planets confirmed to be orbiting other stars, a subset are gaseous planets with characteristics similar to those of Jupiter but orbit very close to their stars, making them blistering hot.

Their close proximity to the star makes them difficult to observe in the glare of starlight. Due to this difficulty, Hubble has only explored a handful of hot Jupiters in the past. These initial studies have found several planets to hold less water than predicted by atmospheric models.

The international team of astronomers has tackled the problem by making the largest-ever spectroscopic catalogue of exoplanet atmospheres. All of the planets in the catalog follow orbits oriented so the planet passes in front of their parent star, as seen from Earth. During this so-called transit, some of the starlight travels through the planet's outer atmosphere. "The atmosphere leaves its unique fingerprint on the starlight, which we can study when the light reaches us," explains co-author Hannah Wakeford, now at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

By combining data from NASA's Hubble and Spitzer Space Telescopes, the team was able to attain a broad spectrum of light covering wavelengths from the optical to infrared. The difference in planetary radius as measured between visible and infrared wavelengths was used to indicate the type of planetary atmosphere being observed for each planet in the sample, whether hazy or clear. A cloudy planet will appear larger in visible light than at infrared wavelengths, which penetrate deeper into the atmosphere. It was this comparison that allowed the team to find a correlation between hazy or cloudy atmospheres and faint water detection.

"I'm really excited to finally see the data from this wide group of planets together, as this is the first time we've had sufficient wavelength coverage to compare multiple features from one planet to another," says David Sing of the University of Exeter, U.K., lead author of the paper. "We found the planetary atmospheres to be much more diverse than we expected."

"Our results suggest it's simply clouds hiding the water from prying eyes, and therefore rule out dry hot Jupiters," explained co-author Jonathan Fortney of the University of California, Santa Cruz. "The alternative theory to this is that planets form in an environment deprived of water, but this would require us to completely rethink our current theories of how planets are born."

The results are being published in the Dec. 14 issue of the British science journal Nature.

The study of exoplanetary atmospheres is currently in its infancy. Hubble's successor, the James Webb Space Telescope, will open a new infrared window on the study of exoplanets and their atmospheres.

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy in Washington, D.C.

NASA's Jet Propulsion Laboratory, Pasadena, California, manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology in Pasadena. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

For images and more information about this study and Hubble, visit:

For more information about Spitzer, visit:

Contacts:

Whitney ClavinNASA's Jet Propulsion Laboratory, Pasadena, California818-354-4673whitney.clavin@jpl.nasa.gov

Rob GutroNASA's Goddard Space Flight Center, Greenbelt, Maryland301-286-4044robert.j.gutro@nasa.gov

Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4514villard@stsci.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Be thankful this star isn’t your neighbor

9 min read

NASA Science Editorial Team

From Harvard-Smithsonian Center for Astrophysics

Our sun is a relatively quiet star that only occasionally releases solar flares or blasts of energetic particles that threaten satellites and power grids. You might think that smaller, cooler stars would be even more sedate. However, astronomers have now identified a tiny star with a monstrous temper. It shows evidence of much stronger flares than anything our Sun produces. If similar stars prove to be just as stormy, then potentially habitable planets orbiting them are likely to be much less hospitable than previously thought.

"If we lived around a star like this one, we wouldn't have any satellite communications. In fact, it might be extremely difficult for life to evolve at all in such a stormy environment," says lead author Peter Williams of the Harvard-Smithsonian Center for Astrophysics (CfA).

The research team targeted a well-known red dwarf star located about 35 light-years from Earth in the constellation Boîtes. The object is so small and cool that it's right on the dividing line between stars (which fuse hydrogen) and brown dwarfs (which don't). One of the things that makes this small star remarkable is that it spins rapidly, completing a full rotation about every two hours. Compare that with our sun, which takes nearly a month to spin once on its axis.

Previous data from the Karl G. Jansky Very Large Array in Socorro, NM showed that this star has a magnetic field several hundred times stronger than our Sun. This puzzled astronomers because the physical processes that generate the Sun's magnetic field shouldn't operate in such a small star.

"This star is a very different beast from our Sun, magnetically speaking," states CfA astronomer and co-author Edo Berger.

The researchers examined the star with the new Atacama Large Millimeter/submillimeter Array (ALMA) and detected emission at a frequency of 95 GHz. This is the first time that flare-like emission at such high frequencies has been detected from a red dwarf star. Our sun generates similar emission from solar flares but only intermittently. What's more, the emission from this star is 10,000 times brighter than what our own Sun produces, even though it has less than one-tenth of the sun's mass. The fact that ALMA detected this emission in a brief four-hour observation suggests that the red dwarf is continuously active.

This has important implications for the search for habitable planets outside the solar system. Red dwarfs are the most common type of star in our galaxy, which makes them promising targets for planet searches. But because a red dwarf is so cool, a planet would have to orbit very close to the star to be warm enough for liquid water to exist. That proximity would put the planet right in the bull's-eye for radiation that could strip its atmosphere or destroy any complex molecules on its surface.

"It's like living in Tornado Alley in the U.S. Your location puts you at greater risk of severe storms," explains Williams. "A planet in the habitable zone of a star like this would be buffeted by storms much stronger than those generated by the sun."

Astronomers will study similar stars in the future to determine whether this one is an oddball or an example of an entire class of stormy stars.

These findings have been accepted for publication in The Astrophysical Journal and are available online.

Our Sun is a relatively quiet star that only occasionally releases solar flares or blasts of energetic particles that threaten satellites and power grids. You might think that smaller, cooler stars would be even more sedate. However, astronomers have now identified a tiny star with a monstrous temper. It shows evidence of much stronger flares than anything our Sun produces. If similar stars prove to be just as stormy, then potentially habitable planets orbiting them are likely to be much less hospitable than previously thought.

"If we lived around a star like this one, we wouldn't have any satellite communications. In fact, it might be extremely difficult for life to evolve at all in such a stormy environment," says lead author Peter Williams of the Harvard-Smithsonian Center for Astrophysics (CfA).

The research team targeted a well-known red dwarf star located about 35 light-years from Earth in the constellation Boîtes. The object is so small and cool that it's right on the dividing line between stars (which fuse hydrogen) and brown dwarfs (which don't). One of the things that makes this small star remarkable is that it spins rapidly, completing a full rotation about every 2 hours. Compare that with our Sun, which takes nearly a month to spin once on its axis.

Previous data from the Karl G. Jansky Very Large Array in Socorro, NM showed that this star has a magnetic field several hundred times stronger than our Sun. This puzzled astronomers because the physical processes that generate the Sun's magnetic field shouldn't operate in such a small star.

"This star is a very different beast from our Sun, magnetically speaking," states CfA astronomer and co-author Edo Berger.

The researchers examined the star with the new Atacama Large Millimeter/submillimeter Array (ALMA) and detected emission at a frequency of 95 GHz. This is the first time that flare-like emission at such high frequencies has been detected from a red dwarf star. Our Sun generates similar emission from solar flares but only intermittently. What's more, the emission from this star is 10,000 times brighter than what our own Sun produces, even though it has less than one-tenth of the Sun's mass. The fact that ALMA detected this emission in a brief 4-hour observation suggests that the red dwarf is continuously active.

This has important implications for the search for habitable planets outside the Solar system. Red dwarfs are the most common type of star in our galaxy, which makes them promising targets for planet searches. But because a red dwarf is so cool, a planet would have to orbit very close to the star to be warm enough for liquid water to exist. That proximity would put the planet right in the bull's-eye for radiation that could strip its atmosphere or destroy any complex molecules on its surface.

"It's like living in Tornado Alley in the U.S. Your location puts you at greater risk of severe storms," explains Williams. "A planet in the habitable zone of a star like this would be buffeted by storms much stronger than those generated by the Sun."

Astronomers will study similar stars in the future to determine whether this one is an oddball or an example of an entire class of stormy stars.

These findings have been accepted for publication in The Astrophysical Journal and are available online.

Headquartered in Cambridge, Mass., the Harvard-Smithsonian Center for Astrophysics (CfA) is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.

- See more at: https://www.cfa.harvard.edu/news/2015-26#sthash.gtarlVEt.dpuf

Our Sun is a relatively quiet star that only occasionally releases solar flares or blasts of energetic particles that threaten satellites and power grids. You might think that smaller, cooler stars would be even more sedate. However, astronomers have now identified a tiny star with a monstrous temper. It shows evidence of much stronger flares than anything our Sun produces. If similar stars prove to be just as stormy, then potentially habitable planets orbiting them are likely to be much less hospitable than previously thought.

"If we lived around a star like this one, we wouldn't have any satellite communications. In fact, it might be extremely difficult for life to evolve at all in such a stormy environment," says lead author Peter Williams of the Harvard-Smithsonian Center for Astrophysics (CfA).

The research team targeted a well-known red dwarf star located about 35 light-years from Earth in the constellation Boîtes. The object is so small and cool that it's right on the dividing line between stars (which fuse hydrogen) and brown dwarfs (which don't). One of the things that makes this small star remarkable is that it spins rapidly, completing a full rotation about every 2 hours. Compare that with our Sun, which takes nearly a month to spin once on its axis.

Previous data from the Karl G. Jansky Very Large Array in Socorro, NM showed that this star has a magnetic field several hundred times stronger than our Sun. This puzzled astronomers because the physical processes that generate the Sun's magnetic field shouldn't operate in such a small star.

"This star is a very different beast from our Sun, magnetically speaking," states CfA astronomer and co-author Edo Berger.

The researchers examined the star with the new Atacama Large Millimeter/submillimeter Array (ALMA) and detected emission at a frequency of 95 GHz. This is the first time that flare-like emission at such high frequencies has been detected from a red dwarf star. Our Sun generates similar emission from solar flares but only intermittently. What's more, the emission from this star is 10,000 times brighter than what our own Sun produces, even though it has less than one-tenth of the Sun's mass. The fact that ALMA detected this emission in a brief 4-hour observation suggests that the red dwarf is continuously active.

This has important implications for the search for habitable planets outside the Solar system. Red dwarfs are the most common type of star in our galaxy, which makes them promising targets for planet searches. But because a red dwarf is so cool, a planet would have to orbit very close to the star to be warm enough for liquid water to exist. That proximity would put the planet right in the bull's-eye for radiation that could strip its atmosphere or destroy any complex molecules on its surface.

"It's like living in Tornado Alley in the U.S. Your location puts you at greater risk of severe storms," explains Williams. "A planet in the habitable zone of a star like this would be buffeted by storms much stronger than those generated by the Sun."

Astronomers will study similar stars in the future to determine whether this one is an oddball or an example of an entire class of stormy stars.

These findings have been accepted for publication in The Astrophysical Journal and are available online.

Headquartered in Cambridge, Mass., the Harvard-Smithsonian Center for Astrophysics (CfA) is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.

- See more at: https://www.cfa.harvard.edu/news/2015-26#sthash.gtarlVEt.dpuf

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Baby pictures: The first photos of a planet being born

5 min read

NASA Science Editorial Team

From University of Arizona

There are 450 light-years between Earth and LkCa15, a young star with a transition disk around it, a cosmic whirling dervish, a birthplace for planets.

Despite the disk’s considerable distance from Earth and its gaseous, dusty atmosphere, University of Arizona researchers captured the first photo of a planet in the making, a planet residing in a gap in LkCa15’s disk.

Of the roughly 2,000 known exoplanets — planets that orbit a star other than our sun — only about 10 have been imaged, and that was long after they had formed, not when they were in the making.

"This is the first time that we’ve imaged a planet that we can say is still forming," says Stephanie Sallum, a UA graduate student, who with Kate Follette, a former UA graduate student now doing postdoctoral work at Stanford University, led the research.

"No one has successfully and unambiguously detected a forming planet before," Follette says. "There have always been alternate explanations, but in this case we've taken a direct picture, and it's hard to dispute that."

The researchers' results were published in the Nov. 19 issue of Nature.

Only months ago, Sallum and Follette were working independently, each on her own Ph.D. project. But serendipitously they had set their sights on the same star. Both were observing LkCa15, which is surrounded by a special kind of protoplanetary disk that contains an inner clearing, or gap.

Protoplanetary disks form around young stars using the debris left over from the star’s formation. It is suspected that planets then form inside the disk, sweeping up dust and debris as the material falls onto the planets instead of staying in the disk or falling onto the star. A gap is then cleared in which planets can reside.

The researchers’ new observations support that view.

"The reason we selected this system is because it’s built around a very young star that has material left over from the star-formation process," Follette says. "It’s like a big doughnut. This system is special because it’s one of a handful of disks that has a solar-system size gap in it. And one of the ways to create that gap is to have planets forming in there."

Sallum says researchers are just now being able to image objects that are close to and much fainter than a nearby star. "That’s because of researchers at the University of Arizona who have developed the instruments and techniques that make that difficult observation possible," she says.

Those instruments include the Large Binocular Telescope, or LBT, the world’s largest telescope, located on Arizona’s Mount Graham, and the UA’s Magellan Telescope and its adaptive optics system, or MagAO, located in Chile.

Capturing sharp images of distant objects is difficult thanks in large part to atmospheric turbulence, the mixing of hot and cold air.

"When you look through the Earth's atmosphere, what you're seeing is cold and hot air mixing in a turbulent way that makes stars shimmer," says Laird Close, UA astronomy professor and Follette's graduate adviser.

"To a big telescope, it's a fairly dramatic thing. You see a horrible-looking image, but it's the same phenomenon that makes city lights and stars twinkle."

Josh Eisner, UA astronomy professor and Sallum's graduate adviser, says big telescopes "always suffer from this type of thing." But by using the LBT adaptive optics system and a novel imaging technique, he and Sallum succeeded in getting the crispest infrared images yet of LkCa15.

Meanwhile, Close and Follette used Magellan's adaptive optics system MagAO to independently corroborate Eisner and Sallum's planetary findings. That is, using MagAO's unique ability to work in visible wavelengths, they captured the planet's "hydrogen alpha" spectral fingerprint, the specific wavelength of light that LkCa 15 and its planets emit as they grow. In fact, almost all young stars are identified by their hydrogen alpha light, says Close, principal investigator of MagAO.

When cosmic objects are forming, they get extremely hot, Close says. And because they're forming from hydrogen, those objects all glow a dark red, which astronomers refer to as H-alpha, a particular wavelength of light. "It's just like a neon sign, the way neon gas glows when it gets energized," he says.

"That single dark shade of red light is emitted by both the planet and the star as they undergo the same growing process," Follette says. "We were able to separate the light of the faint planet from the light of the much brighter star and to see that they were both growing and glowing in this very distinct shade of red."

A color so distinct, Close says, that it's proof positive a planet is forming — something never seen before now.

"Results like this have only been made possible with the application of a lot of very advanced new technology to the business of imaging the stars," says professor Peter Tuthill of the University of Sydney, one of the study's co-authors, "and it's really great to see them yielding such impressive results."

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Innovative Planet-Finding Technology Passes Another Hurdle

6 min read

VNC Now Sensitive to Broader Spectral Range

A potentially revolutionary instrument now being developed to first find Earth-like planets in other solar systems and then study their atmospheres to identify chemical signatures of life has just passed another technological hurdle that makes it an even stronger contender for a future astrophysics mission.

The instrument, called the Visible Nulling Coronagraph (VNC), combines an interferometer with a coronagraph — in itself a first. It's well on its way to demonstrating operations over a broader spectral range, including the ultraviolet, visible, and near-infrared bands, said Brian Hicks, a fellow with NASA's Postdoctoral Program who is working with VNC Principal Investigators Rick Lyon and Mark Clampin, who are scientists at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

"The VNC is demonstrating the spectral range needed for planet characterization," Hicks said. "It will be more sensitive for finding fainter planets. It also will enable spectroscopy, which is what NASA will need to study the atmospheres of exoplanets to identify signatures of water, oxygen, carbon dioxide, methane, and ozone — the chemistry we associate with habitability for life as we know it."

Currently, the Kepler Observatory uses indirect means to detect exoplanets, as will the James Webb Space Telescope and the Transiting Exoplanet Survey Satellite in the future.

The next logical step is direct detection using a next-generation space observatory equipped with highly sophisticated instruments, including a coronagraph or occulting star shade that would block starlight and allow the observatory to directly image faint Earth-like exoplanets.

The VNC, which Clampin and Lyon started developing nearly six years ago, is ideally suited to this task. Its pupil-based technique for separating star from planet light is naturally compatible with segmented or arbitrarily shaped telescope mirrors, similar to the one that will form the heart of the Webb Observatory. Such a mirror folds up for launch and then unfolds once the observatory reaches its orbital destination.

Instead of using internal masks and or an external occulter to block starlight — techniques employed by more traditional coronagraphs — the VNC relies on a two-armed interferometer that splits and then recombines collected light. Under this concept, starlight gathered by the observatory's primary, segmented mirror travels down the VNC's optical path to the first of two beamsplitters, which transmits light into one arm and reflects light into the other interferometer arm.

After traversing both arms, the light encounters a second beamsplitter that recombines the light to create two output paths known as the "bright" and "dark" channels. Starlight passes to the bright channel and planet light to the dark.

However, creating these two channels couldn't be possible without a technology called the multiple mirror array (MMA). This device, comprised of 163 tiny individual mirror segments that each measure about the width of six average human hairs and are perched atop tiny finger-like devices that allow them to piston, tip and tilt up to thousands of times per second, is placed in the interferometer arm that receives reflected light.

The MMA’s job is to correct errors. It first senses and then corrects wavefront errors caused by vibration, dust, and thermal changes that prevent the bright starlight, collected by the primary mirror, from being perfectly “nulled” — in other words, ultimately canceled in the dark channel.

A spectrograph and imager then would analyze the dark-channel light to determine the planet’s physical properties.

Rhombs Provide Solution

In testing with the VNC testbed, the technique proved that it could achieve nearly billion-to-one contrast, but over a narrow band in the visible spectrum. “This first milestone still stands as the deepest contrast ever achieved with a nulling coronagraph,” Lyon said, adding that this achievement was made possible by engineers Udayan Mallik, who set up all computer interfacing to control the devices, and Pete Petrone, who built the VNC hardware and optics. “It also clearly demonstrated nulling with a segmented aperture — another significant milestone.”

The team now is increasing VNC’s sensitivity over a broader spectral range needed to detect and characterize Earth-like planets.

The group incorporated two pairs of identical prisms into both interferometer arms. These “squashed” rectangular-shaped, highly polished prisms, known as Fresnel rhombs, produce polarizing reflections — similar to what happens to sunlight that reaches your eyes after reflecting off cars or pavement. “While this scattered light reduces contrast when driving without wearing sunglasses, the polarization effect is actually helpful in the VNC,” Hicks said.

“The polarization effect achieved through the rhombs is something that can be used to make starlight suppression with the VNC work at high contrast over a broad spectral range,” Hicks said. “Now we are working to demonstrate the instrument with 40 times the bandwidth,” he added.

But the addition of the rhombs isn’t the only new technology the team is pursuing to cement its possible inclusion in a next-generation mission.

Lyon, Clampin, Hicks, and others on the team received NASA technology-development funds to demonstrate the VNC on an actual segmented optical testbed, called the Segmented Aperture Interferometric Nulling Testbed, or SAINT for short, Lyon said. The work will begin in October.

Goddard engineer Matt Bolcar, Hicks, and Lyon also have received additional NASA funding to investigate the use of freeform optics, an emerging optics technology that allows light-gathering devices to take almost any shape, potentially providing improved image quality over a larger field of view — all in a smaller package.

“One of the primary advantages of freeform optics is that they can reduce the total number of elements needed for a flight VNC. Most importantly, this would improve throughput, among other things,” Lyon said. “By custom tailoring the shape of the optics we may achieve a wider field of view.”

“Each of these is a significant improvement and could make the VNC a game changer when it comes to designing the future mission that will have characterizing exoplanets as one of its top priorities,” Hicks said. “The goal is to use the improvements and the enabling technologies to make the VNC an even better choice for yielding the greatest science return.”

For more Goddard technology news, go to
https://gsfctechnology.gsfc.nasa.gov/newsletter/Current.pdf

Lori KeeseyNASA’s Goddard Space Flight Center

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Professor Proposes a new Definition for ‘Planets’

3 min read

NASA Science Editorial Team

From UCLA

Since the late 1980s, scientists have discovered nearly 5,000 planetary bodies orbiting stars other than the sun. But astronomers are still working on what exactly we should call them.

Today at an American Astronomical Society meeting, UCLA professor Jean-Luc Margot described a simple test that can be used to clearly separate planets from other bodies like dwarf planets and minor planets.

The current official definition of a planet, which was issued by the International Astronomical Union in 2006, applies only to bodies in our solar system, which Margot said has created a “definitional limbo” for the newly discovered bodies. A paper by Margot that has been accepted for publication in the Astronomical Journal proposes to extend the planet definition to all planetary systems.

The new approach would require only estimates of the star’s mass and the planet’s mass and orbital period — all of which can be easily obtained with Earth- or space-based telescopes. According to Margot’s criteria, all eight planets in our solar system and all classifiable exoplanets — the large bodies that orbit stars other than our sun — would be confirmed as planets.

Margot, a professor of planetary astronomy, wanted to ensure that the new system would be easy to follow. “One should not need a teleportation device to decide whether a newly discovered object is a planet.”

Some of the current confusion he’s seeking to eliminate stems from the fact that the IAU’s definition did not address how to classify exoplanets — that question was left for future consideration. Now, Margot argues, the recent flood of exoplanet discoveries should encourage the IAU to refine and extend the definition.

The IAU’s definition is based primarily on the ability of a planet to “clear its orbit,” meaning whether it can evacuate, accumulate or dominate small bodies in its orbital neighborhood. Margot’s test can be used to determine whether a body can clear a specific region around its orbit within a specific time frame, such as the lifetime of its host star. The test is easy to implement and it could immediately classify 99 percent of all known exoplanets. (Scientists do not currently have enough data to apply the test to the other 1 percent.)

When applied to our own solar system, the test clearly places the eight planets into one distinct category and the dwarf planets — Ceres, Pluto and Eris — into another.

“The disparity between planets and non-planets is striking,” Margot said. “The sharp distinction suggests that there is a fundamental difference in how these bodies formed, and the mere act of classifying them reveals something profound about nature.”

Margot also found that bodies that can clear their orbits, and therefore qualify as planets, are typically spherical. “When a body has sufficient mass to clear its orbital neighborhood, it also has sufficient mass to overcome material strength and pull itself into a nearly round shape,” he said.

This is important because astronomers can’t always see exoplanets well enough to accurately determine their shape, but they can almost always measure the parameters needed to apply Margot's criteria — and because the current IAU definition requires that a planet be nearly round.

Margot presented his proposal at the annual meeting of the AAS's Division for Planetary Sciences.

It is not known whether the new approach will be considered by the IAU, whose resolutions are typically crafted and reviewed by committees before members vote on them during a general assembly. The next IAU general assembly is scheduled for 2018.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

5,400 mph Winds Discovered Hurtling Around Planet Outside Solar System

3 min read

NASA Science Editorial Team

From University of Warwick

Winds exceeding 1.2 miles per second (2 km per second) have been discovered flowing around a planet outside of the Earth's solar system, new research has found.

The University of Warwick discovery is the first time that a weather system on a planet outside of Earth's solar system has been directly measured and mapped. The wind speed recorded is 20x greater than the fastest ever known on Earth, where it would be seven times the speed of sound.

Commenting on the discovery, lead researcher Tom Louden of the University of Warwick's Astrophysics group, said, "This is the first-ever weather map from outside of our solar system. Whilst we have previously known of wind on exoplanets, we have never before been able to directly measure and map a weather system."

Studying the exoplanet HD 189733 b, the Warwick researchers measured the velocities on the two sides of HD 189733 b and found a strong wind moving at more than 5,400 mph (8,690 kph) blowing from its dayside to its night side. Louden explained: "HD 189733 b's velocity was measured using high resolution spectroscopy of the sodium absorption featured in its atmosphere. As parts of HD 189733 b's atmosphere move towards or away from the Earth the Doppler effect changes the wavelength of this feature, which allows the velocity to be measured."

Explaining how this information was used to measure velocity Louden said, "The surface of the star is brighter at the center than it is at the edge, so as the planet moves in front of the star the relative amount of light blocked by different parts of the atmosphere changes. For the first time we've used this information to measure the velocities on opposite sides of the planet independently, which gives us our velocity map."

The researchers say that the techniques used could help the study of Earth-like planets. Co-researcher, Dr. Peter Wheatley of the University of Warwick's Astrophysics Group explained:

"We are tremendously excited to have found a way to map weather systems on distant planets. As we develop the technique further we will be able to study wind flows in increasing detail and make weather maps of smaller planets. Ultimately this technique will allow us to image the weather systems on Earth-like planets."

HD 189733 b is one of the most studied of a class of planets known as hot Jupiters. At over 10 percent larger than Jupiter, but 180x closer to its star, HD 189733 b has a temperature of 1200 degrees Celsius. Its size and relative closeness to our solar system make it a popular target for astronomers. Past research has shown that the day side of the planet would appear a bright shade of blue to the human eye, probably due to clouds of silicate particles high in its atmosphere.

The data was collected by HARPS, the High Accuracy Radial velocity Planet Searcher, in La Silla, Chile.

The research, Spatially resolved eastward winds and rotation of HD 189733b, is published by Astrophysical Journal Letters.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cloudy with a chance of salt clouds

4 min read

NASA Science Editorial Team

From University of Washington

Scientists have catalogued nearly 2,000 exoplanets around stars near and far. While most of these are giant and inhospitable, improved techniques and spacecraft have uncovered increasingly smaller worlds. The day may soon come when astrophysicists announce our planet's twin around a distant star.

But size alone is insufficient to judge a globe. Though Earth and Venus are nearly identical in size, the latter's surface is hot enough to melt lead. Astronomers must gather information about an exoplanet's atmosphere, often through observing how the planet scatters or absorbs light from its parent star. But, that information is not always useful — as is the case with the exoplanet GJ1214b.

"When an exoplanet passes in front of its star, light can be absorbed at some wavelengths by molecules in the atmosphere, which we can analyze by looking at how light passes through the planet's atmosphere," said Benjamin Charnay, a postdoctoral researcher in the University of Washington Department of Astronomy. "But for this planet, when researchers previously looked with the Hubble Space Telescope, they saw almost no variation with wavelength of light."

This "flat spectrum" for GJ1214b indicated that something in the planet's upper atmosphere blocked light, keeping scientists in the dark regarding its atmosphere. Charnay decided to computationally model what its atmosphere could be, based on the planet's temperature and composition. In the process, as he reports in a new paper in Astrophysical Journal Letters, he and his collaborators became the first to simulate three-dimensional exotic clouds in the atmosphere of another world.

"It's an important step in characterizing exoplanets," said Charnay.

GJ1214b was among the first "mini-Neptune" exoplanets discovered, which are intermediate in size between Earth and Neptune. They're the smallest exoplanets that can be studied with existing technology, and GJ1412b is in an ideal position.

"Most of the other mini-Neptunes that have been discovered orbit stars between 100 and 1,000 light years away," said Charnay. "GJ1214b is quite close to Earth, just 42 light years away, and it orbits its star in just 1.6 days."

That fast orbit gave scientists the opportunity to record the exoplanet's flat spectrum, ruling out an atmosphere of simple hydrogen, water, carbon dioxide or methane. Instead, something high in the atmosphere was blocking light from penetrating farther down.

"There could either be high clouds in the atmosphere or an organic haze — like we see on Titan," said Charnay.

Its atmospheric temperature exceeds the boiling point of water. As a result, if GJ1214b sported clouds, they would probably be some form of salt, said Charnay. But such clouds should form deep in the atmosphere, much lower than the altitude where they are observed. Charnay modeled how the clouds could form in the lower atmosphere and then rise into the upper atmosphere with sufficient circulation.

To accomplish this, Charnay, used a climate model developed by his former research group in Paris. He previously used this model for studying Titan and the early Earth, and adapted it for

GJ1214b.

Charnay ran his three-dimensional cloud model on the UW's Hyak supercomputer. It shows how GJ1214b could create, sustain and lift salt clouds into the upper atmosphere, where they would contribute to the planet's flat spectrum that Hubble detected. His model also makes specific predictions about the effect these clouds will have on the planet's climate and the types of information that future telescopes, like the James Webb Space Telescope, will be able to gather.

Charnay would next like to model the other potential cause of the exoplanet's flat spectrum: photochemical haze, which gives Titan its shrouded orange atmosphere and Los Angeles its persistent dome of polluted air.

“Light splits chemicals in the atmosphere, creating more complex organic compounds that make the haze,” said Charnay.

Charnay will have to wait until the James Webb Space Telescope launches later this decade to find out which theory — clouds or haze — gives GJ1214b a flat spectrum. In the meantime, in addition to his quest to simulate haze on this exoplanet, Charnay would like to model what the atmosphere was like on Earth before life evolved.

“Worlds like Titan and this exoplanet have complex atmospheric chemistry that might be closer to what early Earth's atmosphere was like,” said Charnay. “We can learn a lot about how planetary atmospheres like ours form by looking at them.”

Charnay's co-authors on the paper include UW astronomy professor Victoria Meadows, recent UW astronomy doctoral graduate Amit Misra, UW astronomy graduate student Giada Arney and University of Toronto researcher Jérémy Leconte. Their work was funded by NASA and the UW's Virtual Planet Laboratory.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

PICTURE-B: Seeing Through the Glare

5 min read

Update – Nov. 25, 2015: NASA successfully launched the PICTURE-B payload on a Black Brant IX suborbital sounding rocket at 11:17 p.m. EST (9:17 p.m. MST), Nov. 24, from the White Sands Missile Range in New Mexico. The team is examining the science and engineering data to determine the payload’s performance. The payload flew to an altitude of 135 miles. Recovery of the payload is in progress.

Update – Nov. 24, 2015: The launch of the PICTURE-B payload on a NASA Black Brant IX sounding rocket was postponed Saturday, Nov. 21, because of a payload internal temperature issue. The launch has been rescheduled for Wednesday, Nov. 25.

Update – Nov. 19, 2015: The PICTURE-B payload on a NASA Black Brant IX sounding rocket is scheduled for launch November 21 at 4:30 a.m. EST (2:30 a.m. MST) from the White Sands Missile Range in New Mexico. The previous launch attempt on November 16 was postponed because of high winds.

Update – Nov. 16, 2015: High winds forced the postponement of the PICTURE-B payload on a NASA Black Brant IX sounding rocket Nov. 16 from the White Sands Missile Range in New Mexico. A new launch date has not been determined.

Original Story – Nov. 9, 2015: Have you ever looked directly at a bright light and been blinded? If you look away from the light objects come into focus, but as you get closer to the light you can’t make out the items surrounding it.

Telescopes have the same problem when looking at stars. The light from the stars make it difficult to see any objects close to the star, such as a planet.

A NASA suborbital sounding rocket launch on November 16 from the White Sands Missile Range in New Mexico carrying a payload from the University of Massachusetts Lowell may shed some light on the problem, or in this case dim the light.

The Planet Imaging Coronagraphic Technology Using a Reconfigurable Experimental Base (PICTURE-B) will look at the dusty ring around the star Epsilon Eridani and develop technologies needed to one day image Earth-like exoplanets.

Supriya Chakrabarti, mission principal investigator from the UMass Lowell Center for Space Science and Technology, said, “The reason these regions are difficult to image is the bright starlight overwhelms everything close to it. What the instrument does is to dim the light from the star – sort of like the Deluminator or put-outer in Harry Potter –which makes it easier for us to look at the region near the star. The optical design is rather complex.”

Epsilon Eridani is the third closest star visible to the unaided eye. Smaller than the sun, the approximately one billion year old star is a mere 10.5 light years from Earth.

Ewan Douglas, a project scientist from Boston University, said, “The study of extrasolar planets is one of the most exciting research endeavors of modern astrophysics. Most of these planets have been discovered through the radial velocity and transit measurement techniques. While the list of known planetary systems continues to grow, very few direct images of these systems have been taken in reflected light where many planets are brightest.”

“PICTURE will observe the planetary environment around Epsilon Eridani. It has been suggested that Epsilon Eridani contains at least one planet and several substantial dust disks. A dust ring, with characteristics similar to the Kuiper belt, was discovered around this star in 1998. Astronomers have inferred that colliding asteroids and shedding comets are producing another dusty debris ring, similar to our asteroid belt. Such a bright inner asteroid belt may obscure attempts to directly image dim planets in reflected light." he said.

"The primary goal of the PICTURE mission is a measurement of the reflected light from the inner asteroid belt, which is important for the design of future space telescopes to image reflected light from exoplanets. If successful, this will be one of the first reflected light images of a dust belt orbiting a Sun-like star at a distance similar to that of our own asteroid belt," according to Douglas, a graduate student working on the project with Chakrabarti and Christopher Mendillo, a research scientist at UMass Lowell.

The payload's predecessor, PICTURE was flown on a NASA sounding rocket in October 2011. While not an overwhelming success due to technical issues, Chakrabarti said they were able to demonstrate flight worthiness and the fine pointing system, which is comparable to the Hubble Space Telescope.

Going back to the work bench, the team rebuilt the instrument and developed a new silicon carbide mirror to prepare PICTURE-B for launch.

Chakrabarti noted, "Besides characterizing the regions around a star, we will mature the technology necessary for future exoplanet studies, while training and providing hands-on experience for graduate and undergraduate students on a cutting-edge research endeavor."

Douglas said, "PICTURE will also demonstrate in space several new technologies necessary to directly image exoplanets, a deformable mirror which corrects telescope aberrations, a nulling coronagraph which blocks starlight while transmitting light close to the star (equivalent to dimming a streetlight in order to see a firefly next to it), and lightweight silicon carbide optics."

PICTURE-B will launch on a Black Brant IX sounding rocket at 2:30 a.m. EST (00:30 a.m. MST). It is estimated to fly to a peak altitude of 147 miles before landing in White Sands, where it will be recovered.

The team is already working on PICTURE-C for a NASA scientific balloon flight in 2017.

Chakrabarti said, "The balloon instrument will have two flights. In the first flight we will replace the telescope, but keep the rest of the payload. In the second flight, we use a different optical system called a Vector Vortex Coronagraph and a different detector called a microwave kinetic inductance detector. The balloon will give us the opportunity to look at multiple targets and mature a different set of technologies."

The rocket launch is supported through NASA's Sounding Rocket Program at the Wallops Flight Facility in Virginia. NASA's Heliophysics Division manages the sounding rocket program.

Keith KoehlerNASA's Wallops Flight Facilitykeith.a.koehler@nasa.gov

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Happy Anniversary, Osiris

1 min read

NASA Science Editorial Team

Today marks the anniversary of the discovery exoplanet HD 209458 b. Nicknamed "Osiris," after the Egyptian god of the underworld, this hot Jupiter is having its atmosphere torn off at more than 35,000 km/hour by the radiation of its close-by parent star. The escaping gas forms an envelope of carbon and oxygen that follows the doomed planet like a tail.

HD 209458 b's milestone discovery included a long and impressive list of firsts: It was the first planet discovered using the transit method, the first planet with a detectable atmosphere, the first planet with an evaporating hydrogen atmosphere, and the first exoplanet found with carbon and oxygen.

How do we know about HD 209458 b's atmosphere, if it's so far away? The transit method allows astronomers to study it. As the planet passes in front of its star, it blocks its host star's light. Like someone standing in front of a bright window, the planet is backlit. The starlight streams through the planet's atmosphere to our telescopes, revealing the elements it contains to astronomers.

Distance: 154 light-years in the constellation Pegasus

Orbit: 3.5 days vs. Earth's 365 days

Mass: about 220x Earth's mass

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Finding New Worlds with a Play of Light and Shadow

5 min read

Astronomers have used many different methods to discover planets beyond the solar system, but the most successful by far is transit photometry, which measures changes in a star's brightness caused by a mini-eclipse. When a planet crosses in front of its star along our line of sight, it blocks some of the star's light. If the dimming lasts for a set amount of time and occurs at regular intervals, it likely means an exoplanet is passing in front of, or transiting, the star once every orbital period.

NASA's Kepler Space Telescope has used this technique to become the most successful planet-hunting spacecraft to date, with more than a thousand established discoveries and many more awaiting confirmation. Missions carrying improved technology are now planned, but how much more can they tell us about alien planetary systems similar to our own?

A great deal, according to recently published studies by Michael Hippke at the Institute for Data Analysis in Neukirchen-Vluyn, Germany, and Daniel Angerhausen, a postdoctoral researcher at NASA's Goddard Space Flight Center in Greenbelt, Maryland. They show that in the best-case scenarios upcoming missions could uncover planetary moons, ringed worlds similar to Saturn, and even large collections of asteroids.

“We expect a flood of discoveries from these new missions, so we want to get a feel for the possibilities so scientists can make the most of the data,” Angerhausen said.

Both NASA and the European Space Agency (ESA) are building on Kepler's success. NASA's Transiting Exoplanet Survey Satellite (TESS), scheduled to launch no later than 2018, will be the first-ever spaceborne all-sky transit survey. Over the course of two years, TESS will monitor some 200,000 nearby stars for telltale transits. ESA's Planetary Transits and Oscillations of stars (PLATO) satellite, which is expected to begin a six-year mission in 2024, will search for planets around roughly a million stars spread over half the sky.

The amount of stellar dimming caused by a transiting planet tells astronomers how big the planet is in proportion to its star, while recurring events can tell us how long it takes for the object to orbit its star. Additional transits increase confidence the dimming isn't caused by another cosmic object (such as a faint star), dark sunspot-like regions on the host star, or noise in the detector. Over the operational lifetime of a satellite, the strongest signals always come from larger planets orbiting close to their stars because they produce both a deeper dimming and more frequent transits.

“Planets with sizes and orbits similar to Mars or Mercury will remain out of reach, even when six years of PLATO data are combined,” said Hippke. “But worlds similar to Venus and Earth will show up readily.” Kepler has demonstrated the presence of planets smaller than Earth in very close orbits around stars smaller than the sun, but these sweltering worlds are unlikely to support life. TESS and PLATO will reveal Earth-sized worlds in Earth-like orbits around stars similar to the sun. Orbiting within the star's habitable zone, these planets may possess pools of liquid water, thought to be a prerequisite for the development of life as we know it.

Jupiter and Saturn each take more than a decade to orbit the sun. Similar worlds may only transit once during the TESS and PLATO missions but will produce a strong event. If, like Jupiter, the planet has a few large moons, their transits could show up in the data too. “We wouldn't have a clear detection, and we wouldn't be able to say whether the planet had a single large moon or a set of small ones, but the observation would provide a strong moon candidate for follow-up by other future facilities,” explained Angerhausen.

Today, rings have been detected around only one exoplanet, called J1407b. The ring system is more than 200 times larger than Saturn’s. Considering how a more Saturn-like planet would appear to PLATO, the researchers show that the transiting ring system produces a clear signal that precedes and follows the planet’s passage across its star. These findings were published in the Sept. 1 issue of The Astrophysical Journal.

In a second study, published in the Sept. 20 issue of the same journal, the researchers explored the possibility of detecting asteroids trapped in stable orbital zones called Lagrange points, locations where a planet’s gravitational pull balances its sun’s. These areas lead and follow the planet in its orbit by about 60 degrees. In our solar system, the most prominent example occurs near Jupiter, where at least 6,000 known objects have gathered in two groups collectively called the Trojan asteroids. Less well known is that Earth, Mars, Uranus and Neptune similarly have captured one or more asteroids along their orbits, and astronomers now refer to all objects trapped in this way as Trojan bodies.

The same phenomenon will occur in other planetary systems, so Hippke and Angerhausen combined Kepler observations of more than 1,000 planet-hosting stars to hunt for an average dip in starlight that would indicate transits by Trojan bodies. They turned up a subtle signal corresponding to the expected locations of objects trapped in two Lagrange points.

“As good as the Kepler data are, we’re really pushing them to the limit, so this is a very preliminary result,” Hippke said. “We’ve shown somewhat cautiously that it’s possible to detect Trojan asteroids, but we’ll have to wait for better data from TESS, PLATO and other missions to really nail that down.”

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Shy Giants

4 min read

NASA Science Editorial Team

From NASA

A team of astronomers is proposing that huge spiral patterns seen around some newborn stars, merely a few million years old (about one percent our sun’s age), may be evidence for the presence of giant unseen planets. This idea not only opens the door to a new method of planet detection, but also could offer a look into the early formative years of planet birth.

Though astronomers have cataloged thousands of planets orbiting other stars, the very earliest stages of planet formation are elusive because nascent planets are born and embedded inside vast, pancake-shaped disks of dust and gas encircling newborn stars, known as circumstellar disks.

The conclusion that planets may betray their presence by modifying circumstellar disks on large scales is based on detailed computer modeling of how gas-and-dust disks evolve around newborn stars, which was conducted by two NASA Hubble Fellows, Ruobing Dong of Lawrence Berkeley National Laboratory, and Zhaohuan Zhu of Princeton University. Their research was published in the Aug. 5 edition of The Astrophysical Journal Letters.

“It’s difficult to see suspected planets inside a bright disk surrounding a young star. Based on this study, we are convinced that planets can gravitationally excite structures in the disk. So if you can identify features in a disk and convince yourself those features are created by an underlying planet that you cannot see, this would be a smoking gun of forming planets,” Dong said.

Identifying large-scale features produced by planets offers another method of planet detection that is quite different from all other techniques presently used. This approach can help astronomers find currently-forming planets, and address when, how, and where planets form.

Gaps and rings seen in other circumstellar disks suggest invisible planets embedded in the disk. However gaps, presumably swept clean by a planet’s gravity, often do not help show location of the planet. Also, because multiple planets together may open a single common gap, it's very challenging to estimate their number and masses.

Ground-based telescopes have photographed two large-scale spiral arms around two young stars, SAO 206462 and MWC 758. A few other nearby stars also show smaller spiral-like features. “How they are created has been a big mystery until now. Scientists had a hard time explaining these features,” Dong said. If the disks were very massive, they would have enough self-gravity to become unstable and set up wave-like patterns. But the disks around SAO 206462 and MWC 758 are probably just a few percent of the central star’s mass and therefore are not gravitationally unstable.

The team generated computer simulations of the dynamics of a disk and how the star’s radiation propagates through a disk with embedded planets. This modeling created spiral structures that very closely resemble observations. The mutual gravitational interaction between the disk and the planet creates regions where the density of gas and dust increases, like traffic backing up on a crowded expressway. The differential rotation of the disk around the star smears these over-dense regions into spiral waves. Although it had been speculated that planets can produce spiral arms, we now think we know how.

“Simulations also suggest that these spiral arms have rich information about the unseen planet, revealing not only its position but also its mass,” Zhu said. The simulations show that if there were no planet present, the disk would look smooth. To make the grand-scale spiral arms seen in the SAO 206462 and MWC 758 systems, the unseen planet would have to be bulky, at least 10 times the mass of Jupiter, the largest planet in our solar system.

The first planet orbiting a normal star was identified in 1995. Thanks to ground-based telescopes and NASA's Kepler mission, a few thousand exoplanets have been cataloged to date. But because the planets are in mature systems, many millions or a few billion years old, they offer little direct clues as to how they formed.

“There are many theories about how planets form but very little work based on direct observational evidence confirming these theories,” Dong said. “If you see signs of a planet in a disk right now, it tells you when, where, and how planets form.”

Astronomers will use the upcoming NASA James Webb Space Telescope to probe circumstellar disks and look for features, as simulated by the modeling, and will then try to directly observe the predicted planet causing the density waves.

For more information, visit: http://www.nasa.gov/hubble

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Spirals in Dust Around Young Stars May Betray Presence Of Massive Planets

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

A team of astronomers is proposing that huge spiral patterns seen around some newborn stars, merely a few million years old (about one percent our sun's age), may be evidence for the presence of giant unseen planets. This idea not only opens the door to a new method of planet detection, but also could offer a look into the early formative years of planet birth.

Though astronomers have cataloged thousands of planets orbiting other stars, the very earliest stages of planet formation are elusive because nascent planets are born and embedded inside vast, pancake-shaped disks of dust and gas encircling newborn stars, known as circumstellar disks.

The conclusion that planets may betray their presence by modifying circumstellar disks on large scales is based on detailed computer modeling of how gas-and-dust disks evolve around newborn stars, which was conducted by two NASA Hubble Fellows, Ruobing Dong of Lawrence Berkeley National Laboratory, and Zhaohuan Zhu of Princeton University. Their research was published in the Aug. 5 edition of The Astrophysical Journal Letters.

"It's difficult to see suspected planets inside a bright disk surrounding a young star. Based on this study, we are convinced that planets can gravitationally excite structures in the disk. So if you can identify features in a disk and convince yourself those features are created by an underlying planet that you cannot see, this would be a smoking gun of forming planets," Dong said.

Identifying large-scale features produced by planets offers another method of planet detection that is quite different from all other techniques presently used. This approach can help astronomers find currently-forming planets, and address when, how, and where planets form.

Gaps and rings seen in other circumstellar disks suggest invisible planets embedded in the disk. However gaps, presumably swept clean by a planet's gravity, often do not help show location of the planet. Also, because multiple planets together may open a single common gap, it's very challenging to estimate their number and masses.

Ground-based telescopes have photographed two large-scale spiral arms around two young stars, SAO 206462 and MWC 758. A few other nearby stars also show smaller spiral-like features. "How they are created has been a big mystery until now. Scientists had a hard time explaining these features," Dong said. If the disks were very massive, they would have enough self-gravity to become unstable and set up wave-like patterns. But the disks around SAO 206462 and MWC 758 are probably just a few percent of the central star's mass and therefore are not gravitationally unstable.

The team generated computer simulations of the dynamics of a disk and how the star's radiation propagates through a disk with embedded planets. This modeling created spiral structures that very closely resemble observations. The mutual gravitational interaction between the disk and the planet creates regions where the density of gas and dust increases, like traffic backing up on a crowded expressway. The differential rotation of the disk around the star smears these over-dense regions into spiral waves. Although it had been speculated that planets can produce spiral arms, we now think we know how.

“Simulations also suggest that these spiral arms have rich information about the unseen planet, revealing not only its position but also its mass,” Zhu said. The simulations show that if there were no planet present, the disk would look smooth. To make the grand-scale spiral arms seen in the SAO 206462 and MWC 758 systems, the unseen planet would have to be bulky, at least 10 times the mass of Jupiter, the largest planet in our solar system.

The first planet orbiting a normal star was identified in 1995. Thanks to ground-based telescopes and NASA’s Kepler mission, a few thousand exoplanets have been cataloged to date. But because the planets are in mature systems, many millions or a few billion years old, they offer little direct clues as to how they formed.

“There are many theories about how planets form but very little work based on direct observational evidence confirming these theories,” Dong said. “If you see signs of a planet in a disk right now, it tells you when, where, and how planets form.”

Astronomers will use the upcoming NASA James Webb Space Telescope to probe circumstellar disks and look for features, as simulated by the modeling, and will then try to directly observe the predicted planet causing the density waves.

For more information, visit:

http://www.nasa.gov/hubble

http://hubblesite.org/newscenter/archive/releases/2015/40/

Contact:

Ray VillardSpace Telescope Science Institute, Baltimore, Maryland410-338-4488 / 410-338-4514villard@stsci.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

WFIRST-AFTA: Groundbreaking Space Observatory to Image Exoplanets and Tackle a Universe of Questions

7 min read

We all want the ability to peer into the future.

And that's exactly the focus of NASA's Wide-Field Infrared Survey Telescope (WFIRST) – a mission concept to answer vital questions in both exoplanet detection and dark energy research.

The powerful role that spaceborne telescopes can play in the future was underscored by a seminal study in 2010 called New Worlds, New Horizons in Astronomy and Astrophysics, written by the U.S. National Research Council. That study, which laid out a blueprint for ground- and space-based astronomy and astrophysics for the decade of the 2010's, rated WFIRST as the top-priority large-scale mission.

NASA's current plans call for WFIRST to perform an extraordinarily broad set of scientific investigations: studying the newly-discovered phenomenon of dark energy, measuring the history of cosmic acceleration, completing the exoplanet census begun by NASA's Kepler Space Telescope and demonstrating technology for direct imaging and characterization of exoplanets. By performing these investigations, WFIRST will address three central questions posed by NASA's astrophysics science plan:

• How does the universe work?

• How did we get here?

• Are we alone?

Match made in heaven

The WFIRST mission benefits greatly from a space-rated 2.4-meter-diameter telescope made available to NASA a few years ago by the National Reconnaissance Office (NRO). This existing telescope was significantly larger than the conceptual telescope originally envisioned for the WFIRST mission.

Some tag it as a "match made in heaven."

"As an agency, we asked ourselves what we could do with this unique telescope," said John Gagosian, program executive for the WFIRST mission at NASA Headquarters. "We realized that by using a 2.4-meter diameter telescope to greatly increase the angular resolution of WFIRST we could obtain a lot of scientific improvement," he adds.

Coupled with a to-be-developed coronagraph instrument, the capabilities of WFIRST would now include the possibility of directly imaging exoplanets. "It was a fortuitous series of events," Gagosian notes.

The 2.4-meter telescope is known as the Astrophysics-Focused Telescope Assets (AFTA), and thus the current mission concept has been dubbed "WFIRST-AFTA."

Objects of interest

Exoplanet detection is revolutionizing planetary science. The count is on and quickly trending upward regarding the existence of planet populations beyond our own solar system. There are now nearly 2,000 confirmed planets orbiting other stars, many of these charted by NASA's planet-hunting spacecraft, Kepler.

But what is the occurrence rate of Earth-like habitable planets, circling around Sun-like stars? Indeed, finding habitable zone rocky planets strongly influences the design of future space-based, direct detection missions geared to find exoplanets elsewhere.

One core scientific objective of WFIRST is to detect planets using a technique called "microlensing." This innovative technique infers the presence of planets by observing the way the gravity of the planets affects the refraction of starlight. This is different from the "transit" technique used by the Kepler Space Telescope, and therefore WFRST is expected to find planets that Kepler cannot detect.

Using microlensing, WFIRST will search the cold, outer regions of planetary systems throughout the galaxy. Scientists expect to detect planets with masses from 0.1 Earth to 10,000 Earths. A large percentage of the planets likely found would be "super-Earths," with masses about 10 times that of Earth.

Damping out starlight

Microlensing is not the only exoplanet-hunting technique that WFIRST will use.

The optical performance of the large AFTA telescope has allowed NASA to add a coronagraph for direct imaging of exoplanets and debris disks. Using the coronagraph, WFIRST is expected to collect images of planets in other solar systems, and to study the composition of these planets' atmospheres.

Work on WFIRST-AFTA is leveraging mature technology for flight readiness while harnessing cost control measures. There is a great "bang for the buck" value proposition in the mission. Additionally, WFIRST-AFTA is designed to be robotically serviceable.

The coronagraph works by very precisely blocking the starlight that would otherwise swamp out the evidence of planets circling their home star. "You are talking about a parent star that is more than a billion times brighter than the planet that's orbiting it," says Gagosian. "In the coronagraph, we need to send photons of light where we want them and get rid of the photons that we don't want."

The coronagraph's imperative to damp out starlight is extremely challenging, making use of different masking technologies, in addition to a deformable mirror that is computer controlled. But if it performs as designed, WFIRST's coronagraphic instrument will collect images and characterize the atmospheres of super-Earth planets and Neptune-like planets around nearby Sun-like stars.

Maturity levels

Feng Zhao of NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California, the lead for the WFIRST coronagraph, says that the technology investment in the instrument stems from NASA's Science Mission Directorate (SMD) and the space agency's Space Technology Mission Directorate (STMD) working together.

The funding of the coronagraph for WFIRST matures direct imaging technologies for future space telescope designs now being contemplated. The ability to "mature technology" at NASA is gauged in terms of high technology readiness levels, or TRLs — a type of measurement system used to assess the development stage of a particular technology.

"The WFIRST coronagraph is definitely demonstrating new technology…and is a giant step forward," Zhao points out. Down-selected by specialists from a number of candidate ideas, the high-tech coronagraph work is ongoing, with milestones being met in a step-by-step fashion.

“The coronagraph instrument is considered a technology demonstration,” Zhao says. “It will pave the technology path for future missions. This is a golden time to work on this challenging technology,” he adds.

Development progress

Zhao says the gap between the current coronagraph state of the art and what will someday be needed to characterize a truly Earth-like planet is large. So the best way to close that gap is to fly an intermediate-performance coronagraph instrument such as the one on WFIRST-AFTA.

As the first high-contrast stellar coronagraph in space, Zhao said the effort is maturing the coronagraph to TRL. There are nine milestones to track the technology development progress along the way, he explains, since formulation of the coronagraph in early 2014.

“We’re making good progress and I’m very proud of the dedicated and hardworking team from JPL and many other institutions,” Zhao adds.

Technologies and techniques

“I am very pleased about the potential of WFIRST-AFTA to give the scientific community and the public a bounty of new knowledge.” Gagosian says.

WFIRST-AFTA will revolutionize our understanding of the expansion of the universe, the birth and evolution of galaxies and the formation and atmospheric composition of exoplanets.

“First and foremost, I see WFIRST as a tremendously promising mission that will help us understand the physics and origins of our universe,” Gagosian explains. The observatory, he points out, is also a great opportunity to demonstrate a technology that may allow future missions to discover telltale signs of life outside our solar system.

“We’re going to be proving the technologies and the techniques that will be employed later, perhaps on a bigger mission that’s specifically oriented around that purpose,” Gagosian observes.

WFIRST-AFTA permits risk reduction to take on technologies in the future, Gagosian says. “It’s our job here to make sure that investments in this project and those missions that follow provide the greatest benefit to humankind’s knowledge of the universe,” he concludes.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Most Earth-Like Worlds Have Yet to Be Born, According to Theoretical Study

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Earth came early to the party in the evolving universe. According to a new theoretical study, when our solar system was born 4.6 billion years ago only eight percent of the potentially habitable planets that will ever form in the universe existed. And, the party won't be over when the sun burns out in another 6 billion years. The bulk of those planets - 92 percent - have yet to be born.

This conclusion is based on an assessment of data collected by NASA's Hubble Space Telescope and the prolific planet-hunting Kepler space observatory.

"Our main motivation was understanding the Earth's place in the context of the rest of the universe," said study author Peter Behroozi of the Space Telescope Science Institute (STScI) in Baltimore, Maryland, "Compared to all the planets that will ever form in the universe, the Earth is actually quite early."

Looking far away and far back in time, Hubble has given astronomers a "family album" of galaxy observations that chronicle the universe's star formation history as galaxies grew. The data show that the universe was making stars at a fast rate 10 billion years ago, but the fraction of the universe's hydrogen and helium gas that was involved was very low. Today, star birth is happening at a much slower rate than long ago, but there is so much leftover gas available that the universe will keep cooking up stars and planets for a very long time to come.

"There is enough remaining material [after the big bang] to produce even more planets in the future, in the Milky Way and beyond," added co-investigator Molly Peeples of STScI.

Kepler's planet survey indicates that Earth-sized planets in a star's habitable zone, the perfect distance that could allow water to pool on the surface, are ubiquitous in our galaxy. Based on the survey, scientists predict that there should be 1 billion Earth-sized worlds in the Milky Way galaxy at present, a good portion of them presumed to be rocky. That estimate skyrockets when you include the other 100 billion galaxies in the observable universe.

This leaves plenty of opportunity for untold more Earth-sized planets in the habitable zone to arise in the future. The last star isn't expected to burn out until 100 trillion years from now. That's plenty of time for literally anything to happen on the planet landscape.

The researchers say that future Earths are more likely to appear inside giant galaxy clusters and also in dwarf galaxies, which have yet to use up all their gas for building stars and accompanying planetary systems. By contrast, our Milky Way galaxy has used up much more of the gas available for future star formation.

A big advantage to our civilization arising early in the evolution of the universe is our being able to use powerful telescopes like Hubble to trace our lineage from the big bang through the early evolution of galaxies. The observational evidence for the big bang and cosmic evolution, encoded in light and other electromagnetic radiation, will be all but erased away 1 trillion years from now due to the runaway expansion of space. Any far-future civilizations that might arise will be largely clueless as to how or if the universe began and evolved.

The results will appear in the October 20 Monthly Notices of the Royal Astronomical Society.

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington.

For images and more information visit:

http://www.nasa.gov/hubble

http://hubblesite.org/news/2015/35

Contacts:Donna Weaver / Ray VillardSpace Telescope Science Institute, Baltimore, Marylanddweaver@stsci.edu / villard@stsci.edu

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Mysterious Ripples Found Racing Through Planet-forming Disk

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers using NASA’s Hubble Space Telescope and the European Southern Observatory’s (ESO) Very Large Telescope in Chile have discovered never-before-seen features within the dusty disk surrounding the young, nearby star AU Microscopii (AU Mic).The fast-moving, wave-like structures are unlike anything ever observed, or even predicted in a circumstellar disk, said researchers of a new analysis. This new, unexplained phenomenon may provide valuable clues about how planets form inside these star-surrounding disks.

AU Mic is located 32 light-years away in the southern constellation Microscopium. It is an optimal star to observe because its circumstellar disk is tilted edge-on to our view from Earth. This allow for certain details in the disk to be better seen. Astronomers have been searching AU Mic’s disk for any signs of clumpy or warped features that might offer evidence for planet formation. They discovered a very unusual feature near the star by using ESO’s SPHERE (Spectro-Polarimetric High-contrast Exoplanet Research) instrument, mounted on the Very Large Telescope.

“The images from SPHERE show a set of unexplained features in the disk, which have an arc-like, or wave-like structure unlike anything that has ever been observed before,” said Anthony Boccaletti of the Paris Observatory, the paper’s lead author.

The images reveal a train of wave-like arches, resembling ripples in water. After spotting the features in the SPHERE data the team turned to earlier Hubble images of the disk, taken in 2010 and 2011. These features were not recognized in the initial Hubble observations. But once astronomers reprocessed the Hubble images they not only identified the features but realized that they had changed over time. The researchers report that these ripples are moving — and they are moving very fast.

“We ended up with enough information to track the movement of these strange features over a four-year period,” explained team member Christian Thalmann of the Swiss Federal Institute of Technology in Zurich, Switzerland. “By doing this, we found that the arches are racing away from the star at speeds of up to 10 kilometers per second (22,000 miles per hour)! Co-investigator Carol Grady of Eureka Scientific in Oakland, California, added, “Because nothing like this has been observed or predicted in theory we can only hypothesize when it comes to what we are seeing and how it came about.”

The ripples farther away from the star seem to be moving faster than those closer to it. At least three of the features are moving so fast that they are escaping from the gravitational attraction of the star. Such high speeds rule out the possibility that these features are caused by objects, like planets, gravitationally disturbing material in the disk. The team has also ruled out a series of phenomena as explanations, including the collision of two massive and rare asteroid-like objects releasing large quantities of dust and spiral waves triggered by instabilities in the system’s gravity.

“One explanation for the strange structure links them to the star’s flares. AU Mic is a star with high flaring activity — it often lets off huge and sudden bursts of energy from on or near its surface,” said co-author Glenn Schneider of Steward Observatory in Phoenix, Arizona. “One of these flares could perhaps have triggered something on one of the planets — if there are planets — like a violent stripping of material, which could now be propagating through the disk, propelled by the flare’s force.”

The team plans to continue to observe the AU Mic system to try to understand what is happening. But, for now, these curious features remain an unsolved mystery.

The results will be published Oct. 8 in the British science journal Nature.

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington, D.C.

For illustrations and more information about AU Mic and the Hubble Space Telescope, visit: http://www.nasa.gov/hubble or http://hubblesite.org/news/2015/36

Contact:Ray VillardSpace Telescope Science Institute, Baltimore, Maryland

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Seeing Earth as an Exoplanet: Space Probe Spots Nitrogen

4 min read

NASA Science Editorial Team

From Peter Kelley, University of Washington

Observations of nitrogen in Earth's atmosphere by a NASA spacecraft 17 million miles away are giving astronomers fresh clues to how that gas might reveal itself on faraway planets, thus aiding in the search for life.

Finding and measuring nitrogen in the atmosphere of an exoplanet--one outside our solar system--can be crucial to determining if that world might be habitable. That's because nitrogen can provide clues to surface pressure. If nitrogen is found to be abundant in a planet's atmosphere, that world almost certainly has the right pressure to keep liquid water stable on its surface. Liquid water is one of the prerequisites for life.

Should life truly exist on an exoplanet, detecting nitrogen as well as oxygen could help astronomers verify the oxygen's biological origin by ruling out certain ways oxygen can be produced abiotically, or through means other than life.

The trouble is, nitrogen is hard to spot from afar. It's often called an "invisible gas" because it has few light-altering features in visible or infrared light that would make it easy to detect. The best way to detect nitrogen in a distant atmosphere is to measure nitrogen molecules colliding with each other. The resulting, instantaneously brief "collisional pairs" create a unique and discernable spectroscopic signature.

A paper published Aug. 28 in The Astrophysical Journal by University of Washington astronomy doctoral student and lead author Edward Schwieterman, together with astronomy professor Victoria Meadows and co-authors, shows that a future large telescope could detect this unusual signature in the atmospheres of terrestrial, or rocky planets, given the right instrumentation.

The researchers used three-dimensional planet-modeling data from the UW-based Virtual Planetary Laboratory--of which Meadows is principal investigator--to simulate how the signature of nitrogen molecule collisions might appear in the Earth's atmosphere, and compared this simulated data to real observations of the Earth by NASA's unmanned Deep Impact Flyby spacecraft, launched in 2005.

The craft undertook a revised mission, called EPOXI, which included observation and characterization of the Earth as if it were an exoplanet. By comparing the real data from the EPOXI mission and the simulated data from Virtual Planetary Laboratory models, the authors were able to confirm the signatures of nitrogen collisions in our own atmosphere, and that they would be visible to a distant observer.

"One of the main messages of the Virtual Planetary Laboratory is that you always need validation of an idea--a proof of concept--before you can extrapolate your knowledge to studying a potentially Earth-like exoplanet," Schwieterman said. "That's why studying the Earth as an exoplanet is so important--we were able to validate that nitrogen produces an impact on the spectrum of our own planet as seen by a distant spacecraft. This tells us it's something worth looking for elsewhere."

This confirmation in hand, the researchers used a suite of Virtual Planetary Laboratory models that simulated the appearance of planets beyond the solar system bearing varying amounts of nitrogen in their atmospheres.

The detection of nitrogen will help astronomers characterize the atmospheres of potentially habitable planets and determine the likelihood of oxygen production by nonliving processes, the researchers write.

“One of the interesting results from our study is that, basically, if there’s enough nitrogen to detect at all, you’ve confirmed that the surface pressure is sufficient for liquid water, for a very wide range of surface temperatures,” Schwieterman said.Schwieterman and Meadows’ UW co-author is Amit Misra, who recently completed his doctorate at the UW in astronomy. Other co-authors are Tyler Robinson of the NASA Ames Research Center in Moffet Field, California, who earned his doctorate at the UW; and Shawn Domagal-Goldman of the NASA Goddard Space Flight Center, who completed a postdoctoral appointment at the UW.The research was funded by the NASA Astrobiology Institute.

Climate change is rapidly reshaping a region of the world that’s home to millions of people. In the next 30 years, Pacific Island nations such as Tuvalu, Kiribati, and Fiji will experience at least 6 inches (15 centimeters) of sea level rise, according to an analysis by NASA’s sea level change science team. This amount […]

Arctic sea ice retreated to near-historic lows in the Northern Hemisphere this summer, likely melting to its minimum extent for the year on Sept.11, 2024, according to researchers at NASA and the National Snow and Ice Data Center (NSIDC). The decline continues the decades-long trend of shrinking and thinning ice cover in the Arctic Ocean. […]

Designed to be user-friendly, the resource contains the latest sea level data, explainers, and other information from several U.S. agencies. The U.S. Interagency Task Force on Sea Level Change launched the U.S. Sea Level Change website on Monday, Sept. 23. Designed to help communities prepare for rising seas, the site features the latest science on […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Earth-like exoplanets may have magnetic fields capable of protecting life

5 min read

NASA Science Editorial Team

From University of Washington

Earth-like planets orbiting close to small stars probably have magnetic fields that protect them from stellar radiation and help maintain surface conditions that could be conducive to life, according to research from astronomers at the University of Washington.

A planet's magnetic field emanates from its core and is thought to deflect the charged particles of the stellar wind, protecting the atmosphere from being lost to space. Magnetic fields, born from the cooling of a planet's interior, could also protect life on the surface from harmful radiation as the Earth's magnetic field protects us.

Low-mass stars are among the most common in the universe. Planets orbiting near low-mass stars are easier for astronomers to target for study because when they transit, or pass in front of their host star, they block a larger fraction of the light than if they transited a more massive star. But because such a star is small and dim, its habitable zone — where an orbiting planet gets the heat necessary to maintain life-friendly liquid water on the surface — also lies relatively close in.

And a planet so close to its star is subject to the star's powerful gravitational pull, which could cause it to become tidally locked, with the same side forever facing its host star, as the moon is with the Earth. That same gravitational tug from the star also creates tidally-generated heat inside the planet, or tidal heating. Tidal heating is responsible for driving the most volcanically active body in our solar system, Jupiter's moon Io.

A tidally locked planet orbits its star with only one side facing the star, much like the moon orbits Earth (left). A planet like Earth gets starlight on both its near and far sides (right).

In a paper published Sept. 22 in the journal Astrobiology, lead author Peter Driscoll sought to determine the fate of such worlds across time: "The question I wanted to ask is, around these small stars where people are going to look for planets, are these planets going to be roasted by gravitational tides?" He was curious too about the effect of tidal heating on magnetic fields across long periods of time.

The research combined models of orbital interactions and heating by Rory Barnes, assistant professor of astronomy, with those of thermal evolution of planetary interiors done by Driscoll, who began this work as a UW postdoctoral fellow and is now a geophysicist at the Carnegie Institution for Science in Washington, D.C.

Their simulations ranged from one stellar mass — stars the size of our sun — down to about one-tenth of that size. By merging their models they were able, Barnes said, "to produce a more realistic picture of what is happening inside these planets."

Barnes said there has been a general feeling in the astronomical community that tidally locked planets are unlikely to have protective magnetic fields "and therefore are completely at the mercy of their star." This research suggests that assumption is false.

Far from being harmful to a planet's magnetic field, tidal heating can actually help it along — and in doing so also help the chance for habitability.

This is because of the somewhat counterintuitive fact that the more tidal heating a planetary mantle experiences, the better it is at dissipating its heat, thereby cooling the core, which in turn helps create the magnetic field.

Barnes said that in computer simulations they were able to generate magnetic fields for the lifetimes of these planets, in most cases. “I was excited to see that tidal heating can actually save a planet in the sense that it allows cooling of the core. That’s the dominant way to form magnetic fields.”

And since small or low mass stars are particularly active early in their lives — for the first few billion years or so — “magnetic fields can exist precisely when life needs them the most.”

Driscoll and Barnes also found through orbital calculations that the tidal heating process is more extreme for planets in the habitable zone around very small stars, or those less than half the mass of the sun.

For planets in eccentric, or noncircular, orbits around such low mass stars, they found that these orbits tend to become more circular during the time of extreme tidal heating. Once that circularization takes place, the planet stops experiencing any tidal heating at all.

The research was done through the Virtual Planetary Laboratory, a UW-based interdisciplinary research group funded through the NASA Astrobiology Institute.

“These preliminary results are promising, but we still don’t know how they would change for a planet like Venus, where slow planetary cooling is already hindering magnetic field generation,” Driscoll said. “In the future, exoplanetary magnetic fields could be observable, so we expect there to be a growing interest in this field going forward.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Oxygen on Exoplanets isn’t Proof of Life

3 min read

NASA Science Editorial Team

From Japanese National Institutes of Natural Sciences

The Earth's atmosphere contains oxygen because plants continuously produce it through photosynthesis. This abundant supply of oxygen allows life forms like animals to flourish. Therefore, oxygen had been thought to be an essential biomarker for life on extrasolar planets.

But now, a research assistant professor Norio Narita of the Astrobiology Center of National Institutes of Natural Sciences (NINS), which was founded in April 2015, and an associate professor Shigeyuki Masaoka, of the Institute of Molecular Science of NINS, have presented a novel hypothesis that it could be possible for planets to have large quantities of abiotic (non-biologically produced) oxygen. This study is a good example of interdisciplinary studies that combine knowledge from different fields of science to promote astrobiology in the search for life on extrasolar planets. The study is published in Scientific Reports on Sept. 10, 2015.

Until now, it had been thought that if a planet has oxygen, that must mean that some form of plants are producing it through photosynthesis. Therefore, it had been assumed that when searching for signs of life on habitable extrasolar planets, the presence of oxygen in the atmosphere could be considered a definitive biomarker.

However, non-biological chemical reactions can also affect atmospheric compositions of extrasolar planets. Now, the research team led by Dr. Narita has shown that abiotic oxygen produced by the photocatalytic reaction of titanium oxide, which is known to be abundant on the surfaces of terrestrial planets, meteorolites, and the Moon in the solar system, cannot be discounted.

For a planet with an environment similar to the Sun-Earth system, continuous photocatalytic reaction of titanium oxide on about 0.05 % of the planetary surface could produce the amount of oxygen found in the current Earth's atmosphere. In addition, the team estimated the amount of possible oxygen production for habitable planets around other types of host stars with various masses and temperatures.

They found that even in the least efficient production case of a low-temperature star, the photocatalytic reaction of the titanium oxide on about 3 percent of the planetary surface could maintain this level of atmospheric oxygen through abiotic processes. In other words, it is possible that a habitable extrasolar planet could maintain an atmosphere with Earth-like oxygen, even without organisms to perform photosynthesis.

Dr. Narita said, "To search for life on extrasolar planets through astronomical observation, we need to combine the knowledge from various scientific fields and to promote astrobiology researches to establish the decisive signs of life. Although oxygen is still one of possible biomarkers, it becomes necessary to look for new biomarkers besides oxygen from the present result."

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanets 20/20: Looking back to the future

9 min read

Alicia Cermak

By Pat Brennan,Jet Propulsion Laboratory

Two decades after the discovery that began it all—the first confirmation of a planet in orbit around a Sun-like star—scientists say that it seemed very nearly unbelievable at the time.

Paul Butler remembers being dead tired. Geoff Marcy remembers the hair standing up on the back of his neck.

The groundbreaking discovery had been announced less than a week earlier by the European team of Michel Mayor and Didier Queloz. But the news was met with some initial skepticism in the astronomical community. By a stroke of good luck, Marcy and Butler happened to have previously scheduled observation time on a 120-inch telescope at the Lick Observatory, atop California's Mount Hamilton.

The scientists, who would become two of the world's most famous planet hunters, remember driving down the mountainside together in October 1995. They'd spent four straight nights making their observations. And while further processing would be needed to make the scientific case, their data seemed clear and unmistakable—and almost impossible. A huge planet, at least half the size of Jupiter, was not only orbiting its host star more tightly than Mercury hugs the Sun. It was racing around that star, making a complete orbit in just four days.

The planet, called 51 Pegasi b, would open a new era in humanity's exploration of our galactic neighborhood. It would be the first in a series of "hot Jupiters"—giant planets in fast, tight orbits—discovered in rapid succession. The rush of new worlds would propel Marcy, Butler and their research team into the media spotlight, and forever change our view of the cosmos.

But for the moment, on that solemn drive down the mountainside, Marcy and Butler were alone with their world-altering news. "We knew we were the only people on the planet to be sure that 51 Peg, the planet, really did exist," Marcy said recently. "It was exhilarating. We were absolutely thrilled to know an historic moment in science history was happening before our eyes."

Still, the astronomical pioneers had a few struggles ahead to gain the acceptance of the scientific community. The hunt for extrasolar planets—exoplanets, for short—had a poor track record, with decades' worth of false detections. Among them was the thrilling discovery of a planet orbiting Barnard's star in the 1960s; it turned out to be an unnoticed shift of a telescope lens. Once the shift was accounted for, the "planet" disappeared.

The early '90s had seen the actual detection of "pulsar planets," but these seemed too strange to count, orbiting a rapidly spinning, radiation-spewing stellar remnant called a pulsar. Most scientists would reserve the "first" designation for a planet orbiting a normal star.

"The whole field had a snake-oil sort of feel to it," Butler said in a recent interview. "For the previous fifty years or so, there were many announcements, all proved to be wrong. If we went to a meeting and said we were looking for extrasolar planets, we might as well have said we were looking for little green men."

Even Marcy greeted the announcement of 51 Peg, made at a scientific conference in Florence, Italy, by Mayor and Queloz, with a bit of a yawn—at first.

“This claim on October 6, 1995, of the first planet ever discovered was sort of business as usual,” he said. “Here’s another false claim. This one is more obviously a false claim. The orbital period is claimed to be 4.3 days. Nobody in their right mind thought planets could orbit so close to a star.”

But the four nights of observations at the Lick Observatory—perfectly coinciding with 51 Peg’s four-day orbit—changed all that. Both the Mayor and Marcy teams had been trying to develop a planet-hunting technique based on wobbling stars. The wobbles, known as the star’s “radial velocity,” were induced by the gravitational tugs of orbiting planets. The starlight wavelength was compressed, then stretched, as the star moved toward and away from astronomers’ telescopes.

Now, Mayor and Queloz had proven that the technique worked. And a few days later, Marcy and Butler validated both the method used by Mayor's team and their own very similar detection method.

But Marcy and his team realized something more. The only thing that had kept them from beating Mayor’s group to that first detection was a perfectly reasonable assumption: that big planets moved in stately orbits, like the 12 years it took Jupiter to take one lap around the Sun.

Either they would have to watch stars for a very long time, or they would have to refine their wobble detector until it could pick up the very tiny shifts in a star’s position caused by small planets in tighter, faster orbits.

They were working on just this type of refinement when Mayor announced his discovery. More importantly, they had been recording observations with their wobble-detecting device, known as a spectrograph. Sure enough, when they took another look, big, star-hugging planets began popping out of their data.

At a meeting of the American Astronomical Society in January 1996, Marcy announced two more planet discoveries: 70 Virginis and 47 Ursae Majoris. The first had a 116-day orbit—far more reasonable than 51 Peg’s scorching four days—and its orbit was elliptical, making it unlikely to be anything but a planet. The orbit of 47 Ursae Majoris was more reasonable still: 2.5 years. Together, they provided a “bridge” to our own solar system, Marcy said, with planets behaving themselves as proper planets should.

The discoveries vaulted Marcy and his team into scientific celebrity status, with appearances on nationwide nightly news shows; their new planets even made the cover of Time magazine.

And the Marcy-Butler team was just warming up. The floodgates were opened. They discovered at least 70 of the first 100 exoplanets that were found in the years that followed. Their pioneering, planet-hunting safari went on for a decade. Soon, however, the landscape would change yet again.

The gold rush of planet finding kicked into high gear with the launch of the Kepler Space Telescope in 2009. This spacecraft nestled into an Earth-trailing orbit, then fixed its eye on a small patch of sky—and kept it there for four years.

Within that patch were more than 150,000 stars, a kind of cross-section of an arm of our own Milky Way galaxy, as if Kepler were shining a searchlight into deep space. Kepler was looking for planetary transits -- the infinitesimally tiny dip in starlight that occurs when a planet crosses the face of the star it is orbiting.

The method only works for distant solar systems whose planets’ orbits, from our perspective, are seen edge-on. This way, an exoplanet is silhouetted as it passes between Kepler and its host star, reducing the starlight measured by Kepler.

Kepler was the brainchild of William Borucki of the NASA Ames Research Center in Moffet Field, California. Borucki, who retired in early July 2015, doggedly pressed his case for Kepler. During the 90s, his proposed designs were rejected no less than four times. He finally won approval from

NASA in 2001.

But no one knew what Kepler might find, or even if it would find anything at all.

“We launched Kepler, to some extent, like Magellan or Columbus went to sea, not knowing quite what we were going to encounter,” said James Fanson, deputy manager in the Instruments Division at NASA's Jet Propulsion Laboratory. Fanson was Kepler’s project manager when the spacecraft was launched.

“We knew we were going to make history,” he said. “We just didn’t know what history we were going to make.”

Kepler’s transit watch paid off, however, identifying more than 4,600 candidate planets hundreds to thousands of light-years distant. So far, 1,028 of those have been confirmed—some of them Earth-sized planets that orbit within their star’s so-called habitable zone, where liquid water can exist on a planet. Scientists are still mining Kepler data, regularly turning up new planetary candidates and confirming earlier finds.

Kepler itself ended its initial mission in 2013, when two of four reaction wheels used to keep the spacecraft in a stable position failed. But the Kepler science team developed clever ways to continue squeezing useful data out of the space telescope, relying on the subtle pressure of sunlight to stabilize it on one axis. Kepler is now in its second phase of life, and it’s still discovering planets.

Preceding Kepler was the groundbreaking COROT satellite, a European venture launched in 2006 that discovered numerous planets before it ceased functioning in 2012 -- including the first rocky planet found to orbit a Sun-like star. COROT used the transit method to detect exoplanets, and was the first space mission dedicated to that purpose.

The prolific discoveries still flowing from the Hubble Space Telescope include not only exoplanets, but characterizations of exoplanet atmospheres, identifying a variety of gases. And the Spitzer Space Telescope has found water vapor in exoplanetary atmospheres as well as weather patterns.

Both the wobble and transit methods, relied upon by the exoplanet pioneers, are still in use today, along with several other techniques. And 20 years after the first discovery, the exoplanet total is up to more than 5,000 candidates, with more than 1,800 of those confirmed.

The galaxy, it seems, is crowded with planets. Yet we are not yet able to answer the big question: Are we alone?

A new generation of telescopes in the years and decades ahead, on the ground and in space, will continue to search for an answer. One critical tool will be the same one pioneered by Marcy and the other early planet hunters: spectroscopy. They used this method to dissect the light coming from distant stars, revealing their back-and-forth, planet-induced wobbling as the starlight was stretched and compressed; the newest generation of instruments will do the same thing to the light from the atmospheres of exoplanets. Splitting this planetary light into its constituent parts, a little like the rainbow colors of sunlight shining through a prism, should reveal which gases and chemicals are present in those alien skies.

And one day, some of those atmospheric constituents might suggest the presence of life far beyond planet Earth.

See more: Exoplanet Travel Posters

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s

other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanet snapshot: New imager captures young 'Jupiter'

5 min read

NASA Science Editorial Team

From Bjorn Carey, Stanford University

One of the best ways to learn how our solar system evolved is to look to younger star systems in the early stages of development. Now, a team of astronomers has discovered a Jupiter-like planet within a young system that could serve as a decoder ring for understanding how planets formed around our sun.

The new planet, called 51 Eridani b, is the first exoplanet discovered by the Gemini Planet Imager, a new instrument operated by an international collaboration headed by Bruce Macintosh, a professor of physics at Stanford University and member of the Kavli Institute for Particle Astrophysics and Cosmology. It is a million times fainter than its parent star and shows the strongest methane signature ever detected on an alien planet, which should yield additional clues as to how the planet formed.

The results are published in the current issue of Science.

The Gemini Planet Imager (GPI) was designed specifically for discovering and analyzing faint, young planets orbiting bright stars. While NASA's Kepler space observatory has discovered thousands of planets, it does so indirectly by detecting a loss of starlight as a planet passes in front of its star. GPI instead searches for light from the planet itself.

"To detect planets, Kepler sees their shadow," said Macintosh. "The Gemini Planet Imager instead sees their glow, which we refer to as direct imaging."

The astronomers use adaptive optics to sharpen the image of a star, and then block out the starlight. Any remaining incoming light is then analyzed, with the brightest spots indicating a possible planet.

Last year, the GPI was installed on the 8-meter Gemini South Telescope in Chile, and the team set out to look for planets orbiting young stars, identifying nearly 100 so far.

"This is exactly the kind of system we envisioned discovering when we designed GPI," said James Graham, professor at the University of California, Berkeley, and project scientist for GPI.

"51 Eri is one of the best stars for imaging young planets," said co-author Eric Nielsen, a postdoctoral researcher at Stanford and the SETI Institute. "It's one of the very youngest stars this close to the Sun. 51 Eri was born 20 million years ago, 40 million years after the dinosaurs died out."

As far as the cosmic clock is concerned, 20 million years is young, and that is exactly what made the direct detection of the planet possible. When planets coalesce, material falling into the planet releases energy and heats it up. Over the next hundred million years the planet radiates that energy away, mostly as infrared light.

Once the astronomers zeroed in on the star, they blocked its light and spotted light reflecting off 51 Eridani b, orbiting a little farther away from its parent star than Saturn does from the sun. The light from the planet is very faint – more than 3 million times fainter than its star – but GPI can see it clearly. Observations revealed that it is roughly twice the mass of Jupiter, half or less the mass of the young planets discovered to date.

In addition to being the lowest-mass planet ever imaged, it's also one of the coldest – 800 degrees Fahrenheit, whereas others are around 1,200 F – and features the strongest atmospheric methane signal on record. Previous Jupiter-like exoplanets have shown only faint traces of methane, far different from the heavy methane atmospheres of the gas giants in our solar system.

All of these characteristics, the researchers say, point to a planet that is very much what models suggest Jupiter was like in its infancy.

"Many of the exoplanets astronomers have imaged before have atmospheres that look like very cool stars," said Macintosh, who led the construction of GPI and now leads the planet-hunting survey. "This one looks like a planet."

Of course, it's not exactly like Jupiter – its 800 F temperature is still hot enough to melt lead – but there are signs it will evolve into a familiar shape.

"In the atmospheres of the cold giant planets of our solar system, carbon is found as methane, unlike most exoplanets, where carbon has mostly been found in the form of carbon monoxide," said Mark Marley, an astrophysicist at NASA Ames Research Center. "Since the atmosphere of 51 Eri b is also methane rich, it signifies that this planet is well on its way to becoming a cousin of our own familiar Jupiter."

In addition to expanding the universe of known planets, GPI will provide key clues as to how solar systems form. Astronomers believe that the gas giants in our solar system formed by building up a large core over a few million years and then pulling in a huge amount of hydrogen and other gases to form an atmosphere.

But the Jupiter-like exoplanets that have so far been discovered are much hotter than models have predicted, hinting that they could have formed much faster as material collapses quickly to make a very hot planet. This is an important difference. The core-buildup process can also form rocky planets like Earth; a fast and hot collapse might only make giant gassy planets. 51 Eridani b is young enough that it "remembers" its formation.

"51 Eri b is the first one that's cold enough and close enough to the star that it could have indeed formed right where it is the 'old-fashioned way,'" Macintosh said. "This planet really could have formed the same way Jupiter did – the whole solar system could be a lot like ours."

There are hundreds of planets a little bigger than Earth out there, Macintosh said, but there is so far no way to know if most of them are really "super-Earths" or just micro-sized gas and ice planets like Neptune, or something different altogether. Using GPI to study more young solar systems such as 51 Eridani, he said, will help astronomers understand the formation of our neighbor planets, and how common that planet-forming mechanism is throughout the universe.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

How to teach ‘exoplanets’ and the search for habitable worlds

1 min read

NASA Science Editorial Team

Find out how to turn the most Earth-like exoplanet found so far into a Teachable Moment.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA Releases Hubble Memorable Moments Video: Brute Force

2 min read

NASA Hubble Mission Team

Goddard Space Flight Center

In celebration of the 25 years since the Hubble Space Telescope's April 1990 launch, NASA is releasing the second in a series of videos showcasing moments in Hubble's history that were memorable for Goddard's engineers and flight operators.

"Hubble Memorable Moments: Brute Force," which was produced by NASA's Goddard Space Flight Center in Greenbelt, Maryland, describes repairing the Space Telescope Imaging Spectrograph on Hubble Servicing Mission 4 in May, 2009.

The Space Telescope Imaging Spectrograph, or STIS, was installed on Hubble during Servicing Mission 2 in 1997. A versatile instrument taking measurements in the ultraviolet, visible, and near-infrared wavelengths, STIS has discovered supermassive black holes at the centers of galaxies, and made one of the first spectroscopic measurements of the atmosphere of an exoplanet - a planet orbiting another star.

STIS was originally designed to operate for five years, but it lasted 7.5 until a power supply failed in August, 2004. At the time, STIS was being used for about 30 percent of the Hubble observing program. Because STIS was such an incredibly useful instrument, it became a high-priority task for repair on Hubble's final servicing mission.

Most Hubble servicing mission tasks involve replacing an instrument by swapping out large boxes, not repairing an instrument, which involves much more detailed and nimble work. Gaining access to STIS' electronics cards would involve removing 107 small screws, so Goddard engineers custom-designed a fastener capture plate for the task while the astronauts trained tirelessly at the Johnson Space Center for the months leading up to the mission.

The Hubble team was well prepared for this incredibly complex task. Sometimes, however, it's the simplest items that present a huge obstacle, and the highly trained team must scramble to quickly devise an unusual solution.

Watch the video to see how this spacewalk on May 17, 2009 played out.

"Hubble Memorable Moments: Brute Force" can be downloaded at:

https://svs.gsfc.nasa.gov/11822/

For more information about the Hubble Space Telescope and its 25th anniversary festivities, visit:

http://www.nasa.gov/hubble or http://hubble25th.org

Contacts:

Katrina JacksonNASA's Goddard Space Flight Center

Scientists and engineers tested NASA's LEMS (Lunar Environment Monitoring Station) instrument suite in a "sandbox" of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Telescopes Team Up to Find Distant Uranus-Sized Planet Through Microlensing

8 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA's Hubble Space Telescope and the W.M. Keck Observatory in Hawaii have made independent confirmations of an exoplanet orbiting far from its central star. The planet was discovered through a technique called gravitational microlensing.

This finding opens a new piece of discovery space in the extrasolar planet hunt: to uncover planets as far from their central stars as Jupiter and Saturn are from our sun. The Hubble and Keck Observatory results will appear in two papers in the July 30 edition of The Astrophysical Journal.

The large majority of exoplanets cataloged so far are very close to their host stars because several current planet-hunting techniques favor finding planets in short-period orbits. But this is not the case with the microlensing technique, which can find more distant and colder planets in long-period orbits that other methods cannot detect.

Microlensing occurs when a foreground star amplifies the light of a background star that momentarily aligns with it. If the foreground star has planets, then the planets may also amplify the light of the background star, but for a much shorter period of time than their host star. The exact timing and amount of light amplification can reveal clues to the nature of the foreground star and its accompanying planets.

The system, cataloged as OGLE-2005-BLG-169, was discovered in 2005 by the Optical Gravitational Lensing Experiment (OGLE), the Microlensing Follow-Up Network (MicroFUN), and members of the Microlensing Observations in Astrophysics (MOA) collaborations—groups that search for extrasolar planets through gravitational microlensing.

Without conclusively identifying and characterizing the foreground star, however, astronomers have had a difficult time determining the properties of the accompanying planet. Using Hubble and the Keck Observatory, two teams of astronomers have now found that the system consists of a Uranus-sized planet orbiting about 370 million miles from its parent star, slightly less than the distance between Jupiter and the Sun. The host star, however, is about 70 percent as massive as our Sun.

"These chance alignments are rare, occurring only about once every 1 million years for a given planet, so it was thought that a very long wait would be required before the planetary microlensing signal could be confirmed," said David Bennett, the lead of the team that analyzed the Hubble data. "Fortunately, the planetary signal predicts how fast the apparent positions of the background star and planetary host star will separate, and our observations have confirmed this prediction. The Hubble and Keck Observatory data, therefore, provide the first confirmation of a planetary microlensing signal."

In fact, microlensing is such a powerful tool that it can uncover planets whose host stars cannot be seen by most telescopes. "It is remarkable that we can detect planets orbiting unseen stars, but we'd really like to know something about the stars that these planets orbit," explained Virginie Batista, leader of the Keck Observatory analysis. "The Keck and Hubble telescopes allow us to detect these faint planetary host stars and determine their properties."

Planets are small and faint compared to their host stars; only a few have been observed directly outside our solar system. Astronomers often rely on two indirect techniques to hunt for extrasolar planets. The first method detects planets by the subtle gravitational tug they give to their host stars. In another method, astronomers watch for small dips in the amount of light from a star as a planet passes in front of it.

Both of these techniques work best when the planets are either extremely massive or when they orbit very close to their parent stars. In these cases, astronomers can reliably determine their short orbital periods, ranging from hours to days to a couple years.

But to fully understand the architecture of distant planetary systems, astronomers must map the entire distribution of planets around a star. Astronomers, therefore, need to look farther away from the star—from about the distance of Jupiter is from our sun, and beyond.

“It’s important to understand how these systems compare with our solar system,” said team member Jay Anderson of the Space Telescope Science Institute in Baltimore, MD. “So we need a complete census of planets in these systems. Gravitational microlensing is critical in helping astronomers gain insights into planetary formation theories.”

The planet in the OGLE system is probably an example of a “failed-Jupiter” planet, an object that begins to form a Jupiter-like core of rock and ice weighing around 10 Earth masses, but it doesn’t grow fast enough to accrete a significant mass of hydrogen and helium. So it ends up with a mass more than 20 times smaller than that of Jupiter. “Failed-Jupiter planets, like OGLE-2005-BLG-169Lb, are predicted to be more common than Jupiters, especially around stars less massive than the sun, according to the preferred theory of planet formation. So this type of planet is thought to be quite common,” Bennett said.

Microlensing takes advantage of the random motion of stars, which are generally too small to be noticed without precise measurements. If one star, however, passes nearly precisely in front of a farther background star, the gravity of the foreground star acts like a giant lens, magnifying the light from the background star.

A planetary companion around the foreground star can produce a variation in the brightening of the background star. This brightening fluctuation can reveal the planet, which can be too faint, in some cases, to be seen by telescopes. The duration of an entire microlensing event is several months, while the variation in brightening due to a planet lasts a few hours to a couple of days.

The initial microlensing data of OGLE-2005-BLG-169 had indicated a combined system of foreground and background stars plus a planet. But due to the blurring effects of our atmosphere, a number of unrelated stars are also blended with the foreground and background stars in the very crowded star field in the direction of our galaxy’s center.

The sharp Hubble and Keck Observatory images allowed the research teams to separate out the background source star from its neighbors in the very crowded star field in the direction of our galaxy’s center. Although the Hubble images were taken 6.5 years after the lensing event, the source and lens star were still so close together on the sky that their images merged into what looked like an elongated stellar image.

Astronomers can measure the brightness of both the source and planetary host stars from the elongated image. When combined with the information from the microlensing light curve, the lens brightness reveals the masses and orbital separation of the planet and its host star, as well as the distance of the planetary system from Earth. The foreground and background stars were observed in several different colors with Hubble’s Wide Field Camera 3 (WFC3), allowing independent confirmations of the mass and distance determinations.

The observations, taken with the Near Infrared Camera 2 (NIRC2) on the Keck 2 telescope more than eight years after the microlensing event, provided a precise measurement of the foreground and background stars’ relative motion. “It is the first time we were able to completely resolve the source star and the lensing star after a microlensing event. This enabled us to discriminate between two models that fit the data of the microlensing light curve,” Batista said.

The Hubble and Keck Observatory data are providing proof of concept for the primary method of exoplanet detection that will be used by NASA’s planned, space-based Wide-Field Infrared Survey Telescope (WFIRST), which will allow astronomers to determine the masses of planets found with microlensing. WFIRST will have Hubble’s sharpness to search for exoplanets using the microlensing technique. The telescope will be able to observe foreground, planetary host stars approaching the background source stars prior to the microlensing events, and receding from the background source stars after the microlensing events.

“WFIRST will make measurements like we have made for OGLE-2005-BLG-169 for virtually all the planetary microlensing events it observes. We’ll know the masses and distances for the thousands of planets discovered by WFIRST,” Bennett explained.

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore, Maryland, conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington.

For images and more about this study and the Hubble Space Telescope, visit:

http://www.nasa.gov/hubble

http://hubblesite.org/news/2015/27

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Spitzer Confirms Closest Rocky Exoplanet

4 min read

NASA Science Editorial Team

By Whitney Calvin, Jet Propulsion Laboratory

Using NASA's Spitzer Space Telescope, astronomers have confirmed the discovery of the nearest rocky planet outside our solar system, larger than Earth and a potential gold mine of science data.

Dubbed HD 219134b, this exoplanet, which orbits too close to its star to sustain life, is a mere 21 light-years away. While the planet itself can't be seen directly, even by telescopes, the star it orbits is visible to the naked eye in dark skies in the Cassiopeia constellation, near the North Star.

HD 219134b is also the closest exoplanet to Earth to be detected transiting, or crossing in front of, its star and, therefore, perfect for extensive research.

"Transiting exoplanets are worth their weight in gold because they can be extensively characterized," said Michael Werner, the project scientist for the Spitzer mission at NASA's Jet Propulsion Laboratory in Pasadena, California. "This exoplanet will be one of the most studied for decades to come."

The planet, initially discovered using the HARPS-North instrument on the Italian 3.6-meter Galileo National Telescope in the Canary Islands, is the subject of a study accepted for publication in the journal Astronomy & Astrophysics.

Study lead author Ati Motalebi of the Geneva Observatory in Switzerland said she believes the planet is the ideal target for NASA's James Webb Space Telescope in 2018.

"Webb and future large, ground-based observatories are sure to point at it and examine it in detail," Motalebi said.

Only a small fraction of exoplanets can be detected transiting their stars due to their relative orientation to Earth. When the orientation is just right, the planet's orbit places it between its star and Earth, dimming the detectable light of its star. It's this dimming of the star that is actually captured by observatories such as Spitzer and can reveal not only the size of the planet but also clues about its composition.

"Most of the known planets are hundreds of light-years away. This one is practically a next-door neighbor," said astronomer and study co-author Lars A. Buchhave of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts. For reference, the closest known planet is GJ674b at 14.8 light-years away; its composition is unknown.

HD 219134b was first sighted by the HARPS-North instrument and a method called the radial velocity technique, in which a planet's mass and orbit can be measured by the tug it exerts on its host star. The planet was determined to have a mass 4.5 times that of Earth, and a speedy three-day orbit around its star.

Spitzer followed up on the finding, discovering the planet transits its star. Infrared measurements from Spitzer revealed the planet's size, about 1.6 times that of Earth. Combining the size and mass gives it a density of 3.5 ounces per cubic inch (six grams per cubic centimeter) -- confirming HD 219134b is a rocky planet.

Now that astronomers know HD 219134b transits its star, scientists will be scrambling to observe it from the ground and space. The goal is to tease chemical information out of the dimming starlight as the planet passes before it. If the planet has an atmosphere, chemicals in it can imprint patterns in the observed starlight.

Rocky planets such as this one, with bigger-than-Earth proportions, belong to a growing class of planets termed super-Earths.

"Thanks to NASA's Kepler mission, we know super-Earths are ubiquitous in our galaxy, but we still know very little about them," said co-author Michael Gillon of the University of Liege in Belgium, lead scientist for the Spitzer detection of the transit. "Now we have a local specimen to study in greater detail. It can be considered a kind of Rosetta Stone for the study of super-Earths."

Further observations with HARPS-North also revealed three more planets in the same star system, farther than HD 219134b. Two are relatively small and not too far from the star. Small, tightly packed multi-planet systems are completely different from our own solar system, but, like super-Earths, are being found in increasing numbers.

JPL manages the Spitzer mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology in Pasadena. Spacecraft operations are based at Lockheed Martin Space Systems Co. in Littleton, Colorado. Data are archived at the Infrared Science Archive, housed at Caltech's Infrared Processing and Analysis Center.

For more information about NASA's Spitzer Space Telescope, visit:

http://www.nasa.gov/spitzer

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Jupiter twin orbits a twin of our sun

3 min read

NASA Science Editorial Team

An international group of astronomers has used the ESO 3.6-meter telescope to identify a planet just like Jupiter orbiting at the same distance from a sun-like star, HIP 11915. According to current theories, the formation of Jupiter-mass planets plays an important role in shaping the architecture of planetary systems. The existence of a Jupiter-mass planet in a Jupiter-like orbit around a sun-like star opens the possibility that the system of planets around this star may be similar to our own solar system. HIP 11915 is about the same age as the sun and, furthermore, its sun-like composition suggests that there may also be rocky planets orbiting closer to the star.

So far, exoplanet surveys have been most sensitive to planetary systems that are populated in their inner regions by massive planets, down to a few times the mass of the Earth. This contrasts with our solar system, where there are small rocky planets in the inner regions and gas giants like Jupiter farther out.

According to the most recent theories, the arrangement of our solar system, so conducive to life, was made possible by the presence of Jupiter and the gravitational influence this gas giant exerted on the solar system during its formative years. It would seem, therefore, that finding a Jupiter twin is an important milestone on the road to finding a planetary system that mirrors our own.

A Brazilian-led team has been targeting sun-like stars in a bid to find planetary systems similar to our solar system. The team has now uncovered a planet with a very similar mass to Jupiter, orbiting a sun-like star, HIP 11915, at almost exactly the same distance as Jupiter. The new discovery was made using HARPS, one of the world’s most precise planet-hunting instruments, mounted on the ESO 3.6-meter telescope at the La Silla Observatory in Chile.

Although many planets similar to Jupiter have been found at a variety of distances from sun-like stars, this newly discovered planet, in terms of both mass and distance from its host star, and in terms of the similarity between the host star and our sun, is the most accurate analogue yet found for the sun and Jupiter.

The planet’s host, the solar twin HIP 11915, is not only similar in mass to the sun, but is also about the same age. To further strengthen the similarities, the composition of the star is similar to the sun’s. The chemical signature of our sun may be partly marked by the presence of rocky planets in the solar system, hinting at the possibility of rocky planets also around HIP 11915.

According to Jorge Melendez, of the Universidade de São Paulo, Brazil, the leader of the team and co-author of the paper, "the quest for an Earth 2.0, and for a complete solar system 2.0, is one of the most exciting endeavors in astronomy. We are thrilled to be part of this cutting-edge research, made possible by the observational facilities provided by ESO."

Megan Bedell, from the University of Chicago and lead author of the paper, concludes: “After two decades of hunting for exoplanets, we are finally beginning to see long-period gas giant planets similar to those in our own solar system thanks to the long-term stability of planet hunting instruments like HARPS. This discovery is, in every respect, an exciting sign that other solar systems may be out there waiting to be discovered.”

Follow-up observations are needed to confirm and constrain the finding, but HIP 11915 is one of the most promising candidates so far to host a planetary system similar to our own.

From ESO

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Finding another Earth

6 min read

NASA Science Editorial Team

The discovery of a super-Earth-sized planet orbiting a Sun-like star brings us closer than ever to finding a twin of our own watery world. But NASA's Kepler space telescope has captured evidence of other potentially habitable planets amid the sea of stars in the Milky Way galaxy.

To take a brief tour of the more prominent contenders, it helps to zero in on the "habitable zone" around their stars. This is the band of congenial temperatures for planetary orbits – not too close and not too far. Too close and the planet is fried (we're looking at you, Venus). Too far and it's in deep freeze. But settle comfortably into the habitable zone, and your planet could have liquid water on its surface – just right. Goldilocks has never been more relevant. Scientists have, in fact, taken to calling this water-friendly region the "Goldilocks zone."

The zone can be a wide band or a narrow one, and nearer the star or farther, depending on the star's size and energy output. For small, red-dwarf stars, habitable zone planets might gather close, like marshmallow-roasting campers around the fire. For gigantic, hot stars, the band must retreat to a safer distance.

About a dozen habitable zone planets in the Earth-size ballpark have been discovered so far – that is, 10 to 15 planets between one-half and twice the diameter of Earth, depending on how the habitable zone is defined and allowing for uncertainties about some of the planetary sizes.

The new discovery, Kepler-452b, fires the planet hunter's imagination because it is the most similar to the Earth-Sun system found yet: a planet at the right temperature within the habitable zone, and only about one-and-a-half times the diameter of Earth, circling a star very much like our own Sun. The planet also has a good chance of being rocky, like Earth, its discoverers say.

Kepler-452b is more similar to Earth than any system previously discovered. And the timing is especially fitting: 2015 marks the 20th anniversary of the first exoplanet confirmed to be in orbit around a typical star.

But several other exoplanet discoveries came nearly as close in their similarity to Earth.

Before this, the planet Kepler-186f held the "most similar" distinction (they get the common moniker, "Kepler," because they were discovered with the Kepler space telescope). About 500 light-years from Earth, Kepler-186f is no more than 10 percent larger than Earth, and sails through its star's habitable zone, making its surface potentially watery.

But its 130-day orbit carries it around a red-dwarf star that is much cooler than our sun and only half its size. Thus, the planet is really more like an "Earth cousin," says Thomas Barclay of the Bay Area Environmental Research Institute at NASA's Ames Research Center, Moffett Field, California, a co-author of the paper announcing the discovery in April 2014.

Kepler-186f gets about one-third the energy from its star that Earth gets from our Sun. And that puts it just at the outside edge of the habitable zone. Scientists saythat if you were standing on the planet at noon, the light would look about as bright as it does on Earth an hour before sunset.

That doesn't mean the planet is bereft of life, although it doesn't mean life exists there, either.

Before Kepler-186f, Kepler-62f was the exoplanet known to be most similar to Earth. Like the new discovery, Kepler-62f is a "super Earth," about 40 percent larger than our home planet. But, like

Kepler-186f, its 267-day orbit also carries it around a star that is cooler and smaller than the Sun, some 1,200 light-years away in the constellation Lyra. Still, Kepler-62f does reside in the habitable zone.

Kepler-62f's discovery was announced in April 2013, about the same time as Kepler-69c, another super Earth – though one that is 70 percent larger than our home planet. That's the bad news; astronomers are uncertain about the planet's composition, or just when a "super Earth" becomes so large that it diminishes the chance of finding life on its surface. That also moves it farther than its competitors from the realm of a potential Earth twin. The good news is that Kepler-69c lies in its sun's habitable zone, with a 242-day orbit reminiscent of our charbroiled sister planet, Venus. Its star is also similar to ours in size with about 80 percent of the Sun's luminosity. Its planetary system is about 2,700 light-years away in the constellation Cygnus.

Kepler-22b also was hailed in its day as the most like Earth. It was the first of the Kepler planets to be found within the habitable zone, and it orbits a star much like our sun. But Kepler-22b is a sumo wrestler among super Earths, about 2.4 times Earth's size. And no one knows if it is rocky, gaseous or liquid. The planet was detected almost immediately after Kepler began making observations in 2009, and was confirmed in 2011. This planet, which could have a cloudy atmosphere, is 600 light-years away, with a 290-day orbit not unlike Earth's.

Not all the planets jostling to be most like Earth were discovered using Kepler. A super Earth known as Gliese 667Cc also came to light in 2011, discovered by astronomers combing through data from the European Southern Observatory's 3.6-meter telescope in Chile. The planet, only 22 light-years away, has a mass at least 4.5 times that of Earth. It orbits a red dwarf in the habitable zone, though closely enough – with a mere 28-day orbit – to make the planet subject to intense flares that could erupt periodically from the star's surface. Still, its sun is smaller and cooler than ours, and Gliese 667Cc's orbital distance means it probably receives around 90 percent of the energy we get from the Sun. That's a point in favor of life, if the planet's atmosphere is something like ours. The planet's true size and density remain unknown, however, which means it could still turn out to be a gas planet, hostile to life as we know it. And powerful magnetic fluxes also could mean periodic drop-offs in the amount of energy reaching the planet, by as much as 40 percent. These drop-offs could last for months, according to scientists at the University of Oslo's Institute of Theoretical Astrophysics in Norway.

Deduct two points.

Too big, too uncertain, or circling the wrong kind of star: Shuffle through the catalog of habitable zone planets, and the closest we can come to Earth – at least so far – appears to be the new kid on the interstellar block, Kepler-452b.

NASA's Ames Research Center in Moffett Field, California, manages the Kepler and K2 missions for NASA's Science Mission Directorate. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corp. operates the flight system with support from the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

JPL is managed by the California Institute of Technology for NASA.

2015-244

Written by Pat Brennan, PlanetQuest

Whitney Clavin

Jet Propulsion Laboratory, Pasadena, California

818-354-4673

whitney.clavin@jpl.nasa.gov

Climate change is rapidly reshaping a region of the world that's home to millions of people. In the next 30 years, Pacific Island nations such as Tuvalu, Kiribati, and Fiji will experience at least 6 inches (15 centimeters) of sea level rise, according to an analysis by NASA's sea level change science team. This amount […]

Arctic sea ice retreated to near-historic lows in the Northern Hemisphere this summer, likely melting to its minimum extent for the year on Sept.11, 2024, according to researchers at NASA and the National Snow and Ice Data Center (NSIDC). The decline continues the decades-long trend of shrinking and thinning ice cover in the Arctic Ocean. […]

Designed to be user-friendly, the resource contains the latest sea level data, explainers, and other information from several U.S. agencies. The U.S. Interagency Task Force on Sea Level Change launched the U.S. Sea Level Change website on Monday, Sept. 23. Designed to help communities prepare for rising seas, the site features the latest science on […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Will the real ‘first exoplanet’ please stand up?

5 min read

NASA Science Editorial Team

By Pat Brennan

Jet Propulsion Laboratory

Exoplanet hunters disagree over who made the first discovery of a world orbiting another star. The question can even inspire a bit of intercontinental rivalry, with both American and European teams laying claim to “firsts.”

The very first planetary bodies outside our solar system to be clearly identified orbit a bizarre object called a pulsar. This is the extremely dense, rapidly spinning core of a star that has died a spectacular death: blowing itself apart in a supernova explosion.

Pulsars shoot intense beams of radio waves in opposite directions as they spin, like rapidly rotating lighthouse beacons. This characteristic came in handy during early attempts to locate planets circling other stars.

By measuring changes in the pulsing beat from just such a spinning, stellar corpse, Dr. Alexander Wolszczan of Pennsylvania State University found three “pulsar planets.” The planets’ gravitational tugs altered the rhythm of the pulsar, revealing their existence by a kind of interstellar Morse code.

Wolszczan announced the discovery of two in 1992, confirming the third two years later.

Many scientists, however, say the strange circumstances that give rise to pulsar planets—not to mention the extreme environment of destructive radiation around a pulsar—make them radically different from planets orbiting still-living stars.

For the first exoplanet detection in that category, the prize goes to a Swiss team led by Michel Mayor and Didier Queloz, who announced their discovery of 51 Pegasi b on October 6, 1995. This is widely acknowledged as the first true exoplanet to be identified in orbit around a normal star, a scientific milestone that proved worthy of a 20th anniversary celebration.

Score that first of firsts for the Europeans.

But the Americans soon entered the spotlight, taking center stage and staying there throughout the early years of planet hunting. A team led out of San Francisco State University went head-to-head with their European competitors.

The team found 70 of the first 100 exoplanets in a legendary burst of planet-hunting that lasted until 2005.

Members of this team headed to the Lick Observatory, on a mountaintop near San Jose, to confirm the existence of 51 Pegasi b.

Their observations over four days matched beautifully the properties of the new planet described by the Europeans. But those properties were so strange that many scientists had difficulty believing it was really a planet.

Fifty-one Peg, as it came to be known, was half the size of Jupiter with a seemingly impossible, sun-hugging orbit: a year on the planet—the time it takes to make one orbit around its star—lasts only 4.3 Earth days.

Later observations confirmed its existence.

The US team might have won the race to find the first exoplanet—if only they'd known what was already in their possession. For months, they'd been recording observations of stars using a light-splitting device called a spectrograph to hunt for stellar wobbles. It was the same method the European team used: capturing subtle changes in starlight being stretched and squeezed as the star moved farther away and then closer to Earth in response to gravitational tugs from an orbiting planet.

They never imagined finding a big, heavy, star-hugging planet with a 4-day orbit. When Butler and the team re-examined their data, they began finding one planet after another: large, hot Jupiters that also were rapidly circling their stars.

Another "almost first" involved a Canadian team that devised the wobble technique. A 1987 press conference brought a revelation: Astronomers Gordon Walker and Bruce Campbell believed they'd found a 2.5-year wobble in the star gamma Cephei—possibly the sign of an orbiting exoplanet. But the announcement was greeted with skepticism; in 1992, Walker rewrote a paper about the discovery on the advice of a colleague, saying the wobble was likely the star's own pulsations—not the tugs of an orbiting world.

But Walker's first draft had been correct. In 2003, a Jupiter-sized planet was confirmed to be in orbit around gamma Cephei.

And an important historical footnote raises yet another claim to the real "first," though one largely dismissed at the time. In the late 1980s, astronomer Dave Latham of Harvard experimented with the same technique that other teams later used: measuring subtle stellar wobbles.

Latham saw something remarkable. A very large object was orbiting a star about 128 light years away. But while he thought it might be a planet, he and other astronomers believed that a small star or even a brown dwarf—a kind of failed star—seemed more likely. Latham's team said so in their 1989 paper announcing the discovery; the object just seemed too big and too close to its star to be anything else.

In the years that followed, however, discoveries of gigantic, star-hugging planets, now known as "hot Jupiters," began to pile up. Latham's object eventually was accepted as a planet, making it a true, if unsung, "first."

But 51 Peg still manages to retain its first-ever status, and it's all about the timing. The 1989 announcement suggested a possible planet, though its discoverers lacked enough data to be sure. Confirmation would not come until long after 51 Peg made its big splash in 1995 as the first exoplanet to be reliably identified in orbit around a normal star.

So raise a toast to this star-crisped half Jupiter, the unlikely trailblazer that opened the door to a galactic menagerie of weird worlds taking wild rides around distant stars. Welcome to the age of exoplanets.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Can planets be rejuvenated around dead stars?

4 min read

NASA Science Editorial Team

For a planet, this would be like a day at the spa. After years of growing old, a massive planet could, in theory, brighten up with a radiant, youthful glow. Rejuvenated planets, as they are nicknamed, are only hypothetical. But new research from NASA's Spitzer Space Telescope has identified one such candidate, seemingly looking billions of years younger than its actual age.

"When planets are young, they still glow with infrared light from their formation," said Michael Jura of UCLA, coauthor of a new paper on the results in the June 10 issue of the Astrophysical Journal Letters. "But as they get older and cooler, you can't see them anymore. Rejuvenated planets would be visible again."

How might a planet reclaim the essence of its youth? Years ago, astronomers predicted that some massive, Jupiter-like planets might accumulate mass from their dying stars. As stars like our sun age, they puff up into red giants and then gradually lose about half or more of their mass, shrinking into skeletons of stars, called white dwarfs. The dying stars blow winds of material outward that could fall onto giant planets that might be orbiting in the outer reaches of the star system.

Thus, a giant planet might swell in mass, and heat up due to friction felt by the falling material. This older planet, having cooled off over billions of years, would once again radiate a warm, infrared glow.

The new study describes a dead star, or white dwarf, called PG 0010+280. An undergraduate student on the project, Blake Pantoja, then at UCLA, serendipitously discovered unexpected infrared light around this star while searching through data from NASA's Wide-field Infrared Survey Explorer, or WISE. Follow-up research led them to Spitzer observations of the star, taken back in 2006, which also showed the excess of infrared light.

At first, the team thought the extra infrared light was probably coming from a disk of material around the white dwarf. In the last decade or so, more and more disks around these dead stars have been discovered -- around 40 so far. The disks are thought to have formed when asteroids wandered too close to the white dwarfs, becoming chewed up by the white dwarfs' intense, shearing gravitational forces.

Other evidence for white dwarfs shredding asteroids comes from observations of the elements in white dwarfs. White dwarfs should contain only hydrogen and helium in their atmospheres, but researchers have found signs of heavier elements -- such as oxygen, magnesium, silicon and iron -- in about 100 systems to date. The elements are thought to be leftover bits of crushed asteroids, polluting the white dwarf atmospheres.

But the Spitzer data for the white dwarf PG 0010+280 did not fit well with models for asteroid disks, leading the team to look at other possibilities. Perhaps the infrared light is coming from a companion small "failed" star, called a brown dwarf -- or more intriguingly, from a rejuvenated planet.

"I find the most exciting part of this research is that this infrared excess could potentially come from a giant planet, though we need more work to prove it," said Siyi Xu of UCLA and the European Southern Observatory in Germany. "If confirmed, it would directly tell us that some planets can survive the red giant stage of stars and be present around white dwarfs."

In the future, NASA's upcoming James Webb Space Telescope could possibly help distinguish between a glowing disk or a planet around the dead star, solving the mystery. But for now, the search for rejuvenated planets -- much like humanity's own quest for a fountain of youth -- endures.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology in Pasadena. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

For more information on Spitzer, visit:

http://spitzer.caltech.edu

http://www.nasa.gov/spitzer

Media Contact

Whitney ClavinJet Propulsion Laboratory, Pasadena, California818-354-4673whitney.clavin@jpl.nasa.gov

2015-218

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Hubble Sees a “Behemoth” Bleeding Atmosphere Around a Warm Exoplanet

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers using NASA’s Hubble Space Telescope have discovered an immense cloud of hydrogen dubbed “The Behemoth” bleeding from a planet orbiting a nearby star. The enormous, comet-like feature is about 50 times the size of the parent star. The hydrogen is evaporating from a warm, Neptune-sized planet, due to extreme radiation from the star.

This phenomenon has never been seen around an exoplanet so small. It may offer clues to how other planets with hydrogen-enveloped atmospheres could have their outer layers evaporated by their parent star, leaving behind solid, rocky cores. Hot, rocky planets such as these that roughly the size of Earth are known as Hot-Super Earths.

“This cloud is very spectacular, though the evaporation rate does not threaten the planet right now,” explains the study’s leader, David Ehrenreich of the Observatory of the University of Geneva in Switzerland. “But we know that in the past, the star, which is a faint red dwarf, was more active. This means that the planet evaporated faster during its first billion years of existence because of the strong radiation from the young star. Overall, we estimate that it may have lost up to 10 percent of its atmosphere over the past several billion years.”

The planet, named GJ 436b, is considered to be a “Warm Neptune,” because of its size and because it is much closer to its star than Neptune is to our sun. Although it is in no danger of having its atmosphere completely evaporated and stripped down to a rocky core, this planet could explain the existence of so-called Hot Super-Earths that are very close to their stars.

These hot, rocky worlds were discovered by the Convection Rotation and Planetary Transits (CoRoT) and NASA’s Kepler space telescope. Hot Super-Earths could be the remnants of more massive planets that completely lost their thick, gaseous atmospheres to the same type of evaporation.

Because the Earth’s atmosphere blocks most ultraviolet light, astronomers needed a space telescope with Hubble’s ultraviolet capability and exquisite precision to find “The Behemoth.”

“You would have to have Hubble’s eyes,” says Ehrenreich. “You would not see it in visible wavelengths. But when you turn the ultraviolet eye of Hubble onto the system, it’s really kind of a transformation, because the planet turns into a monstrous thing.”

Because the planet’s orbit is tilted nearly edge-on to our view from Earth, the planet can be seen passing in front of its star. Astronomers also saw the star eclipsed by ”The Behemoth” hydrogen cloud around the planet.

Ehrenreich and his team think that such a huge cloud of gas can exist around this planet because the cloud is not rapidly heated and swept away by the radiation pressure from the relatively cool red dwarf star. This allows the cloud to stick around for a longer time. The team’s findings will be published in the June 25 edition of the journal Nature.

Evaporation such as this may have happened in the earlier stages of our own solar system, when the Earth had a hydrogen-rich atmosphere that dissipated over 100 to 500 million years. If so, the

Earth may previously have sported a comet-like tail.

GJ 436b resides very close to its star – less than 2 million miles — and whips around it in just 2.6 Earth days. In comparison, the Earth is 93 million miles from our sun and orbits it every 365.24 days. This exoplanet is at least 6 billion years old, and may even be twice that age. It has a mass of around 23 Earths. At just 30 light-years from Earth, it's one of the closest known extrasolar planets.

Finding "The Behemoth" could be a game-changer for characterizing atmospheres of the whole population of Neptune-sized planets and Super-Earths in ultraviolet observations. In the coming years, Ehrenreich expects that astronomers will find thousands of this kind of planet.

The ultraviolet technique used in this study also may also spot the signature of oceans evaporating on smaller, more Earth-like planets. It will be extremely challenging for astronomers to directly see water vapor on those worlds, because it's too low in the atmosphere and shielded from telescopes. However, when water molecules are broken by the stellar radiation into hydrogen and oxygen, the relatively light hydrogen atoms can escape the planet. If scientists spot this hydrogen evaporating from a planet that is slightly more temperate and less massive than GJ 436b, it could be an indication of an ocean on the surface.

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, in Washington.

For images and more information about Hubble, visit:

www.nasa.gov/hubble

hubblesite.org/news/2015/17

Contacts:

Felicia Chou

Headquarters, Washington

202-358-0257

felicia.chou@nasa.gov

Ann Jenkins / Ray Villard

Space Telescope Science Institute, Baltimore, Maryland

410-338-4488 / 410-338-4514

jenkins@stsci.edu / villard@stsci.edu

Scientists and engineers tested NASA's LEMS (Lunar Environment Monitoring Station) instrument suite in a "sandbox" of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New NASA Supercomputer Model Shows Planet Making Waves in Nearby Debris Disk

5 min read

A new NASA supercomputer simulation of the planet and debris disk around the nearby star Beta Pictoris reveals that the planet's motion drives spiral waves throughout the disk, a phenomenon that causes collisions among the orbiting debris. Patterns in the collisions and the resulting dust appear to account for many observed features that previous research has been unable to fully explain.

"We essentially created a virtual Beta Pictoris in the computer and watched it evolve over millions of years," said Erika Nesvold, an astrophysicist at the University of Maryland, Baltimore County, who co-developed the simulation. "This is the first full 3-D model of a debris disk where we can watch the development of asymmetric features formed by planets, like warps and eccentric rings, and also track collisions among the particles at the same time."

In 1984, Beta Pictoris became the second star known to be surrounded by a bright disk of dust and debris. Located only 63 light-years away, Beta Pictoris is an estimated 21 million years old, or less than 1 percent the age of our solar system. It offers astronomers a front-row seat to the evolution of a young planetary system and it remains one of the closest, youngest and best-studied examples today. The disk, which we see edge on, contains rock and ice fragments ranging in size from objects larger than houses to grains as small as smoke particles. It's a younger version of the Kuiper belt at the fringes of our own planetary system.

Nesvold and her colleague Marc Kuchner, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, presented the findings Thursday during the "In the Spirit of Lyot 2015" conference in Montreal, which focuses on the direct detection of planets and disks around distant stars. A paper describing the research has been submitted to The Astrophysical Journal.

In 2009, astronomers confirmed the existence of Beta Pictoris b, a planet with an estimated mass of about nine times Jupiter's, in the debris disk around Beta Pictoris. Traveling along a tilted and slightly elongated 20-year orbit, the planet stays about as far away from its star as Saturn does from our sun.

Astronomers have struggled to explain various features seen in the disk, including a warp apparent at submillimeter wavelengths, an X-shaped pattern visible in scattered light, and vast clumps of carbon monoxide gas. A common ingredient in comets, carbon monoxide molecules are destroyed by ultraviolet starlight in a few hundred years. To explain why the gas is clumped, previous researchers suggested the clumps could be evidence of icy debris being corralled by a second as-yet-unseen planet, resulting in an unusually high number of collisions that produce carbon monoxide. Or perhaps the gas was the aftermath of an extraordinary crash of icy worlds as large as Mars.

"Our simulation suggests many of these features can be readily explained by a pair of colliding spiral waves excited in the disk by the motion and gravity of Beta Pictoris b," Kuchner said. "Much like someone doing a cannonball in a swimming pool, the planet drove huge changes in the debris disk once it reached its present orbit."

Keeping tabs on thousands of fragmenting particles over millions of years is a computationally difficult task. Existing models either weren't stable over a sufficiently long time or contained approximations that could mask some of the structure Nesvold and Kuchner were looking for.

Working with Margaret Pan and Hanno Rein, both now at the University of Toronto, they developed a method where each particle in the simulation represents a cluster of bodies with a range of sizes and similar motions. By tracking how these “superparticles” interact, they could see how collisions among trillions of fragments produce dust and, combined with other forces in the disk, shape it into the kinds of patterns seen by telescopes. The technique, called the Superparticle-Method Algorithm for Collisions in Kuiper belts (SMACK), also greatly reduces the time required to run such a complex computation.

Using the Discover supercomputer operated by the NASA Center for Climate Simulation at Goddard, the SMACK-driven Beta Pictoris model ran for 11 days and tracked the evolution of 100,000 superparticles over the lifetime of the disk.

As the planet moves along its tilted path, it passes vertically through the disk twice each orbit. Its gravity excites a vertical spiral wave in the disk. Debris concentrates in the crests and troughs of the waves and collides most often there, which explains the X-shaped pattern seen in the dust and may help explain the carbon monoxide clumps.

The planet’s orbit also is slightly eccentric, which means its distance from the star varies a little every orbit. This motion stirs up the debris and drives a second spiral wave across the face of the disk. This wave increases collisions in the inner regions of the disk, which removes larger fragments by grinding them away. In the real disk, astronomers report a similar clearing out of large debris close to the star.

“One of the nagging questions about Beta Pictoris is how the planet ended up in such an odd orbit,” Nesvold explained. “Our simulation suggests it arrived there about 10 million years ago, possibly after interacting with other planets orbiting the star that we haven’t detected yet.”

Related Links

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Finding out what makes hot Jupiters tick

2 min read

NASA Science Editorial Team

From Michelle Moyer, NASA Ames Research Center

In the two decades since the first exoplanets were found in the mid-1990s, astronomers have discovered nearly 2,000 planets outside our solar system. Many of these are known as "hot Jupiters," planets that are similar in size to Jupiter but are much closer to their host stars, and therefore have faster orbits and much hotter surface temperatures.

To learn more about the interior dynamics of hot Jupiter exoplanets and their stars, astrophysicist Tamara Rogers and her team at the University of Arizona's Lunar and Planetary Laboratory ran a series of groundbreaking simulations on the Pleiades supercomputer, located at the NASA Advanced Supercomputing (NAS) facility at Ames Research Center.

"Modeling and simulation on high-performance computers are very effective tools for researching the dynamical processes that occur within stars and planets," said Rogers, now a lecturer at Newcastle University in the U.K. "Understanding these phenomena can help us learn how hot Jupiters formed and how they affect the evolution of planetary systems."

The team's simulations of hot Jupiters—which were the first to include magnetic fields—along with their massive star simulations, can help astronomers interpret data collected from space-based observatories like NASA's Kepler, Spitzer, and Hubble telescopes. For example, the team's findings may help explain some puzzling observations, such as why planets circling cool stars tend to have orbits that align with the star's spin direction while those around hot stars often have misaligned orbits; and why many hot Jupiters are bigger and less dense than expected given their mass, even accounting for their extreme temperatures. The simulation results also reveal how magnetic effects can influence winds on these planets, a finding that could provide a method for estimating the planets' magnetic fields based on observations of their atmospheres.

By studying hot Jupiters, so different from the gas giants that slowly circle our own Sun, astronomers are expanding their knowledge of planetary structure and evolution—research that is crucial to the search for rocky, Earth-like exoplanets that may support life.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Living color: life on other worlds

4 min read

NASA Science Editorial Team

From Peter Kelley, University of Washington

To find life in the universe, it helps to know what it might look like. If there are organisms on other planets that do not rely wholly on photosynthesis — as some on Earth do not — how might those worlds appear from light-years away?

That's among the questions University of Washington doctoral student Edward Schwieterman and astronomer Victoria Meadows of the UW-based, interdisciplinary Virtual Planetary Laboratory sought to answer in research published in May in the journal Astrobiology.

Using computer simulations, the researchers found that if organisms with nonphotosynthetic pigments — those that process light for tasks other than energy production — cover enough of a distant planet's surface, their spectral signal could be strong enough to be detected by powerful future telescopes now being designed. The knowledge could add a new perspective to the hunt for life beyond Earth.

Such organisms "will produce reflectance, or brightness, signatures different than those of land vegetation like trees," said lead author Schwieterman. "This could push us to broaden our conception of what surface biosignatures might look like" on an exoplanet, or world beyond our solar system.

He said the research grew from a meeting with co-author Charles Cockell of the UK Centre for Astrobiology in 2012. Schwieterman sought a topic for a research rotation in the UW Astrobiology program in which students do work outside their main field of study.

"I was interested in doing biology in the lab and linking it to remotely detectable biosignatures, which are indications there is life on a planet based on observations that could be made from a space-based telescope or large ground-based telescope," Schwieterman said.

There had already been literature about looking for something akin to Earth's vegetation "red edge" as a possible biosignature on exoplanets, he said. The red edge — caused by oxygen-producing organisms such as trees — is the increase in brightness when you move from the visible wavelength range to the infrared, or light too red to see. It's why foliage looks bright in infrared photography and is often used to map vegetation cover by Earth-observing satellites.

Schwieterman and Cockell, a University of Edinburgh astrobiologist, decided to look further, and measure the reflectance of Earthly organisms with different kinds of pigments. They included those that do not rely on photosynthesis to see what biosignatures they produce and how those might differ from photosynthetic organisms — or indeed from nonliving surface features like rocks and minerals.

Pigments that absorb light are helpful to Earthly organisms in ways other than just producing energy. Some protect against the sun's radiation or have antioxidants to help the organism survive extreme environments such as salt concentrations, high temperatures or acidity. There are even photosynthetic pigments that do not produce oxygen at all.

Schwieterman and Meadows then plugged their results Virtual Planetary Laboratory spectral models — which include the effects of the atmosphere and clouds — to simulate hypothetical planets with surfaces covered to varying degrees with such organisms.

“With those models we could determine the potential detectability of those signatures,” he said.

Exoplanets are much too far away to observe in any detail; even near-future telescopes will deliver light from such distant targets condensed to a single pixel. So even a strong signal of nonphotosynthetic pigments would be seen at best only in the “disk average,” or average planetary brightness in the electromagnetic spectrum, Schwieterman said.

“This broader perspective might allow us to pick up on something we might have missed or offer an additional piece of evidence, in conjunction with a gaseous biosignature like oxygen, for example, that a planet is inhabited,” Schwieterman said.

The UW-based planetary lab has a growing database of spectra and pigments of nonphotosynthetic organisms and more that is available to the public, and to which data from this project have been added.

Schwieterman said much work remains to catalog the range of spectral features that life on Earth produces and also to quantify how much of a planetary surface could conceivably be covered with pigmented organisms of any type.

“We also need to think about what kinds of adaptations might exist on other worlds that don’t exist on Earth — and what that means for the interaction of those possible extraterrestrial organisms with their light environments.”

The research was funded by a grant from the NASA Astrobiology Institute.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Hubble Telescope Detects ‘Sunscreen’ Layer on Distant Planet

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA’s Hubble Space Telescope has detected a stratosphere, one of the primary layers of Earth’s atmosphere, on a massive and blazing-hot exoplanet known as WASP-33b.

The presence of a stratosphere can provide clues about the composition of a planet and how it formed. This atmospheric layer includes molecules that absorb ultraviolet and visible light, acting as a kind of “sunscreen” for the planet it surrounds. Until now, scientists were uncertain whether these molecules would be found in the atmospheres of large, extremely hot planets in other star systems.

These findings will appear in the June 12 issue of the Astrophysical Journal.

“Some of these planets are so hot in their upper atmospheres, they’re essentially boiling off into space,” said Avi Mandell, a planetary scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and a co-author of the study. “At these temperatures, we don’t necessarily expect to find an atmosphere that has molecules that can lead to these multilayered structures.”

In Earth’s atmosphere, the stratosphere sits above the troposphere -- the turbulent, active-weather region that reaches from the ground to the altitude where nearly all clouds top out. In the troposphere, the temperature is warmer at the bottom – ground level – and cools down at higher altitudes.

The stratosphere is just the opposite. In this layer, the temperature increases with altitude, a phenomenon called temperature inversion. On Earth, temperature inversion occurs because ozone in the stratosphere absorbs much of the sun’s ultraviolet radiation, preventing it from reaching the surface, protecting the biosphere, and therefore warming the stratosphere instead.

Similar temperature inversions occur in the stratospheres of other planets in our solar system, such as Jupiter and Saturn. In these cases, the culprit is a different group of molecules called hydrocarbons. Neither ozone nor hydrocarbons, however, could survive at the high temperatures of most known exoplanets, which are planets outside our solar system. This leads to a debate as to whether stratospheres would exist on them at all.

Using Hubble, the researchers have settled this debate by identifying a temperature inversion in the atmosphere of WASP-33b, which has about four-and-a-half times the mass of Jupiter. Team members also think they know which molecule in WASP-33b’s atmosphere caused the inversion -- titanium oxide.

“These two lines of evidence together make a very convincing case that we have detected a stratosphere on an exoplanet,” said Korey Haynes, lead author of the study. Haynes was a graduate student at George Mason University in Fairfax, Virginia, and was working at Goddard with Mandell when the research was conducted.

The researchers analyzed observations made with Hubble’s Wide Field Camera 3 by co-author Drake Deming at the University of Maryland in College Park. Wide Field Camera 3 can capture a spectrum of the near-infrared region where the signature for water appears. Scientists can use the spectrum to identify water and other gases in a distant planet’s atmosphere and determine its temperature.

Haynes and her colleagues used the Hubble observations, and data from previous studies, to measure emission from water and compare it to emission from gas deeper in the atmosphere. The team determined that emission from water was produced in the stratosphere at about 6,000 degrees Fahrenheit. The rest of the emission came from gas lower in the atmosphere that was at a temperature about 3,000 degrees Fahrenheit.

The team also presented the first observational evidence that WASP-33b’s atmosphere contains titanium oxide, one of only a few compounds that is a strong absorber of visible and ultraviolet radiation and capable of remaining in gaseous form in an atmosphere as hot as this one.

“Understanding the links between stratospheres and chemical compositions is critical to studying atmospheric processes in exoplanets,” said co-author Nikku Madhusudhan of the University of Cambridge, United Kingdom. “Our finding marks a key breakthrough in this direction.”

For images and more information about Hubble, visit:

http://www.nasa.gov/hubble

-end-

Contact:

Felicia ChouHeadquarters, Washington202-358-0257felicia.chou@nasa.gov

Nancy Neal-Jones / Elizabeth ZubritskyGoddard Space Flight Center, Greenbelt, Md.301-286-0039 / 301-614-5438nancy.n.jones@nasa.gov / elizabeth.a.zubritsky@nasa.gov

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

Possible European Space Agency mission: surveying 500 exoplanet atmospheres

2 min read

NASA Science Editorial Team

From ESA

Exoplanets, plasma physics and the X-ray Universe are the topics chosen by ESA to be considered for the fourth medium-class mission in its Cosmic Vision science program, for launch in 2025.

Following the recommendation by a peer review committee, Alvaro Giménez, Director of Science and Robotic Exploration, decided that three candidate concepts submitted to its ‘M4’ mission call will be studied further: the Atmospheric Remote-Sensing Infrared Exoplanet Large-survey (Ariel), the Turbulence Heating ObserveR (Thor) and the X-ray Imaging Polarimetry Explorer (Xipe).

“The selection of these three exciting mission concepts for study is an important step in the continuation of ESA’s long-term presence in space,” says Professor Giménez.

“The three proposals each offer the chance to tackle some of the major outstanding scientific questions about our place in the Universe.”

Ariel would analyze the atmospheres of around 500 planets orbiting close to nearby stars, to determine their chemical composition and physical conditions. The results would help scientists better understand planet formation, putting our own Solar System in context.

Thor would address a fundamental problem in space plasma physics concerned with the heating of plasma and the subsequent dissipation of energy. Planned to orbit Earth, its studies would include the interaction of the solar wind with Earth’s magnetic field.

The investigation would shed light on the underlying physical mechanisms of plasma behavior under turbulent conditions, in order to understand a key interaction between planets and their host stars.

Xipe would study X-ray emissions from high-energy sources such as supernovas, galaxy jets, black holes and neutron stars, to discover more about the behavior of matter under extreme conditions.

It would be the first observatory sensitive enough to make high-resolution measurements of the polarization of these sources, opening a new window into the high-energy Universe.

The three mission concepts were chosen from 27 proposals that were submitted in response to the mission call made by ESA to the scientific community last year.

After a study period aimed at making a detailed technical and scientific definition of the three concepts, one mission will be selected to fill the fourth medium-class (M4) opportunity in ESA’s Cosmic Vision 2015–2025 Plan, for launch in 2025.

Solar Orbiter, Euclid, and PLATO have already been selected as medium-class missions and are scheduled for launch in 2018, 2020 and 2024 respectively.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s

other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble in ‘Oh Planet, What Art Thou?’ 25th Anniversary Video

3 min read

NASA Hubble Mission Team

Goddard Space Flight Center

"Oh Planet, What Art Thou?" is the sixth video in a series celebrating Hubble's 25th anniversary this year.

The video explains how Hubble has helped scientists study exoplanets, or planets outside our solar system, as never before.

When Hubble was launched in 1990, the only planets we knew about were those orbiting our own sun. Since then, astronomers using both space-based telescopes such as NASA’s Kepler observatory and ground-based telescopes, have discovered a rapidly-growing number of so-called exoplanets around other stars.

"One main way we have found planets is by the transit technique," said Sara Seager, Professor of Planetary Science and Professor of Physics at the Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts. "That is when a planet goes in front of its parent star as seen from the telescope. The observed starlight drops by a tiny amount, by 1 percent or even less. And by measuring a star’s brightness. Minute-by-minute or hour–by-hour or day by day, we are able to spot a planet transit."

With Hubble, scientists can go beyond measuring basic properties of transiting planets, like their mass and their size, to actually studying their atmospheric composition. They do that using spectroscopy. The light from a star with a transiting planet is spread out by Hubble’s spectrographs into its constituent colors, or wavelengths. Some of this starlight will have passed through the outer atmosphere of the exoplanet. Scientists look for places in the color spectrum where light is missing, absorbed by gases in the atmosphere. Each gas has its own distinct set of lines it removes from the starlight spectrum, so particular gases in the planet’s atmosphere can be identified. With this technique, astronomers have identified sodium, nitrogen, hydrogen, and even water vapor in various exoplanetary systems.

The Wide Field Camera 3 (WFC3) is being used to study abundance of water vapor in the atmosphere of exoplanets. WFC3 is also used to study how temperatures change in the profile (different heights) of an exoplanet's atmosphere.

Studying the chemical makeup of an exoplanet may help find answers to the question of where life could exist elsewhere in the cosmos.

"I’d say my dream is to start my career as an astronomer and end it as a biologist," said Dave Charbonneau, Professor of Astronomy at Harvard University. "So what I would really like to do is get at the question of life in the universe."

The "Hubble 25th Anniversary" video series is produced by the Space Telescope Science Institute (STScI), Baltimore, which manages Hubble on behalf of NASA.

Related Links

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Helium-shrouded planets may be common in our galaxy

4 min read

NASA Science Editorial Team

From JPL

They wouldn't float like balloons or give you the chance to talk in high, squeaky voices, but planets with helium skies may constitute an exotic planetary class in our Milky Way galaxy. Researchers using data from NASA's Spitzer Space Telescope propose that warm Neptune-size planets with clouds of helium may be strewn about the galaxy by the thousands.

"We don't have any planets like this in our own solar system," said Renyu Hu, NASA Hubble Fellow at the agency's Jet Propulsion Laboratory in Pasadena, California, and lead author of a new study on the findings accepted for publication in the Astrophysical Journal. "But we think planets with helium atmospheres could be common around other stars."

Prior to the study, astronomers had been investigating a surprising number of so-called warm Neptunes in our galaxy. NASA's Kepler space telescope has found hundreds of candidate planets that fall into this category. They are the size of Neptune or smaller, with tight orbits that are closer to their stars than our own sizzling Mercury is to our sun. These planets reach temperatures of more than 1,340 degrees Fahrenheit (1,000 Kelvin), and orbit their stars in as little as one or two days.

In the new study, Hu and his team make the case that some warm Neptunes -- and warm sub-Neptunes, which are smaller than Neptune -- could have atmospheres enriched with helium. They say that the close proximity of these planets to their searing stars would cause the hydrogen in their atmospheres to boil off.

"Hydrogen is four times lighter than helium, so it would slowly disappear from the planets' atmospheres, causing them to become more concentrated with helium over time," said Hu. "The process would be gradual, taking up to 10 billion years to complete." For reference, our planet Earth is about 4.5 billion years old.

Warm Neptunes are thought to have either rocky or liquid cores, surrounded by gas. If helium is indeed the dominant component in their atmospheres, the planets would appear white or gray. By contrast, the Neptune of our own solar system is a brilliant azure blue. The methane in its atmosphere absorbs the color red, giving Neptune its blue hue.

A lack of methane in one particular warm Neptune, called GJ-436 b, is in fact what led Hu and his team to develop their helium planet theory. Spitzer had previously observed GJ-436 b, located 33 light-years away, and found evidence for carbon but not methane. This was puzzling to scientists, because methane molecules are made of one carbon and four hydrogen atoms, and planets like this are expected to have a lot of hydrogen. Why wasn't the hydrogen linking up with carbon to produce methane?

According to the new study, the hydrogen might have been slow-cooked off the planet by radiation from the host stars. With less hydrogen around, the carbon would pair up with oxygen to make carbon monoxide. In fact, Spitzer found evidence for a predominance of carbon monoxide in the atmosphere of GJ-436 b.

The next step to test this theory is to look at other warm Neptunes for signs of carbon monoxide and carbon dioxide, which are indicators of helium atmospheres. The team says this might be possible with the help of NASA's Hubble Space Telescope, and NASA's upcoming James Webb Space Telescope may one day directly detect that helium.

Meanwhile, the wacky world of exoplanets continues to surprise astronomers.

"Any planet one can imagine probably exists, out there, somewhere, as long as it fits within the laws of physics and chemistry," said co-author Sara Seager of the Massachusetts Institute of Technology in Cambridge and JPL. "Planets are so incredibly diverse in their masses, sizes and orbits that we expect this to extend to exoplanet atmospheres."

A third author of the paper is Yuk Yung of the California Institute of Technology in Pasadena and JPL.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology in Pasadena. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Our Sun Came Late to the Milky Way's Star-Birth Party

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

In one of the most comprehensive multi-observatory galaxy surveys yet, astronomers find that galaxies like our Milky Way underwent a stellar "baby boom," churning out stars at a prodigious rate, about 30 times faster than today.

Our sun, however, is a late "boomer." The Milky Way's star-birthing frenzy peaked 10 billion years ago, but our sun was late for the party, not forming until roughly 5 billion years ago. By that time the star formation rate in our galaxy had plunged to a trickle.

Missing the party, however, may not have been so bad. The sun's late appearance may actually have fostered the growth of our solar system's planets. Elements heavier than hydrogen and helium were more abundant later in the star-forming boom as more massive stars ended their lives early and enriched the galaxy with material that served as the building blocks of planets and even life on Earth.

Astronomers don't have baby pictures of our Milky Way's formative years to trace the history of stellar growth so they studied galaxies similar in mass to our Milky Way, found in deep surveys of the universe. The farther into the universe astronomers look, the further back in time they are seeing, because starlight from long ago is just arriving at Earth now. From those surveys, stretching back in time more than 10 billion years, researchers assembled an album of images containing nearly 2,000 snapshots of Milky Way-like galaxies.

The new census provides the most complete picture yet of how galaxies like the Milky Way grew over the past 10 billion years into today's majestic spiral galaxies. The multi-wavelength study spans ultraviolet to far-infrared light, combining observations from NASA's Hubble and Spitzer space telescopes, the European Space Agency's Herschel Space Observatory, and ground-based telescopes, including the Magellan Baade Telescope at the Las Campanas Observatory in Chile.

"This study allows us to see what the Milky Way may have looked like in the past," said Casey Papovich of Texas A&M; University in College Station, lead author on the paper that describes the study's results. "It shows that these galaxies underwent a big change in the mass of its stars over the past 10 billion years, bulking up by a factor of 10, which confirms theories about their growth. And most of that stellar-mass growth happened within the first 5 billion years of their birth."

The new analysis reinforces earlier research which showed that Milky Way-like galaxies began as small clumps of stars. The galaxies swallowed large amounts of gas that ignited a firestorm of star birth.

The study reveals a strong correlation between the galaxies' star formation and growth in stellar mass. So, when the galaxies slow down making stars, their growth decreases as well. "I think the evidence suggests that we can account for the majority of the buildup of a Milky Way-like galaxy through its star formation," Papovich said. "When we calculate the star-formation rate of a Milky Way-like galaxy in the past and add up all the stars it would have produced, it is pretty consistent with the mass growth we expected. To me, that means we're able to understand the growth of the 'average' galaxy with the mass of a Milky Way galaxy."

The astronomers selected the Milky Way-like progenitors by sifting through more than 24,000 galaxies in the entire catalogs of the Cosmic Assembly Near-infrared Deep Extragalactic Legacy Survey (CANDELS), taken with Hubble, and the FourStar Galaxy Evolution Survey (ZFOURGE), made with the Magellan telescope.

They used the ZFOURGE, CANDELS, and Spitzer near-infrared data to study the galaxy stellar masses. The Hubble images from the CANDELS survey also provided structural information about galaxy sizes and how they evolved. Far-infrared light observations from Spitzer and Herschel helped the astronomers trace the star-formation rate.

The team’s results will appear in the April 9 issue of The Astrophysical Journal.

For images and more information about the Hubble Space Telescope, visit:
http://www.nasa.gov/hubble or http://hubblesite.org/news/2015/11

Contacts:

Donna WeaverSpace Telescope Science Institute, Baltimore, Maryland410-338-4493

Earth-like planets more likely around Sun-like stars than red dwarfs

5 min read

NASA Science Editorial Team

From: Tokyo Institute of Technology

Simulations by researchers at Tokyo Institute of Technology and Tsinghua University indicate that Earth-like planets are more likely to be found orbiting Sun-like stars rather than lower-mass stars that are currently targeted, in terms of water contents of planets.

The search for habitable planets currently focuses on so-called M dwarfs - stars with less than half the mass of the Sun. These stars are thought to have more habitable orbiting planets that are easier to find compared with G dwarfs - stars that have a similar mass to the Sun. However, according to recent simulations by a collaborative research team composed of Shigeru Ida at Tokyo Tech and Feng Tian at Tsinghua University, M dwarf systems may not be the best places to look.

For planets to be habitable, they must orbit stars within the 'habitable zone' where it is not too hot or too cold. In addition, recent studies on habitability of planets suggest that the water-land ratio must be similar to the Earth. That is, the water mass fraction should not be far from that of the Earth's (~0.01wt%): planets with too much water (> 1 wt%)-"ocean planets"-lead to an unstable climate and lack of nutrient supply; and water-poor planets like Venus -"dune planets"-become too arid for inhabiting.

Whereas G dwarfs - stars with the mass of our Sun - keep almost constant luminosity during the 'pre-main sequence' of their evolution, the luminosity of M dwarfs decreases by more than an order of magnitude during this stage. This means that planets with the right amount of water at the right distance from M stars may become too arid from over-exposure during the higher-luminosity early pre-main sequence period, while ocean planets retain their large amount of water.

Ida and Tian simulated planet distributions around stars with 0.3, 0.5 and 1.0 times the mass of the Sun. They then applied a model for water loss and accounted for the change in luminosity. They found that Earth-mass planets with Earth-like water contents occur 10-100 times less frequently around M dwarfs than around G dwarfs. They conclude, "We suggest that stars close to the size of the Sun should be the primary targets for detecting Earth-like planets."

Planetary formation simulations

Planets are understood to form alongside stars. As matter condenses under gravity to form the star, the surrounding circulating matter begins to flatten into a protoplanetary disk, a little like a spun clump of dough flattening to form a pizza base. Matter in this disk coalesces to form planets.

Several complex and competing processes are in play during planetary formation. The initial mass of the coalescing planet, the distribution of material feeding into the formation of stars and surrounding systems, density, star luminosity, orbit and potential collisions are all factors that affect planetary formation and the final characteristics of the planet formed.

Models incorporating the various factors have been developed, tested against observations and augmented, making it possible to simulate the planetary bodies likely to form and their characteristics. However until this study nobody had modeled how the change in luminosity of M stars might affect the surface water content of planets in the habitable zone.

Planetary observations

As well as simulations there are a number of projects and facilities to provide data on real planets and their characteristics. Bulk density measurements and multiband spectral data allow planets with Earth-like water contents to be distinguished from ocean or dune planets by future observations.

Of the stars observed within 30 light years of the Sun, 60% are less than 0.3 the mass of the Sun, 35% are between 0.3 and 1 solar masses and 20% are between 0.6 and 1 solar mass. Missions and facilities that will be used in the search for Earth like planets around nearby stars over the next ten years include TESS and Plato.

Planetary simulation results

The simulations by Ida and Tian indicated that for 1000 stars of 0.3 solar masses there might be 69,000 orbiting planetary bodies, of which 5,000 had a similar mass to the Earth and 55 were in the habitable zone. Those in the habitable zone included 31 ocean planets. 23 dune planets and just 1 with Earth-like water content.

For 1000 stars with half the mass of the Sun the simulation produced 75,000 planetary bodies, of which more than 9000 had Earth-like masses, and 292 were in the habitable zone: 60 ocean planets; 220 dune planets and 12 with Earth-like water content.

Finally for 1000 simulated stars with a similar mass to the Sun, there were 38,000 planetary bodies, 8,000 with Earth-like masses and 407 in the inhabitable zone. Those in the habitable zone included 91 ocean planets and 45 dune planets, but 271 - the vast majority - had Earth-like water content.

Although the detailed numbers in the statistics are not important, Ida and Tian highlight the contrast in the fraction of planets in the habitable zones having Earth-like water content between Sun-like stars and lower-mass stars is significant. At the same time, they caveat that further studies are needed to determine how efficiently water is retained in the mantle, as well as the evolution of its release to the surface.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Small Planets, Circular Orbits: a Better Chance for Life

6 min read

NASA Science Editorial Team

From MIT

Viewed from above, our solar system's planetary orbits around the sun resemble rings around a bulls-eye. Each planet, including Earth, keeps to a roughly circular path, always maintaining the same distance from the sun.

For decades, astronomers have wondered whether the solar system's circular orbits might be a rarity in our universe. Now a new analysis suggests that such orbital regularity is instead the norm, at least for systems with planets as small as Earth.

In a paper published in the Astrophysical Journal, researchers from MIT and Aarhus University in Denmark report that 74 exoplanets, located hundreds of light-years away, orbit their respective stars in circular patterns, much like the planets of our solar system.

These 74 exoplanets, which orbit 28 stars, are about the size of Earth, and their circular trajectories stand in stark contrast to those of more massive exoplanets, some of which come extremely close to their stars before hurtling far out in highly eccentric, elongated orbits.

“Twenty years ago, we only knew about our solar system, and everything was circular and so everyone expected circular orbits everywhere,” says Vincent Van Eylen, a visiting graduate student in MIT's Department of Physics. “Then we started finding giant exoplanets, and we found suddenly a whole range of eccentricities, so there was an open question about whether this would also hold for smaller planets. We find that for small planets, circular is probably the norm.”

Ultimately, Van Eylen says that's good news in the search for life elsewhere. Among other requirements, for a planet to be habitable, it would have to be about the size of Earth — small and compact enough to be made of rock, not gas. If a small planet also maintained a circular orbit, it would be even more hospitable to life, as it would support a stable climate year-round. (In contrast, a planet with a more eccentric orbit might experience dramatic swings in climate as it orbited close in, then far out from its star.)

“If eccentric orbits are common for habitable planets, that would be quite a worry for life, because they would have such a large range of climate properties,” Van Eylen says. “But what we find is, probably we don't have to worry too much because circular cases are fairly common.”

In the past, researchers have calculated the orbital eccentricities of large, “gas giant” exoplanets using radial velocity — a technique that measures a star's movement. As a planet orbits a star, its gravitational force will tug on the star, causing it to move in a pattern that reflects the planet's orbit. However, the technique is most successful for larger planets, as they exert enough gravitational pull to influence their stars.

Researchers commonly find smaller planets by using a transit-detecting method, in which they study the light given off by a star, in search of dips in starlight that signify when a planet crosses, or “transits,” in front of that star, momentarily diminishing its light. Ordinarily, this method only illuminates a planet's existence, not its orbit. But Van Eylen and his colleague Simon Albrecht, of Aarhus University, devised a way to glean orbital information from stellar transit data.

They first reasoned that if they knew the mass and radius of a planet's star, they could calculate how long a planet would take to orbit that star, if its orbit were circular. The mass and radius of a star determines its gravitational pull, which in turn influences how fast a planet travels around the star.

By calculating a planet's orbital velocity in a circular orbit, they could then estimate a transit's duration — how long a planet would take to cross in front of a star. If the calculated transit matched an actual transit, the researchers reasoned that the planet's orbit must be circular. If the transit were longer or shorter, the orbit must be more elongated, or eccentric.

To obtain actual transit data, the team looked through data collected over the past four years by NASA's Kepler telescope — a space observatory that surveys a slice of the sky in search of habitable planets. The telescope has monitored the brightness of over 145,000 stars, only a fraction of which have been characterized in any detail.

The team chose to concentrate on 28 stars for which mass and radius have previously been measured, using asteroseismology — a technique that measures stellar pulsations, which reflect a star's mass and radius.

These 28 stars host multiplanet systems — 74 exoplanets in all. The researchers obtained Kepler data for each exoplanet, looking not only for the occurrence of transits, but also their duration. Given the mass and radius of the host stars, the team calculated each planet's transit duration if its orbit were circular, then compared the estimated transit durations with actual transit durations from Kepler data.

Across the board, Van Eylen and Albrecht found the calculated and actual transit durations matched, suggesting that all 74 exoplanets maintain circular, not eccentric, orbits.

"We found that most of them matched pretty closely, which means they're pretty close to being circular," Van Eylen says. "We are very certain that if very high eccentricities were common, we would've seen that, which we don't."

Van Eylen says the orbital results for these smaller planets may eventually help to explain why larger planets have more extreme orbits.

"We want to understand why some exoplanets have extremely eccentric orbits, while in other cases, such as the solar system, planets orbit mostly circularly," Van Eylen says. "This is one of the first times we've reliably measured the eccentricities of small planets, and it's exciting to see they are different from the giant planets, but similar to the solar system."

David Kipping, an astronomer at the Harvard-Smithsonian Center for Astrophysics, notes that Van Eylen's sample of 74 exoplanets is a relatively small slice, considering the hundreds of thousands of stars in the sky.

"I think that the evidence for smaller planets having more circular orbits is presently tentative," says Kipping, who was not involved in the research. "It prompts us to investigate this question in more detail and see whether this is indeed a universal trend, or a feature of the small sample considered."

In regard to our own solar system, Kipping speculates that with a larger sample of planetary systems, "one might investigate eccentricity as a function of multiplicity, and see whether the solar system's eight planets are typical or not."

This research was funded in part by the European Research Council.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing.

Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

1k for Kepler

4 min read

NASA Science Editorial Team

How many stars like our sun host planets like our Earth? NASA's Kepler Space Telescope continuously monitored more than 150,000 stars beyond our solar system, and to date has offered scientists an assortment of more than 4,000 candidate planets for further study -- the 1,000th of which was recently verified.

Using Kepler data, scientists reached this millenary milestone after validating that eight more candidates spotted by the planet-hunting telescope are, in fact, planets. The Kepler team also has added another 554 candidates to the roll of potential planets, six of which are near-Earth-size and orbit in the habitable zone of stars similar to our sun.

Three of the newly-validated planets are located in their distant suns' habitable zone, the range of distances from the host star where liquid water might exist on the surface of an orbiting planet. Of the three, two are likely made of rock, like Earth.

"Each result from the planet-hunting Kepler mission's treasure trove of data takes us another step closer to answering the question of whether we are alone in the universe," said John Grunsfeld, associate administrator of NASA's Science Mission Directorate at the agency's headquarters in Washington. "The Kepler team and its science community continue to produce impressive results with the data from this venerable explorer."

To determine whether a planet is made of rock, water or gas, scientists must know its size and mass. When its mass can't be directly determined, scientists can infer what the planet is made of based on its size.

Two of the newly validated planets, Kepler-438b and Kepler-442b, are less than 1.5 times the diameter of Earth. Kepler-438b, 475 light-years away, is 12 percent bigger than Earth and orbits its star once every 35.2 days. Kepler-442b, 1,100 light-years away, is 33 percent bigger than Earth and orbits its star once every 112 days.

Both Kepler-438b and Kepler-442b orbit stars smaller and cooler than our sun, making the habitable zone closer to their parent star, in the direction of the constellation Lyra. The research paper reporting this finding has been accepted for publication in The Astrophysical Journal.

"With each new discovery of these small, possibly rocky worlds, our confidence strengthens in the determination of the true frequency of planets like Earth," said co-author Doug Caldwell, SETI Institute Kepler scientist at NASA's Ames Research Center at Moffett Field, California. "The day is on the horizon when we'll know how common temperate, rocky planets like Earth are."

With the detection of 554 more planet candidates from Kepler observations conducted May 2009 to April 2013, the Kepler team has raised the candidate count to 4,175. Eight of these new candidates are between one to two times the size of Earth, and orbit in their sun's habitable zone. Of these eight, six orbit stars that are similar to our sun in size and temperature. All candidates require follow-up observations and analysis to verify they are actual planets.

"Kepler collected data for four years -- long enough that we can now tease out the Earth-size candidates in one Earth-year orbits," said Fergal Mullally, SETI Institute Kepler scientist at Ames who led the analysis of a new candidate catalog. "We're closer than we've ever been to finding Earth twins around other sun-like stars. These are the planets we're looking for."

These findings also have been submitted for publication in The Astrophysical Journal Supplement.

Work is underway to translate these recent discoveries into estimates of how often rocky planets appear in the habitable zones of stars like our sun, a key step toward NASA's goal of understanding our place in the universe.

Scientists also are working on the next catalog release of Kepler's four-year data set. The analysis will include the final month of data collected by the mission and also will be conducted using sophisticated software that is more sensitive to the tiny telltale signatures of small Earth-size planets than software used in the past.

Ames is responsible for Kepler's mission operations, ground system development and science data analysis. NASA's Jet Propulsion Laboratory in Pasadena, California, managed Kepler mission development. Ball Aerospace & Technologies Corp. in Boulder, Colorado, developed the Kepler flight system and supports mission operations with the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder. The Space Telescope Science Institute in Baltimore archives, hosts and distributes Kepler science data. Kepler is NASA's 10th Discovery Mission and was funded by the agency's Science Mission Directorate in Washington.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Gets Best View of Circumstellar Debris Disk Distorted by Planet

3 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers have used NASA’s Hubble Space Telescope to take the most detailed edge on picture to date of a large disk of gas and dust encircling the 20 million-year-old star Beta Pictoris.

Beta Pictoris is the only star to date where astronomers have detected an embedded giant planet in a directly-imaged debris disk. The planet, which was discovered in 2009, goes around the star once every 18 to 20 years. This allows scientists to study in a comparably short time how a large planet distorts the massive gas and dust encircling the star. These observations should yield new insights into how planets are born around young stars.

The new visible-light Hubble image traces the disk to within about 650 million miles of the star. The giant planet orbits at 900 million miles, and was directly imaged in infrared light by the European Southern Observatory’s Very Large Telescope six years ago.

“Some computer simulations predicted a complicated structure for the inner disk due to the gravitational pull by the giant planet. The new images reveal the inner disk and confirm the predicted structures. This finding validates models that will help us to deduce the presence of other exoplanets in other disks,” said Daniel Apai of the University of Arizona, Tucson. These structures include a warp in the inner disk caused by the giant planet.

When comparing the latest 2012 images to Hubble images taken in 1997, astronomers find that the disk’s dust distribution has barely changed over 15 years despite the fact that the entire structure is orbiting the star like a carousel. This means the disk's structure is smooth and continuous, at least over the interval between the Hubble observations.

In 1984 Beta Pictoris was the very first star discovered to be surrounded by a bright disk of dust and debris. Since then, Beta Pictoris has been an object of intense scrutiny with Hubble and ground-based telescopes.

The disk is easily seen because of its edge-on angle, and is especially bright due to a very large amount of starlight-scattering dust. What’s more, Beta Pictoris is 63 light-years away, closer to Earth than most of the other known disk systems.

Though nearly all of the approximately two-dozen known light-scattering circumstellar disks have been viewed by Hubble to date, Beta Pictoris is the first and best example of what a young planetary system looks like.

For one thing, the Beta Pictoris disk is exceptionally dusty. This may be due to recent major collisions among unseen planet and asteroid-sized objects embedded within the disk. In particular, a bright lobe of dust and gas on the southwestern side of the disk may be the result of the pulverization of a Mars-sized object in a giant collision.

Both the 1997 and 2012 images were taken in visible light with Hubble’s Space Telescope Imaging Spectrograph in its coronagraphic imaging mode. A coronagraph blocks out the glare of the central star so that the disk can be seen.

The Hubble Space Telescope is a project of international cooperation between NASA and ESA (European Space Agency). NASA's Goddard Space Flight Center in Greenbelt, Maryland, manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, Inc., in Washington.

For images and more information about the Hubble Space Telescope, visit:

http://hubblesite.org/news/2015/06

http://www.nasa.gov/hubble

Contacts:

Ray VillardSpace Telescope Science Institute, Baltimore410-338-4514villard@stsci.edu

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Four-fathers: New exoplanet discovery part of a quadruple-star system

5 min read

NASA Science Editorial Team

Growing up as a planet with more than one parent star has its challenges. Though the planets in our solar system circle just one star – our Sun – other, more distant planets, called exoplanets, can be reared in families with two or more stars. Researchers wanting to know more about the complex influences of multiple stars on planets have come up with two new case studies: a planet found to have three parents, and another with four.

The discoveries were made using instruments fitted to telescopes at the Palomar Observatory in San Diego: the Robo-AO adaptive optics system, developed by the Inter-University Center for Astronomy and Astrophysics in India and the California Institute of Technology in Pasadena, and the PALM-3000 adaptive optics system, developed by NASA's Jet Propulsion Laboratory in Pasadena, California, and Caltech.

This is only the second time a planet has been identified in a quadruple star system. While the planet was known before, it was thought to have only three stars, not four. The first four-star planet, KIC 4862625, was discovered in 2013 by citizen scientists using public data from NASA's Kepler mission.

The latest discovery suggests that planets in quadruple star systems might be less rare than once thought. In fact, recent research has shown that this type of star system, which usually consists of two pairs of twin stars slowly circling each other at great distances, is itself more common than previously believed.

"About four percent of solar-type stars are in quadruple systems, which is up from previous estimates because observational techniques are steadily improving," said co-author Andrei Tokovinin of the Cerro Tololo Inter-American Observatory in Chile.

The newfound four-star planetary system, called 30 Ari, is located 136 light-years away in the constellation Aries. The system's gaseous planet is enormous, with 10 times the mass of Jupiter, and it orbits its primary star every 335 days. The primary star has a relatively close partner star, which the planet does not orbit. This pair, in turn, is locked in a long-distance orbit with another pair of stars about 1,670 astronomical units away (an astronomical unit is the distance between Earth and the sun). Astronomers think it's highly unlikely that this planet, or any moons that might circle it, could sustain life.

Were it possible to see the skies from this world, the four parent stars would look like one small sun and two very bright stars that would be visible in daylight. One of those stars, if viewed with a large enough telescope, would be revealed to be a binary system, or two stars orbiting each other.

In recent years, dozens of planets with two or three parent stars have been found, including those with "Tatooine" sunsets reminiscent of the Star Wars movies. Finding planets with multiple parents isn't too much of a surprise, considering that binary stars are more common in our galaxy than single stars.

"Star systems come in myriad forms. There can be single stars, binary stars, triple stars, even quintuple star systems," said Lewis Roberts of JPL, lead author of the new findings appearing in the journal Astronomical Journal. "It's amazing the way nature puts these things together."

Roberts and his colleagues want to understand the effects that multiple parent stars can have on their developing youthful planets. Evidence suggests that stellar companions can influence the fate of planets by changing the planets' orbits and even triggering some to grow more massive. For example, the "hot Jupiters" – planets around the mass of Jupiter that whip closely around their stars in just days – might be gently nudged closer to their primary parent star by the gravitational hand of a stellar companion.

In the new study, the researchers describe using the automated Robo-AO system on Palomar Observatory to scan the night skies, searching hundreds of stars each night for signs of stellar companions. They found two candidates hosting exoplanets: the four-star system 30 Ari, and a triple-star planetary system called HD 2638. The findings were confirmed using the higher-resolution PALM-3000 instrument, also at Palomar Observatory.

The new planet with a trio of stars is a hot Jupiter that circles its primary star tightly, completing one lap every three days. Scientists already knew this primary star was locked in a gravitational tango with another star, about 0.7 light-years away, or 44,000 astronomical units. That's relatively far apart for a pair of stellar companions. The latest discovery is of a third star in the system, which orbits the primary star from a distance of 28 astronomical units – close enough to have influenced the hot Jupiter's development and final orbit.

"This result strengthens the connection between multiple star systems and massive planets," said Roberts.

In the case of Ari 30, the discovery brought the number of known stars in the system from three to four. The fourth star lies at a distance of 23 astronomical units from the planet. While this stellar companion and its planet are closer to each other than those in the HD 2638 system, the newfound star does not appear to have impacted the orbit of the planet. The exact reason for this is uncertain, so the team is planning further observations to better understand the orbit of the star and its complicated family dynamics.

JPL is managed for NASA by the California Institute of Technology in Pasadena, California.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

M-dwarf mirage

4 min read

NASA Science Editorial Team

From the University of Washington

Planets orbiting close to low-mass stars — easily the most common stars in the universe — are prime targets in the search for extraterrestrial life.

But new research led by an astronomy graduate student at the University of Washington indicates some such planets may have long since lost their chance at hosting life because of intense heat during their formative years.

Low-mass stars, also called M dwarfs, are smaller than the sun, and also much less luminous, so their habitable zone tends to be fairly close in. The habitable zone is that swath of space that is just right to allow liquid water on an orbiting planet's surface, thus giving life a chance.

Planets close to their host stars are easier for astronomers to find than their siblings farther out. Astronomers discover and measure these worlds by studying the slight reduction in light when they transit, or pass in front of their host star; or by measuring the star's slight "wobble" in response to the planet's gravity, called the radial velocity method.

But in a paper to be published in the journal Astrobiology, doctoral student Rodrigo Luger and co-author Rory Barnes, a UW research assistant professor, find through computer simulations that some planets close to low-mass stars likely had their water and atmospheres burned away when they were still forming.

"All stars form in the collapse of a giant cloud of interstellar gas, which releases energy in the form of light as it shrinks," Luger said. "But because of their lower masses, and therefore lower gravities, M dwarfs take longer to fully collapse — on the order of many hundreds of millions of years."

"Planets around these stars can form within 10 million years, so they are around when the stars are still extremely bright. And that's not good for habitability, since these planets are going to initially be very hot, with surface temperatures in excess of a thousand degrees. When this happens, your oceans boil and your entire atmosphere becomes steam."

Also boding ill for the atmospheres of these worlds is the fact that M dwarf stars emit a lot of X-ray and ultraviolet light, which heats the upper atmosphere to thousands of degrees and causes gas to expand so quickly it leaves the planet and is lost to space, Luger said.

"So, many of the planets in the habitable zones of M dwarfs could have been dried up by this process early on, severely decreasing their chance of actually being habitable."

A side effect of this process, Luger and Barnes write, is that ultraviolet radiation can split up water into its component hydrogen and oxygen atoms. The lighter hydrogen escapes the atmosphere more easily, leaving the heavier oxygen atoms behind. While some oxygen is clearly good for life, as on Earth, too much oxygen can be a negative factor for the origin of life.

"Rodrigo has shown that this prolonged runaway greenhouse phase can produce huge atmospheres full of oxygen — like, 10 times denser than that of Venus and all oxygen," said Barnes. "Searches for life often rely on oxygen as a tracer of extraterrestrial life — so the abiological production of such huge quantities of oxygen could confound our search for life on exoplanets."

Luger said the working title of their paper was “Mirage Earths.”

“Because of the oxygen they build up, they could look a lot like Earth from afar — but if you look more closely you’ll find that they’re really a mirage; there’s just no water there.”

The research was funded by NASA’s Astrobiology Institute, through the Virtual Planetary Laboratory.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cosmic crowdsourcing project marks millionth potential disk-overy

6 min read

NASA Science Editorial Team

A NASA-sponsored website designed to crowdsource analysis of data from the agency's Wide-field Infrared Survey Explorer (WISE) mission has reached an impressive milestone. In less than a year, citizen scientists using DiskDetective.org have logged 1 million classifications of potential debris disks and disks surrounding young stellar objects (YSO). This data will help provide a crucial set of targets for future planet-hunting missions.

"This is absolutely mind-boggling," said Marc Kuchner, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, and the project's principal investigator. "We've already broken new ground with the data, and we are hugely grateful to everyone who has contributed to Disk Detective so far."

Combing through objects identified by WISE during its infrared survey of the entire sky, Disk Detective aims to find two types of developing planetary environments. The first, known as a YSO disk, typically is less than 5 million years old, contains large quantities of gas, and often is found in or near young star clusters. The second planetary habitat, known as a debris disk, tends to be older than 5 million years, holds little or no gas, and possesses belts of rocky or icy debris that resemble the asteroid and Kuiper belts found in our own solar system. Vega and Fomalhaut, two of the brightest stars in the sky, host debris disks.

Planets form and grow within disks of gas, dust and icy grains surrounding young stars. The particles absorb the star's light and reradiate it as heat, which makes the stars brighter at infrared wavelengths -- in this case, 22 microns -- than they would be without a disk.

Computer searches already have identified some objects seen by the WISE survey as potential dust-rich disks. But software can't distinguish them from other infrared-bright sources, such as galaxies, interstellar dust clouds and asteroids. There may be thousands of potential planetary systems in the WISE data, but the only way to know for sure is to inspect each source by eye.

Kuchner recognized that searching the WISE database for dusty disks was a perfect opportunity for crowdsourcing. He worked with NASA to team up with the Zooniverse, a collaboration of scientists, software developers and educators who collectively develop and manage citizen science projects on the Internet.

At DiskDetective.org, volunteers watch a 10-second "flip book" of a disk candidate shown at several different wavelengths as observed from three different telescopes, including WISE. They then click one or more buttons that best describe the object's appearance. Each classification helps astronomers decide which images may be contaminated by background galaxies, interstellar matter or image artifacts, and which may be real disks that should be studied in more detail.

In March 2014, just two months after Disk Detective launched, Kuchner was amazed to find just how invested in the project some users had become. Volunteers complained about seeing the same object over and over. "We thought at first it was a bug in the system," Kuchner explained, "but it turned out they were seeing repeats because they had already classified every single object that was online at the time."

Some 28,000 visitors around the world have participated in the project to date. What's more, volunteers have translated the site into eight foreign languages, including Romanian, Mandarin and

Bahasa, and have produced their own video tutorials on using it.

Many of the project's most active volunteers are now joining in science team discussions, and the researchers encourage all users who have performed more than 300 classifications to contact them and take part.

One of these volunteers is Tadeáš Cernohous, a postgraduate student in geodesy and cartography at Brno University of Technology in the Czech Republic. "I barely understood what scientists were looking for when I started participating in Disk Detective, but over the past year I have developed a basic sense of which stars are worthy of further exploration," he said.

Alissa Bans, a postdoctoral fellow at Adler Planetarium in Chicago and a member of the Disk Detective science team, recalls mentioning that she was searching for candidate YSOs and presented examples of what they might look like on Disk Detective. "In less than 24 hours," she said, "Tadeáš had compiled a list of nearly 100 objects he thought could be YSOs, and he even included notes on each one."

Speaking at a press conference at the American Astronomical Society meeting in Seattle on Tuesday, Kuchner said the project has so far netted 478 objects of interest, which the team is investigating with a variety of ground-based telescopes in Arizona, California, New Mexico, Argentina and Chile. "We now have at least 37 solid new disk candidates, and we haven't even looked at all the new telescope data yet," he said.

Disk Detective currently includes about 278,000 WISE sources. The team expects to wrap up the current project sometime in 2018, with a total of about 3 million classifications and perhaps 1,000 disk candidates. The researchers then plan to add an additional 140,000 targets to the site.

"We've come a long way, but there's still lots and lots more work to do -- so please drop by the site and do a little science with us!" added Kuchner.

WISE has made infrared measurements of more than 745 million objects, compiling the most comprehensive survey of the sky at mid-infrared wavelengths currently available. With its primary mission complete, the satellite was placed in hibernation in 2011. WISE was awoken in September 2013, renamed the Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE), and given a new mission to assist NASA's efforts in identifying the population of potentially hazardous near-Earth objects (NEOs).

JPL manages the NEOWISE mission for NASA's Science Mission Directorate in Washington. The Space Dynamics Laboratory in Logan, Utah, built the science instrument. Ball Aerospace & Technologies Corp. of Boulder, Colo., built the spacecraft. Science operations and data processing take place at the Infrared Processing and Analysis Center at the California Institute of Technology in Pasadena. Caltech manages JPL for NASA.

Facilities involved in follow-up studies of objects found with Disk Detective include Apache Point Observatory in Sunspot, New Mexico; Palomar Observatory on Palomar Mountain, California; the Fred Lawrence Whipple Observatory on Mount Hopkins, Arizona; the Leoncito Astronomical Complex in El Leoncito National Park, Argentina; and Las Campanas Observatory, located in the Atacama Desert of Chile.

NASA is exploring our solar system and beyond to understand the universe and our place in it. We seek to unravel the secrets of our universe, its origins and evolution, and search for life among the stars. Today's announcement shares the discovery of our ever-changing cosmos, and brings us closer to learning whether we are alone in the universe.

More information about WISE is online at:

http://www.nasa.gov/wise

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Dust difficulties may be diminished

5 min read

NASA Science Editorial Team

Planet hunters received some good news recently. A new study concluded that, on average, sun-like stars aren't all that dusty. Less dust means better odds of snapping clear pictures of the stars' planets in the future.

These results come from surveying nearly 50 stars from 2008 to 2011 using the Keck Interferometer, a former NASA key science project that combined the power of the twin W. M. Keck Observatory telescopes atop Mauna Kea, Hawaii.

"Dust is a double-edged sword when it comes to imaging distant planets," explained Bertrand Mennesson of NASA's Jet Propulsion Laboratory, Pasadena, California, lead author of an Astrophysical Journal report to be published online Dec. 8. "The presence of dust is a signpost for planets, but too much dust can block our view." Mennesson has been involved in the Keck Interferometer project since its inception more than 10 years ago, both as a scientist and as the optics lead for one of its instruments.

Ground- and space-based telescopes have already captured images of exoplanets -- planets orbiting stars beyond our sun. These early images, which show giant planets in cool orbits far from the glow of their stars, represent a huge technological leap. The glare from stars can overwhelm the light of planets, like a firefly buzzing across the sun. So, researchers have developed complex instruments to block the starlight, allowing information about the planet to shine through.

The next challenge is to image smaller planets in the "habitable" zone around stars where possible life-bearing "exo-Earths" -- Earth-like planets outside the solar system -- could reside. Such a lofty goal may take decades, but researchers are already on the path to getting there, developing new instrument designs and analyzing the dust kicked up around stars to better understand how to snap crisp planetary portraits. Scientists want to find out which stars have the most dust, and how dusty the habitable zones of sun-like stars are.

The Keck Interferometer was built to seek out this dust, and to ultimately help in the design and target selection of future NASA exo-Earth missions. Like planets around other stars, dust near a star is also hard to detect. Interferometry is a high-resolution imaging technique that can be used to block out a star's light, making the region nearby easier to observe. Light waves from the precise location of a star, collected separately by the twin 10-meter Keck Observatory telescopes, are combined and canceled out in a process called nulling.

"If you don't turn off the star, you are blinded and can't see dust or planets," said co-author Rafael Millan-Gabet of NASA's Exoplanet Science Institute at the California Institute of Technology in Pasadena, who led the Keck Interferometer's science operations system.

In the latest study, mature, sun-like stars were analyzed with high precision to search for warm, room-temperature dust in their habitable zones. Roughly half of the stars selected for the study had previously shown no signs of cool dust circling in their outer reaches. This outer dust is easier to see than the inner, warm dust due to its greater distance from the star. Of this first group of stars, none were found to host the warm dust, making them good targets for planet imaging, and a good indication that other, relatively dust-free stars are out there.

The other stars in the study were already known to have significant amounts of distant, cold dust orbiting them. In this group, many of the stars were found to also have the room-temperature dust. This is the first time a direct link between the cold and warm dust has been established. In other words, if a star is observed to have a cold belt of dust, astronomers now can make an educated guess that its warm habitable zone is also riddled with dust, making it a poor target for imaging exo-Earths.

"We want to avoid planets that are buried in dust," said Mennesson. "The dust glows in the infrared and reflects starlight in the visible, both of which can outshine the planet's light."

Like a busy construction site, the process of building planets is messy. It is common for young, developing star systems to be covered in dust. Proto-planets collide, scattering dust. But eventually, the chaos settles and the dust clears -- except around some older stars. Why are these mature stars still laden with warm dust in their habitable zones?

The newfound link between cold and warm dust belts helps answer this question.

"The outer belt is somehow feeding material into the inner, warm belt," said Geoff Bryden of JPL, a co-author of the study. "This transport of material could be accomplished as dust smoothly flows inward, or there could be larger comets thrown directly into the inner system."

Upcoming, more-sensitive measurements by NASA's Large Binocular Telescope Interferometer on Mount Graham in Arizona will further improve these measurements of dust in star systems, narrowing in on its quantity, origin and whereabouts. With these early efforts to sift through the murk around stars, astronomers are making their way down the path to one day finding planets similar to our own.

The Keck Interferometer completed its NASA prime mission in 2012. It was funded by NASA and managed by JPL. JPL is managed by Caltech for NASA.

The W. M. Keck Observatory operates the largest, most scientifically productive telescopes on Earth. The two, 10-meter optical/infrared telescopes near the summit of Mauna Kea on the Island of Hawaii feature a suite of advanced instruments including imagers, multi-object spectrographs, high-resolution spectrographs, integral-field spectrographs and world-leading laser guide star adaptive optics systems.

Keck Observatory is a private 501(c) 3 non-profit organization and a scientific partnership of Caltech, the University of California System and NASA.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers Discover First “Ice Giant” Exoplanet

4 min read

NASA Science Editorial Team

From Ohio State University

Our view of other solar systems just got a little more familiar, with the discovery of a planet 25,000 light-years away that resembles our own Uranus.

Astronomers have discovered hundreds of planets around the Milky Way, including rocky planets similar to Earth and gas planets similar to Jupiter. But there is a third type of planet in our solar system—part gas, part ice—and this is the first time anyone has spotted a twin for our so-called “ice giant” planets, Uranus and Neptune.

While Uranus and Neptune are mostly composed of hydrogen and helium, they both contain significant amounts of methane ice, which gives them their bluish appearance. Given that the newly discovered planet is so far away, astronomers can’t actually tell anything about its composition. But its distance from its star suggests that it’s an ice giant—and since the planet’s orbit resembles that of Uranus, the astronomers are considering it to be a Uranus analog.

Regardless, the newly discovered planet leads a turbulent existence: it orbits one star in a binary star system, with the other star close enough to disturb the planet’s orbit.

The find may help solve a mystery about the origins of the ice giants in our solar system, said Andrew Gould, professor of astronomy at Ohio State.

“Nobody knows for sure why Uranus and Neptune are located on the outskirts of our solar system, when our models suggest that they should have formed closer to the sun,” Gould said. “One idea is that they did form much closer, but were jostled around by Jupiter and Saturn and knocked farther out.

“Maybe the existence of this Uranus-like planet is connected to interference from the second star,” he continued. “Maybe you need some kind of jostling to make planets like Uranus and Neptune.”

The binary star system lies in our Milky Way galaxy, in the direction of Sagittarius. The first star is about two thirds as massive as our sun, and the second star is about one sixth as massive. The planet is four times as massive as Uranus, but it orbits the first star at almost exactly the same distance as Uranus orbits our sun.

The astronomers spotted the solar system due to a phenomenon called gravitational microlensing—when the gravity of a star focuses the light from a more distant star and magnifies it like a lens. Very rarely, the signature of a planet orbiting the lens star appears within that magnified light signal.

In this case, there were two separate microlensing events, one in 2008 that revealed the main star and suggested the presence of the planet, and one in 2010 that confirmed the presence of the planet and revealed the second star. Both observations were done with the 1.3-meter Warsaw Telescope at Las Campanas Observatory in Chile as part of the Optical Gravitational Lensing Experiment (OGLE).

Poleski led the analysis, which entailed combining the two OGLE observations. When he did, he was able to calculate the masses of the two stars and the planet, and their distances from one another—a feat that he says can only be done via microlensing.

“Only microlensing can detect these cold ice giants that, like Uranus and Neptune, are far away from their host stars. This discovery demonstrates that microlensing is capable of discovering planets in very wide orbits,” Poleski said.

"We were lucky to see the signal from the planet, its host star, and the companion star. If the orientation had been different, we would have seen only the planet, and we probably would have called it a free-floating planet,” he added.

The 2008 and 2010 events are part of the OGLE database, which contains 13,000 microlensing events that have been recorded since the project began. Part of Poleski’s job at Ohio State entails writing software to mine the database for other possible connections that could lead to additional planet discoveries—including more ice giants.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Hubble Surveys Debris-Strewn Exoplanetary Construction Yards

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers using NASA’s Hubble Space Telescope have completed the largest and most sensitive visible-light imaging survey of dusty debris disks around other stars. These dusty disks, likely created by collisions between leftover objects from planet formation, were imaged around stars as young as 10 million years old and as mature as more than 1 billion years old.

“It’s like looking back in time to see the kinds of destructive events that once routinely happened in our solar system after the planets formed,” said survey leader Glenn Schneider of the University of Arizona's Steward Observatory. The survey’s results appeared in the Oct. 1, 2014 issue of The Astronomical Journal.

Once thought to be simply pancake-like structures, the unexpected diversity and complexity and varying distribution of dust among these debris systems strongly suggest the disks are gravitationally-affected by unseen exoplanets orbiting the star. Alternatively, these effects could result from the stars passing through interstellar space.

The researchers discovered that no two "disks" of material surrounding stars look the same. “We find that the systems are not simply flat with uniform surfaces,” Schneider said. “These are actually pretty complicated three-dimensional debris systems, often with embedded smaller structures. Some of the substructures could be signposts of unseen planets." The astronomers used Hubble’s Space Telescope Imaging Spectrograph to study 10 previously discovered circumstellar debris systems.

Irregularities observed in one ring-like system in particular, around a star called HD 181327, resemble a huge spray of debris possibly caused by the recent collision of two bodies into the outer part of the system. .

“This spray of material is fairly distant from its host star — roughly twice the distance that Pluto is from the sun,” said co-investigator Christopher Stark. “Catastrophically destroying an object that massive at such a large distance is difficult to explain, and it should be very rare. If we are in fact seeing the recent aftermath of a massive collision, the unseen planetary system may be quite chaotic.”

Another interpretation for the irregularity is that the disk has been mysteriously warped by the star’s passage through interstellar space, directly interacting with unseen interstellar material. “Either way, the answer is exciting,” Schneider said. “Our team is currently analyzing follow-up observations that will help reveal the true cause of the irregularity.”

Over the past few years astronomers have found an incredible variety in the architecture of exoplanetary systems – planets are arranged in orbits that are markedly different than found in our solar system, “We are now seeing a similar diversity in the architecture of the accompanying debris systems.” Schneider said. “How are the planets affecting the disks, and how are the disks affecting the planets? There is some sort of interdependence between a planet and the accompanying debris that might affect the evolution of these exoplanetary debris systems.”

From this small sample, the most important message to take away is one of diversity, Schneider said. He added that astronomers really need to understand the internal and external influences on these systems, such as stellar winds and interactions with clouds of interstellar material, and how they are influenced by the mass and age of the parent star, and the abundance of heavier elements needed to build planets.

Though astronomers have found nearly 4,000 exoplanet candidates since 1995, mostly by indirect detection methods, only about two dozen light-scattering, circumstellar debris systems have been imaged over that same time period. That’s because the disks are typically 100,000 times fainter than, and often very close to, their bright parent stars. The majority have been seen because of Hubble’s ability to perform high-contrast imaging, in which the overwhelming light from the star is blocked to reveal the faint disk that surrounds the star.

The new imaging survey also yields insight into how our solar system formed and evolved 4.6 billion years ago. In particular, the suspected planet collision seen in the disk around HD 181327 may be similar to how the Earth-moon system formed. In those cases, collisions between planet-sized bodies cast debris that then coalesced into a companion moon.

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Md., manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, Inc., in Washington.

Contacts:

Ray Villard

Space Telescope Science Institute, Baltimore, Md.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hidden in a dust halo

4 min read

NASA Science Editorial Team

Researchers studying what appears to be a beefed-up version of our solar system have discovered that it is encased in a halo of fine dust. The findings are based on infrared data from NASA's Spitzer Space Telescope and the European Space Agency's Herschel Space Observatory, in which NASA is a partner.

The dusty star system, called HD 95086, is located 295 light-years from Earth in the constellation Carina. It is thought to include two belts of dust, which lie within the newfound outer dust halo. One of these belts is warm and closer to its star, as is the case with our solar system's asteroid belt, while the second belt is cooler and farther out, similar to our own Kuiper belt of icy comets.

"By looking at other star systems like these, we can piece together how our own solar system came to be," said Kate Su, an associate astronomer at the University of Arizona, Tucson, and lead author of the paper.

Within our solar system, the planets Jupiter, Saturn, Uranus and Neptune are sandwiched between the two dust belts. Scientists think something similar is happening in the star system HD 95086, only on larger scales. One planet, about five times the mass of Jupiter, is already known to sit right inside HD 95086's cooler belt. Other massive planets may be lurking between the two dust belts, waiting to be discovered.

Studies like this from Spitzer and Herschel point the way for ground-based telescopes to snap pictures of such planets in hiding, a technique referred to as direct imaging. The one planet known to exist in HD 95086 was, in fact, discovered and imaged using this technique in 2013. The images aren't sharp because the planets are so faint and far away, but they reveal new information about the global architecture of a planetary system.

"By knowing where the debris is, plus the properties of the known planet in the system, we can get an idea of what other kinds of planets can be there," said Sarah Morrison, a co-author of the paper and a PhD student at the University of Arizona. She ran computer models to constrain the possibilities of how many planets are likely to inhabit the system. "We know that we should be looking for multiple planets instead of a single giant planet."

To learn what HD 95086 looks like, the astronomers turned to a similar star system called HR 8799. It too has an inner and outer belt of debris surrounded by a large halo of fine dust, and four known planets between the belts -- among the first exoplanets, or planets beyond our solar system, to be directly imaged.

Comparing data from the two star systems hints that HD95086, like its cousin HR 8799, is a possible home to multiple planets that have yet to be seen. Ground-based telescopes might be able to take pictures of the family of planets.

Both HD 95086 and HR 8799 are much younger and dustier than our solar system. When planetary systems are young and still forming, collisions between growing planetary bodies, asteroids and comets kick up dust. Some of the dust coagulates into planets, some winds up in the belts, and the rest is either blown out into a halo, or funneled onto the star.

Herschel and Spitzer are ideally suited to study the dust structures in these systems, which glow at the infrared wavelengths the telescopes detect.

The researchers will present the findings at the Division for Planetary Science Meeting of the American Astronomical Society held in Tucson, Arizona from Nov. 8 to 15.

Read more about the research at:

http://uanews.org/story/baby-photos-of-a-scaled-up-solar-system

Other coauthors of the paper include Zoltan Balog at the Max-Planck Institute of Astronomy, Heidelberg, Germany, and Renu Malhotra, Paul Smith and George Rieke of the University of Arizona.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Telescopes Find Clear Skies and Water Vapor on Exoplanet

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers using data from three of NASA's space telescopes -- Hubble, Spitzer and Kepler -- have discovered clear skies and steamy water vapor on a gaseous planet outside our solar system. The planet is about the size of Neptune, making it the smallest planet from which molecules of any kind have been detected.

“This discovery is a significant milepost on the road to eventually analyzing the atmospheric composition of smaller, rocky planets more like Earth,” said John Grunsfeld, assistant administrator of NASA’s Science Mission Directorate in Washington. “Such achievements are only possible today with the combined capabilities of these unique and powerful observatories.”

Clouds in a planet’s atmosphere can block the view to underlying molecules that reveal information about the planet’s composition and history. Finding clear skies on a Neptune-size planet is a good sign that smaller planets might have similarly good visibility.

"When astronomers go observing at night with telescopes, they say 'clear skies' to mean good luck," said Jonathan Fraine of the University of Maryland, College Park, lead author of a new study appearing in Nature. "In this case, we found clear skies on a distant planet. That's lucky for us because it means clouds didn't block our view of water molecules."

The planet, HAT-P-11b, is categorized as an exo-Neptune -- a Neptune-sized planet that orbits the star HAT-P-11. It is located 120 light-years away in the constellation Cygnus. This planet orbits closer to its star than does our Neptune, making one lap roughly every five days. It is a warm world thought to have a rocky core and gaseous atmosphere. Not much else was known about the composition of the planet, or other exo-Neptunes like it, until now.

Part of the challenge in analyzing the atmospheres of planets like this is their size. Larger Jupiter-like planets are easier to see because of their impressive girth and relatively inflated atmospheres. In fact, researchers already have detected water vapor in the atmospheres of those planets. The handful of smaller planets observed previously had proved more difficult to probe partially because they all appeared to be cloudy.

In the new study, astronomers set out to look at the atmosphere of HAT-P-11b, not knowing if its weather would call for clouds. They used Hubble's Wide Field Camera 3, and a technique called transmission spectroscopy, in which a planet is observed as it crosses in front of its parent star. Starlight filters through the rim of the planet's atmosphere; if molecules like water vapor are present, they absorb some of the starlight, leaving distinct signatures in the light that reaches our telescopes.

Using this strategy, Hubble was able to detect water vapor in HAT-P-11b. But before the team could celebrate clear skies on the exo-Neptune, they had to show that starspots -- cooler "freckles" on the face of stars -- were not the real sources of water vapor. Cool starspots on the parent star can contain water vapor that might erroneously appear to be from the planet.

The team turned to Kepler and Spitzer. Kepler had been observing one patch of sky for years, and HAT-P-11b happens to lie in the field. Those visible-light data were combined with targeted Spitzer observations taken at infrared wavelengths. By comparing these observations, the astronomers figured out that the starspots were too hot to have any steam. It was at that point the team could celebrate detecting water vapor on a world unlike any in our solar system. This discovery indicates the planet did not have clouds blocking the view, a hopeful sign that more cloudless planets can be located and analyzed in the future.

"We think that exo-Neptunes may have diverse compositions, which reflect their formation histories," said study co-author Heather Knutson of the California Institute of Technology in Pasadena. "Now with data like these, we can begin to piece together a narrative for the origin of these distant worlds."

The results from all three telescopes demonstrate that HAT-P-11b is blanketed in water vapor, hydrogen gas and likely other yet-to-be-identified molecules. Theorists will be drawing up new models to explain the planet's makeup and origins.

"We are working our way down the line, from hot Jupiters to exo-Neptunes," said Drake Deming, a co-author of the study also from University of Maryland. "We want to expand our knowledge to a diverse range of exoplanets."

The astronomers plan to examine more exo-Neptunes in the future, and hope to apply the same method to super-Earths -- massive, rocky cousins to our home world with up to 10 times the mass. Although our solar system doesn't have a super-Earth, NASA's Kepler mission is finding them in droves around other stars. NASA's James Webb Space Telescope, scheduled to launch in 2018, will search super-Earths for signs of water vapor and other molecules; however, finding signs of oceans and potentially habitable worlds is likely a ways off.

"The work we are doing now is important for future studies of super-Earths and even smaller planets, because we want to be able to pick out in advance the planets with clear atmospheres that will let us detect molecules," said Knutson.

Once again, astronomers will be crossing their fingers for clear skies.

More information about Hubble, Kepler and Spitzer is online at:

http://www.nasa.gov

-end-

NASA’s Hubble Maps the Temperature and Water Vapor on an Extreme Exoplanet

5 min read

NASA Hubble Mission Team

Goddard Space Flight Center

A team of scientists using NASA’s Hubble Space Telescope has made the most detailed global map yet of the glow from a turbulent planet outside our solar system, revealing its secrets of air temperatures and water vapor.

Hubble observations show the exoplanet, called WASP-43b, is no place to call home. It is a world of extremes, where seething winds howl at the speed of sound from a 3,000-degree-Fahrenheit “day” side, hot enough to melt steel, to a pitch-black “night” side with plunging temperatures below 1,000 degrees Fahrenheit.

Astronomers have mapped the temperatures at different layers of the planet's atmosphere and traced the amount and distribution of water vapor. The findings have ramifications for the understanding of atmospheric dynamics and how giant planets like Jupiter are formed.

“These measurements have opened the door for a new kinds of ways to compare the properties of different types of planets,” said team leader Jacob Bean of the University of Chicago.

First discovered in 2011, WASP-43b is located 260 light-years away. The planet is too distant to be photographed, but because its orbit is observed edge-on to Earth, astronomers detected it by observing regular dips in the light of its parent star as the planet passes in front of it.

“Our observations are the first of their kind in terms of providing a two-dimensional map on the longitude and altitude of the planet’s thermal structure that can be used to constrain atmospheric circulation and dynamical models for hot exoplanets,” said team member Kevin Stevenson of the University of Chicago.

As a hot ball of predominantly hydrogen gas, there are no surface features on the planet, such as oceans or continents that can be used to track its rotation. Only the severe temperature difference between the day and night sides can be used by a remote observer to mark the passage of a day on this world.

The planet is about the same size as Jupiter, but is nearly twice as dense. The planet is so close to its orange dwarf host star that it completes an orbit in just 19 hours. The planet also is gravitationally locked so that it keeps one hemisphere facing the star, just as our moon keeps one face toward Earth.

This was the first time astronomers were able to observe three complete rotations of any planet, which occurred during a span of four days. Scientists combined two previous methods of analyzing exoplanets in an unprecedented technique to study the atmosphere of WASP-43b. They used spectroscopy, dividing the planet’s light into its component colors, to determine the amount of water and the temperatures of the atmosphere. By observing the planet’s rotation, the astronomers also were able to precisely measure how the water is distributed at different longitudes.

Because there is no planet with these tortured conditions in our solar system, characterizing the atmosphere of such a bizarre world provides a unique laboratory for better understanding planet formation and planetary physics.

“The planet is so hot that all the water in its atmosphere is vaporized, rather than condensed into icy clouds like on Jupiter,” said team member Laura Kreidberg of the University of Chicago.

The amount of water in the giant planets of our solar system is poorly known because water that has precipitated out of the upper atmospheres of cool gas giant planets like Jupiter is locked away as ice. But so-called “hot Jupiters,” gas giants that have high surface temperatures because they orbit very close to their stars, water is in a vapor that can be readily traced.

“Water is thought to play an important role in the formation of giant planets, since comet-like bodies bombard young planets, delivering most of the water and other molecules that we can observe,” said Jonathan Fortney, a member of the team from the University of California, Santa Cruz.

In order to understand how giant planets form astronomers want to know how enriched they are in different elements. The team found that WASP-43b has about the same amount of water as we would expect for an object with the same chemical composition as our sun, shedding light on the fundamentals about how the planet formed. The team next aims to make water-abundance measurements for different planets.

The results are presented in two new papers, one published online in Science Express Thursday and the other published in The Astrophysical Journal Letters on Sept. 12.

The Hubble Space Telescope is a project of international cooperation between NASA and the European Space Agency. NASA's Goddard Space Flight Center in Greenbelt, Maryland manages the telescope. The Space Telescope Science Institute (STScI) in Baltimore conducts Hubble science operations. STScI is operated for NASA by the Association of Universities for Research in Astronomy, Inc., in Washington.

For images and more information about Hubble, visit:

http://www.nasa.gov/hubble

and

http://hubblesite.org/news/2014/28

-end-

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Sunny Outlook for ‘Weather’ on Exoplanets

1 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Scientists were excited to discover clear skies on a relatively small planet, about the size of Neptune, using the combined power of NASA's Hubble, Spitzer and Kepler space telescopes. The view from this planet -- were it possible to fly a spaceship into its gaseous layers -- is illustrated at right. Before now, all of the planets observed in this size range had been found to have high cloud layers that blocked the ability to detect molecules in the planet’s atmosphere (illustrated at left).

The clear planet, called HAT-P-11b, is gaseous with a rocky core, much like our own Neptune. Its atmosphere may have clouds deeper down, but the new observations show that the upper region is cloud-free. This good visibility enabled scientists to detect water vapor molecules in the planet's atmosphere.

Image credit: NASA/JPL-Caltech

The most precise measurement of an alien world’s size

5 min read

NASA Science Editorial Team

What does it take to find life in the universe? Dr. Sara Seager of MIT is working hard to find out. Seager was recently interviewed by NPR’s Science Friday at NASA’s Jet Propulsion Laboratory in Pasadena, Calif. Sara believes the current search for exoplanets has broader implications for our future. “It’s a special time for us here on Earth. It’s the first time in human history that we actually have the technological capability to find other Earths, to identify them as Earths, and to hope to look for signs of life on the first handful or the first dozens or hundreds of exoplanets, and that’s a special time in history. So I’m trying to do what I can to make sure that happens now.”

Thanks to NASA's Kepler and Spitzer Space Telescopes, scientists have made the most precise measurement ever of the radius of a planet outside our solar system. The size of the exoplanet, dubbed Kepler-93b, is now known to an uncertainty of just 74 miles (119 kilometers) on either side of the planetary body.

The findings confirm Kepler-93b as a "super-Earth" that is about one-and-a-half times the size of our planet. Although super-Earths are common in the galaxy, none exist in our solar system. Exoplanets like Kepler-93b are therefore our only laboratories to study this major class of planet.

With good limits on the sizes and masses of super-Earths, scientists can finally start to theorize about what makes up these weird worlds. Previous measurements, by the Keck Observatory in Hawaii, had put Kepler-93b's mass at about 3.8 times that of Earth. The density of Kepler-93b, derived from its mass and newly obtained radius, indicates the planet is in fact very likely made of iron and rock, like Earth.

"With Kepler and Spitzer, we've captured the most precise measurement to date of an alien planet's size, which is critical for understanding these far-off worlds," said Sarah Ballard, a NASA Carl Sagan Fellow at the University of Washington in Seattle and lead author of a paper on the findings published in the Astrophysical Journal.

"The measurement is so precise that it's literally like being able to measure the height of a six-foot tall person to within three quarters of an inch -- if that person were standing on Jupiter," said Ballard.

Kepler-93b orbits a star located about 300 light-years away, with approximately 90 percent of the sun's mass and radius. The exoplanet's orbital distance -- only about one-sixth that of Mercury's from the sun -- implies a scorching surface temperature around 1,400 degrees Fahrenheit (760 degrees Celsius). Despite its newfound similarities in composition to Earth, Kepler-93b is far too hot for life.

To make the key measurement about this toasty exoplanet's radius, the Kepler and Spitzer telescopes each watched Kepler-93b cross, or transit, the face of its star, eclipsing a tiny portion of starlight. Kepler's unflinching gaze also simultaneously tracked the dimming of the star caused by seismic waves moving within its interior. These readings encode precise information about the star's interior. The team leveraged them to narrowly gauge the star's radius, which is crucial for measuring the planetary radius.

Spitzer, meanwhile, confirmed that the exoplanet's transit looked the same in infrared light as in Kepler's visible-light observations. These corroborating data from Spitzer -- some of which were gathered in a new, precision observing mode -- ruled out the possibility that Kepler's detection of the exoplanet was bogus, or a so-called false positive.

Taken together, the data boast an error bar of just one percent of the radius of Kepler-93b. The measurements mean that the planet, estimated at about 11,700 miles (18,800 kilometers) in diameter, could be bigger or smaller by about 150 miles (240 kilometers), the approximate distance between Washington, D.C., and Philadelphia.

Spitzer racked up a total of seven transits of Kepler-93b between 2010 and 2011. Three of the transits were snapped using a "peak-up" observational technique. In 2011, Spitzer engineers repurposed the spacecraft's peak-up camera, originally used to point the telescope precisely, to control where light lands on individual pixels within Spitzer's infrared camera.

The upshot of this rejiggering: Ballard and her colleagues were able to cut in half the range of uncertainty of the Spitzer measurements of the exoplanet radius, improving the agreement between the Spitzer and Kepler measurements.

"Ballard and her team have made a major scientific advance while demonstrating the power of Spitzer's new approach to exoplanet observations," said Michael Werner, project scientist for the Spitzer Space Telescope at NASA's Jet Propulsion Laboratory, Pasadena, California.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology in Pasadena. Spacecraft operations are based at Lockheed Martin Space Systems Company, Littleton, Colorado. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

NASA's Ames Research Center in Moffett Field, California, is responsible for Kepler's ground system development, mission operations and science data analysis. JPL managed Kepler mission development. Ball Aerospace & Technologies Corp. in Boulder, Colorado, developed the Kepler flight system and supports mission operations with the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder. The Space Telescope Science Institute in Baltimore archives, hosts and distributes Kepler science data. Kepler is NASA's 10th Discovery Mission and was funded by the agency's Science Mission Directorate.

For more information about the Kepler mission, visit:

http://www.nasa.gov/kepler

For more information about Spitzer, visit:

http://spitzer.caltech.edu

http://www.nasa.gov/spitzer

Whitney ClavinJet Propulsion Laboratory, Pasadena, Calif.818-354-4673whitney.clavin@jpl.nasa.gov

2014-239

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Finding Life Beyond Earth is Within Reach

4 min read

Many scientists believe we are not alone in the universe. It's probable, they say, that life could have arisen on at least some of the billions of planets thought to exist in our galaxy alone — just as it did here on planet Earth. This basic question about our place in the Universe is one that may be answered by scientific investigations. What are the next steps to finding life elsewhere?

Experts from NASA and its partner institutions addressed this question on July 14, at a public talk held at NASA Headquarters in Washington. They outlined NASA's roadmap to the search for life in the universe, an ongoing journey that involves a number of current and future telescopes. Watch the video of the event:

"Sometime in the near future, people will be able to point to a star and say, 'that star has a planet like Earth'," says Sara Seager, professor of planetary science and physics at the Massachusetts Institute of Technology in Cambridge, Massachusetts. "Astronomers think it is very likely that every single star in our Milky Way galaxy has at least one planet."

NASA's quest to study planetary systems around other stars started with ground-based observatories, then moved to space-based assets like the Hubble Space Telescope, the Spitzer Space Telescope, and the Kepler Space Telescope. Today's telescopes can look at many stars and tell if they have one or more orbiting planets. Even more, they can determine if the planets are the right distance away from the star to have liquid water, the key ingredient to life as we know it.

The NASA roadmap will continue with the launch of the Transiting Exoplanet Surveying Satellite (TESS) in 2017, the James Webb Space Telescope (Webb Telescope) in 2018, and perhaps the proposed Wide Field Infrared Survey Telescope – Astrophysics Focused Telescope Assets (WFIRST-AFTA) early in the next decade. These upcoming telescopes will find and characterize a host of new exoplanets — those planets that orbit other stars — expanding our knowledge of their atmospheres and diversity. The Webb telescope and WFIRST-AFTA will lay the groundwork, and future missions will extend the search for oceans in the form of atmospheric water vapor and for life as in carbon dioxide and other atmospheric chemicals, on nearby planets that are similar to Earth in size and mass, a key step in the search for life.

"This technology we are using to explore exoplanets is real," said John Grunsfeld, astronaut and associate administrator for NASA's Science Mission Directorate in Washington. "The James Webb Space Telescope and the next advances are happening now. These are not dreams — this is what we do at NASA."

Since its launch in 2009, Kepler has dramatically changed what we know about exoplanets, finding most of the more than 5,000 potential exoplanets, of which more than 1700 have been confirmed. The Kepler observations have led to estimates of billions of planets in our galaxy, and shown that most planets within one astronomical unit are less than three times the diameter of Earth. Kepler also found the first Earth-size planet to orbit in the "habitable zone" of a star, the region where liquid water can pool on the surface.

"What we didn't know five years ago is that perhaps 10 to 20 percent of stars around us have Earth-size planets in the habitable zone," says Matt Mountain, director and Webb telescope scientist at the Space Telescope Science Institute in Baltimore. "It's within our grasp to pull off a discovery that will change the world forever. It is going to take a continuing partnership between NASA, science, technology, the U.S. and international space endeavors, as exemplified by the James Webb Space Telescope, to build the next bridge to humanity's future."

This decade has seen the discovery of more and more super Earths, which are rocky planets that are larger and heftier than Earth. Finding smaller planets, the Earth twins, is a tougher challenge because they produce fainter signals. Technology to detect and image these Earth-like planets is being developed now for use with the future space telescopes. The ability to detect alien life may still be years or more away, but the quest is underway.

Said Mountain, “Just imagine the moment, when we find potential signatures of life. Imagine the moment when the world wakes up and the human race realizes that its long loneliness in time and space may be over — the possibility we’re no longer alone in the universe.”

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Research Gives Guideline for Future Alien Life Search

8 min read

Astronomers searching the atmospheres of alien worlds for gases that might be produced by life can't rely on the detection of just one type, such as oxygen, ozone, or methane, because in some cases these gases can be produced non-biologically, according to extensive simulations by researchers in the NASA Astrobiology Institute's Virtual Planetary Laboratory.

The researchers carefully simulated the atmospheric chemistry of alien worlds devoid of life thousands of times over a period of more than four years, varying the atmospheric compositions and star types. "When we ran these calculations, we found that in some cases, there was a significant amount of ozone that built up in the atmosphere, despite there not being any oxygen flowing into the atmosphere," said Shawn Domagal-Goldman of NASA's Goddard Space Flight Center in Greenbelt, Maryland. "This has important implications for our future plans to look for life beyond Earth."

Methane is a carbon atom bound to four hydrogen atoms. On Earth, much of it is produced biologically (flatulent cows are a classic example), but it can also be made inorganically; for example, volcanoes at the bottom of the ocean can release the gas after it is produced by reactions of rocks with seawater.

Ozone and oxygen were previously thought to be stronger biosignatures on their own. Ozone is three atoms of oxygen bound together. On Earth, it is produced when molecular oxygen (two oxygen atoms) and atomic oxygen (a single oxygen atom) combine, after the atomic oxygen is created by other reactions powered by sunlight or lightning. Life is the dominant source of the molecular oxygen on our planet, as the gas is produced by photosynthesis in plants and microscopic, single-cell organisms. Because life dominates the production of oxygen, and oxygen is needed for ozone, both gases were thought to be relatively strong biosignatures. But this study demonstrated that both molecular oxygen and ozone can be made without life when ultraviolet light breaks apart carbon dioxide (a carbon atom bound to two oxygen atoms). Their research suggests this non-biological process could create enough ozone for it to be detectable across space, so the detection of ozone by itself would not be a definitive sign of life.

"However, our research strengthens the argument that methane and oxygen together, or methane and ozone together, are still strong signatures of life," said Domagal-Goldman. "We tried really, really hard to make false-positive signals for life, and we did find some, but only for oxygen, ozone, or methane by themselves." Domagal-Goldman and Antígona Segura from the Universidad Nacional Autónoma de México in Mexico City are lead authors of a paper about this research, along with astronomer Victoria Meadows, geologist Mark Claire, and Tyler Robison, an expert on what Earth would look like as an extrasolar planet. The paper appeared in the Astrophysical Journal Sept. 10, and is available online.

Methane and oxygen molecules together are a reliable sign of biological activity because methane doesn't last long in an atmosphere containing oxygen-bearing molecules. "It's like college students and pizza," says Domagal-Goldman. "If you see pizza in a room, and there are also college students in that room, chances are the pizza was freshly delivered, because the students will quickly eat the pizza. The same goes for methane and oxygen. If both are seen together in an atmosphere, the methane was freshly delivered because the oxygen will be part of a network of reactions that will consume the methane. You know the methane is being replenished. The best way to replenish methane in the presence of oxygen is with life. The opposite is true, as well. In order to keep the oxygen around in an atmosphere that has a lot of methane, you have to replenish the oxygen, and the best way to do that is with life."

Scientists have used computer models to simulate the atmospheric chemistry on planets beyond our solar system (exoplanets) before, and the team used a similar model in its research. However, the researchers also developed a program to automatically compute the calculations thousands of times, so they could see the results with a wider range of atmospheric compositions and star types.

In doing these simulations, the team made sure they balanced the reactions that could put oxygen molecules in the atmosphere with the reactions that might remove them from the atmosphere. For example, oxygen can react with iron on the surface of a planet to make iron oxides; this is what gives most red rocks their color. A similar process has colored the dust on Mars, giving the Red Planet its distinctive hue. Calculating the appearance of a balanced atmosphere is important because this balance would allow the atmosphere to persist for geological time scales. Given that planetary lifetimes are measured in billions of years, it's unlikely astronomers will happen by chance to be observing a planet during a temporary surge of oxygen or methane lasting just thousands or even millions of years.

It was important to make the calculations for a wide variety of cases, because the non-biological production of oxygen is subject to both the atmospheric and stellar environment of the planet. If there are a lot of gases that consume oxygen, such as methane or hydrogen, then any oxygen or ozone produced will be destroyed in the atmosphere. However, if the amount of oxygen-consuming gases is vanishingly small, the oxygen and the ozone might stick around for a while. Likewise, the production and destruction of oxygen, ozone, and methane is driven by chemical reactions powered by light, making the type of star important to consider as well. Different types of stars produce the majority of their light at specific colors. For example, massive, hot stars or stars with frequent explosive activity produce more ultraviolet light. “If there is more ultraviolet light hitting the atmosphere, it will drive these photochemical reactions more efficiently,” said Domagal-Goldman. “More specifically, different colors (or wavelengths) of ultraviolet light can affect oxygen and ozone production and destruction in different ways.”

Astronomers detect molecules in exoplanet atmospheres by measuring the colors of light from the star the exoplanet is orbiting. As this light passes through the exoplanet's atmosphere, some of it is absorbed by atmospheric molecules. Different molecules absorb different colors of light, so astronomers use these absorption features as unique “signatures” of the type and quantity of molecules present.

“One of the main challenges in identifying life signatures is to distinguish between the products of life and those compounds generated by geological processes or chemical reactions in the atmosphere. For that we need to understand not only how life may change a planet but how planets work and the characteristics of the stars that host such worlds”, said Segura.

The team plans to use this research to make recommendations about the requirements for future space telescopes designed to search exoplanet atmospheres for signs of alien life. “Context is key – we can't just look for oxygen, ozone, or methane alone,” says Domagal-Goldman. “To confirm life is making oxygen or ozone, you need to expand your wavelength range to include methane absorption features. Ideally, you'd also measure other gases like carbon dioxide and carbon monoxide [a molecule with one carbon atom and one oxygen atom]. So we're thinking very carefully about the issues that could trip us up and give a false-positive signal, and the good news is by identifying them, we can create a good path to avoid the issues false positives could cause. We now know which measurements we need to make. The next step is figuring out what we need to build and how to build it.”

The research was funded in part by the NASA Astrobiology Institute's (NAI) Virtual Planetary Laboratory (VPL). The NAI is administered by NASA's Ames Research Center in Mountain View, California, and funded as part of the NASA Astrobiology Program at NASA Headquarters, Washington. The VPL is based at the University of Washington, and comprises researchers at 20 institutions working to understand how telescopic observations and modeling studies can determine if exoplanets are able to support life, or had life in the past. Additional support for the research was

provided by the NASA Postdoctoral Program, managed by Oak Ridge Associated Universities.

The team represented an international collaboration that included researchers from NASA Goddard, NASA Ames, the NAI/VPL, the Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, Mexico; the University of St. Andrews, St. Andrews, Scotland; and the University of Washington, Seattle.

For more information about the NASA Astrobiology Institute, visit:

http://astrobiology.nasa.gov/

The research paper is available online at:

http://stacks.iop.org/0004-637X/792/90

William SteigerwaldNASA's Goddard Space Flight Center, Greenbelt, Maryland

Gabriela FriasUniversidad Nacional Autonoma de Mexico, Mexico City

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Finds Friction from Tides Could Help Distant Earths Survive, and Thrive

5 min read

As anybody who has started a campfire by rubbing sticks knows, friction generates heat. Now, computer modeling by NASA scientists shows that friction could be the key to survival for some distant Earth-sized planets traveling in dangerous orbits.

The findings are consistent with observations that Earth-sized planets appear to be very common in other star systems. Although heat can be a destructive force for some planets, the right amount of friction, and therefore heat, can be helpful and perhaps create conditions for habitability.

“We found some unexpected good news for planets in vulnerable orbits,” said Wade Henning, a University of Maryland scientist working at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and lead author of the new study. “It turns out these planets will often experience just enough friction to move them out of harm’s way and into safer, more-circular orbits more quickly than previously predicted.”

Simulations of young planetary systems indicate that giant planets often upset the orbits of smaller inner worlds. Even if those interactions aren’t immediately catastrophic, they can leave a planet in a treacherous eccentric orbit – a very elliptical course that raises the odds of crossing paths with another body, being absorbed by the host star, or getting ejected from the system.

Another potential peril of a highly eccentric orbit is the amount of tidal stress a planet may undergo as it draws very close to its star and then retreats away. Near the star, the gravitational force is powerful enough to deform the planet, while in more distant reaches of the orbit, the planet can ease back into shape. This flexing action produces friction, which generates heat. In extreme cases, tidal stress can produce enough heat to liquefy the planet.

In this new study, available online in the July 1, 2014, issue of the Astrophysical Journal, Henning and his colleague Terry Hurford, a planetary scientist at Goddard, explored the effects of tidal stresses on planets that have multiple layers, such as rocky crust, mantle or iron core.

One conclusion of the study is that some planets could move into a safer orbit about 10 to 100 times faster than previously expected – in as a little as a few hundred thousand years, instead of the more typical rate of several million years. Such planets would be driven close to the point of melting or, at least, would have a nearly melted layer, similar to the one right below Earth’s crust. Their interior temperatures could range from moderately warmer than our planet is today up to the point of having modest-sized magma oceans.

The transition to a circular orbit would be speedy because an almost-melted layer would flex easily, generating a lot of friction-induced heat. As the planet threw off that heat, it would lose energy at a fast rate and relax quickly into a circular orbit. (Later, tidal heating would turn off, and the planet’s surface could become safe to walk on.)

In contrast, a world that had completely melted would be so fluid that it would produce little friction. Before this study, that is what researchers expected to happen to planets undergoing strong tidal stresses.

Cold, stiff planets tend to resist the tidal stress and release energy very slowly. In fact, Henning and Hurford found that many of them actually generate less friction than previously thought. This may be especially true for planets farther from their stars. If these worlds are not crowded by other bodies, they may be stable in their eccentric orbits for a long time.

“In this case, the longer, non-circular orbits could increase the ‘habitable zone,’ because the tidal stress will remain an energy source for longer periods of time,” said Hurford. “This is great for dim stars or ice worlds with subsurface oceans.”

Surprisingly, another way for a terrestrial planet to achieve high amounts of heating is to be covered in a very thick ice shell, similar to an extreme “snowball Earth.” Although a sheet of ice is a slippery, low-friction surface, an ice layer thousands of miles thick would be very springy. A shell like this would have just the right properties to respond strongly to tidal stress, generating a lot of heat. (The high pressures inside these planets could prevent all but the topmost layers from turning into liquid water.)

The researchers found that the very responsive layers of ice or almost-melted material could be relatively thin, just a few hundred miles deep in some cases, yet still dominate the global behavior.

The team modeled planets that are the size of Earth and up to two-and-a-half times larger. Henning added that superEarths – planets at the high end of this size range – likely would experience stronger tidal stresses and potentially could benefit more from the resulting friction and heating.

Now that the researchers have shown the importance of the contributions of different layers of a planet, the next step is to investigate how layers of melted material flow and change over time.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Frozen world discovered in binary star system

8 min read

NASA Science Editorial Team

From Ohio State University

A newly discovered planet in a binary star system located 3,000 light-years from Earth is expanding astronomers' notions of where Earth-like—and even potentially habitable—planets can form, and how to find them.

At twice the mass of Earth, the planet orbits one of the stars in the binary system at almost exactly the same distance from which Earth orbits the sun. However, because the planet's host star is much dimmer than the sun, the planet is much colder than the Earth—a little colder, in fact, than Jupiter's icy moon Europa.

Four international research teams, led by professor Andrew Gould of The Ohio State University, published their discovery in the July 4 issue of the journal Science.

The study provides the first evidence that terrestrial planets can form in orbits similar to Earth's, even in a binary star system where the stars are not very far apart. Although this planet itself is too cold to be habitable, the same planet orbiting a sun-like star in such a binary system would be in the so-called " habitable zone" —the region where conditions might be right for life.

"This greatly expands the potential locations to discover habitable planets in the future," said Scott Gaudi, professor of astronomy at Ohio State. "Half the stars in the galaxy are in binary systems. We had no idea if Earth-like planets in Earth-like orbits could even form in these systems. "

Very rarely, the gravity of a star focuses the light from a more distant star and magnifies it like a lens. Even more rarely, the signature of a planet appears within that magnified light signal. The technique astronomers use to find such planets is called gravitational microlensing , and computer modeling of these events is complicated enough when only one star and its planet are acting as the lens, much less two stars.

When the astronomers succeeded in detecting this new planet, they were able to document that it produced two separate signatures—the primary one, which they typically use to detect planets, and a secondary one that had previously been only hypothesized to exist.Searching for planets within binary systems is tricky for most techniques, because the light from the second star complicates the interpretation of the data. "But in gravitational microlensing," Gould explained, "we don't even look at the light from the star-planet system. We just observe how its gravity affects light from a more distant, unrelated, star. This gives us a new tool to search for planets in binary star systems."

The first was a brief dimming of light, as the planet's gravity disrupted one of the magnified images of the source star. But the second effect was an overall distortion of the light signal.

"Even if we hadn't seen the initial signature of the planet, we could still have detected it from the distortion alone," Gould said, pointing to a graph of the light signal. "The effect is not obvious. You can't see it by eye, but the signal is unmistakable in the computer modeling."

Gaudi explained the implications.

"Now we know that with gravitational microlensing, it's actually possible to infer the existence of a planet—and to know its mass, and its distance from a star—without directly detecting the dimming due to the planet," he said. "We thought we could do that in principle, but now that we have empirical evidence, we can use this method to find planets in the future."

The nature of these distortions is still somewhat of a mystery, he admitted.

"We don't have an intuitive understanding of why it works. We have some idea, but at this point, I think it would be fair to say that it's at the frontier of our theoretical work."

The planet, called OGLE-2013-BLG-0341LBb, first appeared as a "dip" in the line tracing the brightness data taken by the OGLE (Optical Gravitational Lensing Experiment) telescope on April 11, 2013. The planet briefly disrupted one of the images formed by the star it orbits as the system crossed in front of a much more distant star 20,000 light-years away in the constellation Sagittarius.

"Before the dip, this was just another microlensing event," Gould said. It was one of approximately 2,000 discovered every year by OGLE, with its new large-format camera that monitors 100 million stars many times per night searching for such events.

"It's really the new OGLE-IV survey that made this discovery possible," he added. "They got a half dozen measurements of that dip and really nailed it." From the form of the dip, whose "wings" were traced out in MOA (Microlensing Observations in Astrophysics) data, they could see that the source was headed directly toward the central star.

Then, for two weeks, astronomers watched the magnified light continue to brighten from telescopes in Chile, New Zealand, Israel and Australia. The teams included OGLE, MOA, MicroFUN (the Microlensing Follow Up Network), and the Wise Observatory .

Even then, they still didn't know that the planet's host star had another companion—a second star locked into orbit with it. But because they were already paying close attention to the signal, the astronomers noticed when the binary companion unexpectedly caused a huge eruption of light called a caustic crossing.

By the time they realized that the lens was not one star, but two, they had captured a considerable amount of data—and made a surprising discovery: the distortion.

Weeks after all signs of the planet had faded, the light from the binary-lens caustic crossing became distorted, as if there were a kind of echo of the original planet signal.

Intensive computer analysis by professor Cheongho Han at Chungbuk National University in Korea revealed that the distortion contained information about the planet—its mass, separation from its star, and orientation—and that information matched perfectly with what astronomers saw during their direct observation of the dip due to the planet. So the same information can be captured from the distortion alone.

This detailed analysis showed that the planet is twice the mass of Earth, and orbits its star from an Earth-like distance, around 90 million miles. But its star is 400 times dimmer than our sun, so the planet is very cold—around 60 Kelvin (-352 degrees Fahrenheit or -213 Celsius), which makes it a little colder than Jupiter's moon Europa. The second star in the star system is only as far from the first star as Saturn is from our sun. But this binary companion, too, is very dim.

Still, binary star systems composed of dim stars like these are the most common type of star system in our galaxy, the astronomers said. So this discovery suggests that there may be many more terrestrial planets out there—some possibly warmer, and possibly harboring life.

Three other planets have been discovered in binary systems that have similar separations, but using a different technique. This is the first one close to Earth-like size that follows an Earth-like orbit, and its discovery within a binary system by gravitational microlensing was by chance.

“Normally, once we see that we have a binary, we stop observing. The only reason we took such intensive observations of this binary is that we already knew there was a planet,” Gould said. “In the future we’ll change our strategy.”

In particular, Gould singled out the work of amateur astronomer and frequent collaborator Ian Porritt of Palmerston North, New Zealand, who watched for gaps in the clouds on the night of April 24 to get the first few critical measurements of the jump in the light signal that revealed that the planet was in a binary system. Six other amateurs from New Zealand and Australia contributed as well.

Other project collaborators hailed from Ohio State, Warsaw University Observatory, Chungbuk National University, Harvard-Smithsonian Center for Astrophysics, University of Cambridge, Universidad de Concepción, Auckland Observatory, Auckland University of Technology, University of Canterbury, Texas A&M; University, Korea Astronomy and Space Science Institute, Solar-Terrestrial Environment Laboratory, University of Notre Dame, Massey University, University of Auckland, National Astronomical Observatory of Japan, Osaka University, Nagano National College of Technology, Tokyo Metropolitan College of Aeronautics, Victoria University, Mt. John University Observatory, Kyoto Sangyo University, Tel-Aviv University, and the University of British Columbia.

Funding came from the National Science Foundation, NASA (including a NASA Sagan Fellowship), European Research Council, Polish Ministry of Science and Higher Education, National Research Foundation of Korea, U.S.-Israel Binational Science Foundation, Japan Society for the Promotion of Science, Marsden Fund from the Royal Society of New Zealand, and the Israeli Centers of Research Excellence.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Astronomers discover death dance of doomed planets

3 min read

NASA Science Editorial Team

Via Harvard-Smithsonian Center for Astrophysics

Two worlds orbiting a distant star are about to become a snack of cosmic proportions. Astronomers announced today that the planets Kepler-56b and Kepler-56c will be swallowed by their star in a short time by astronomical standards. Their ends will come in 130 million and 155 million years, respectively.

"As far as we know, this is the first time two known exoplanets in a single system have a predicted 'time of death,'" says lead author Gongjie Li of the Harvard-Smithsonian Center for Astrophysics (CfA).

She presented her research today in a press conference at a meeting of the American Astronomical Society.

The Kepler-56 system provides a glimpse into the future of our solar system. In about five billion years our Sun will become a red giant star, swelling to immense proportions and engulfing Mercury and Venus.

The star Kepler-56 is becoming a red giant star as well. It already has ballooned out to four times the Sun's size. As it ages, it will continue to expand outward. Not only will the star grow larger, but its tides will get stronger, dragging its planets inward to their eventual doom.

Kepler-56b orbits its host star once every 10.5 days, while Kepler-56c orbits every 21.4 days. Both of them are much closer to their star than Mercury is to the Sun. As a result, they will meet their fate much faster. Li and her collaborators calculated the evolution of both the star's size (using the publicly available MESA code) and the planets' orbits to predict when the planets will be destroyed.

Even before they vanish, the two planets will be subjected to immense heating from the steadily growing star. Their atmospheres will begin to boil off, and the planets themselves will be stretched into egg shapes by stellar tides.

The only survivor in the system will be Kepler-56d, a gas giant planet circling in a 3.3-Earth-year orbit. It will watch from a safe distance as its two sibling worlds meet their demise.

The Kepler-56 planetary system also is notable for being the first "tilted" multiplanet system to be discovered. The orbits of the inner two planets are tipped significantly from the star's equator. This was unexpected since planets form from the same disk of gas and dust as the star, so they should orbit in nearly the same plane as the star's equator (as do the planets in our solar system).

The team was able to better constrain the tilt of these planets, compared to earlier work. They found that the most probable tilt was either 37 or 131 degrees.

Li and her colleagues also investigated the inclination of the outer planet and determined that its orbit is likely to be tilted relative to the star as well. Future observations should help astronomers to characterize this system, and to explain how it became so skewed.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Q&A; Session About NASA’s WFIRST Mission

6 min read

Q&A; Session About NASA’s WFIRST Mission

Recently, Neil Gehrels, WFIRST Project Scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland, and Dominic Benford, the NASA Program Scientist at Headquarters, Washington, provided answers to questions about NASA’s upcoming WFIRST mission with a focus on the portion of the mission directed at better understanding dark energy. Dark energy is a mysterious pressure that appears to be making the universe expand at an ever-faster pace.

Q: What is WFIRST?

WFIRST stands for the Wide-Field Infrared Survey Telescope. It’s a NASA mission designed to study dark energy, perform galactic and extragalactic surveys, and explore exoplanets. WFIRST was originally configured with a telescope mirror of 1.5 meters across or smaller, but in 2012 NASA acquired two telescopes with 2.4-meter mirrors — as big as the Hubble Space Telescope’s — from the National Reconnaissance Office. Last year, NASA requested further study of the WFIRST mission under the assumption that it would use one of these telescopes. This version is now called WFIRST-AFTA (for Astrophysics Focused Telescope Assets).

Q: What things will WFIRST focus on?

A: WFIRST-AFTA will perform excellent observations related to dark energy, but it is important to point out that it will also do other kinds of science. As specified by “New World New Horizons,” the 2010 decadal survey of astronomy and astrophysics, the mission will have a tripod of science — dark energy, exoplanets and near-infrared surveys — for the astronomical community. The mission will carry out significant investigations in galaxy evolution, exoplanet surveying, exoplanet characterization, and astrophysics within our own galaxy, and it will have a robust guest investigator program.

Q: What about studying dark energy?

A: Astronomers observe that the expansion of the universe is accelerating and have proposed that what drives this acceleration is an all-pervasive form of energy — dark energy — that we do not yet understand. WFIRST-AFTA is a survey mission that will make the most precise measurements of how dark energy and dark matter — an as-yet-unidentified form of matter whose presence can be determined only through its gravitational effects — influence the universe. It is designed to conduct these observations using five observational strategies techniques: supernovae, baryon acoustic oscillations, weak lensing, redshift-space distortions, and the formation of galaxy clusters.

Q: How will type Ia supernovae survey help investigate the mystery of dark energy?

A: As with the discovery of dark energy in 1998, supernovae will be used as standard candles to measure the expansion rate of the universe. All type Ia supernovae emit almost the same amount of light. Measuring their brightness with WFIRST-AFTA will therefore tell us accurately how far away they are. We can trace out how the universe is expanding more rapidly at the present time than earlier in its history and use that to constrain models of dark energy.

Q: How does WFIRST’s resolution compare with previous/existing telescopes?

A: The use of the WFIRST-AFTA 2.4-meter telescope provides a very high angular resolution and wide field of view, exceeding what is possible with either the Hubble Space Telescope or the largest ground-based optical telescopes. This permits precision measurements such as weak lensing —

mapping distortions of galaxy images caused by the effect of intervening dark matter on their light — to be made with unprecedented sensitivity and accuracy.

WFIRST-AFTA complements the James Webb Space Telescope, which is expected to launch in 2018. Both missions achieve a hundred-fold improvement over the current capabilities of the Hubble. One way to think of it is that WFIRST-AFTA's view of the cosmos is wide and shallow, while JWST's is narrow and deep. The wide-field survey performed by WFIRST-AFTA will cover 200 times the sky area of the Hubble Ultra-Deep Field. JWST will take images and spectra 100 times more sensitive than Hubble.

Q: How do the three surveys to be undertaken by WFIRST complement one another?

A: WFIRST-AFTA uses a combination of techniques stemming from two surveys: a wide-field imaging survey, a wide-field slitless spectroscopy survey, and a repeated supernova photometry survey. (Slitless spectroscopy is astronomical spectroscopy done without a small slit to allow only light from a small region to be diffracted.) These complementary surveys allow scientists to use the multiple techniques to measure supernova distances, the scale size of baryon acoustic oscillations (BAO), the distribution of matter via weak lensing, the growth of redshift-space distortions, and cluster formation. The combined power of all of these probes will give the best understanding of dark energy in the current universe and how it evolved with time as the universe expanded. WFIRST-AFTA is the only observatory in space or on the ground that combines all of these probes.

Q: How will WFIRST study BAO? How will this compare to studies by the European Space Agency's planned Euclid mission and other existing telescopes?

A: The BAO study will be done by measuring the size of spherical disturbances in the universe (acoustic oscillations) left over from its early expansion. We will accurately measure the position and distance of a 100 million galaxies to map out these disturbances. WFIRST-AFTA and Euclid will make complementary observations, with WFIRST-AFTA observing fainter galaxies and Euclid observing more of the sky. The combined data set will be much larger and more accurate than any other BAO measurement.Q: What role do you see WFIRST playing in the ongoing search for dark energy?

A: Dark energy is an explanatory theory to allow us to understand what we observe about the expansion of the universe and the assembly of galaxies and clusters of galaxies across cosmic time. WFIRST-AFTA will make a suite of state-of-the-art measurements to probe dark energy and dark matter and their effects on the universe from the present day back more than 10 billion years. No other current project has the combination of breadth, depth, and scope to characterize the physics of dark energy and dark matter.

Q: Is WFIRST a NASA-only mission?

A: During the current mission concept studies, WFIRST is being reviewed as a NASA-only mission. NASA remains open to potential partnerships on WFIRST at the appropriate time.

Q: When is WFIRST expected to launch?

A: If authorized for a mission start in 2017, WFIRST-AFTA would launch in the early 2020s.

By Francis ReddyNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanets Soon to Gleam in the Eye of NESSI

4 min read

The New Mexico Exoplanet Spectroscopic Survey Instrument (NESSI) will soon get its first “taste” of exoplanets, helping astronomers decipher their chemical composition. Exoplanets are planets that orbit stars beyond our sun.

NESSI got its first peek at the sky on April 3, 2014. It looked at Pollux, a star in the Gemini constellation, and Arcturus, in the Boötes constellation, confirming that all modes of the instrument are working.

“After five years of development, it’s really exciting to turn on our instrument and see its first light,” said Michele Creech-Eakman, the principal investigator of the project at the New Mexico Institute of Mining and Technology in Socorro, N.M. “Planet hunters have found thousands of exoplanets, but what do we know about them? NESSI will help us find out more about their atmospheres and compositions.”

Partly funded by NASA’s EPSCoR (Experimental Program to Stimulate Competitive Research), in partnership with the New Mexico Institute of Mining and Technology, the NESSI instrument is located on the institute’s 2.4-meter Magdalena Ridge Observatory in Socorro County, N.M.

NESSI will focus on about 100 exoplanets, ranging from massive versions of Earth, called super-Earths, to scorching gas giants known as “hot Jupiters.” All of the instrument’s targets orbit closely to their stars. Future space telescopes will use similar technology to probe planets more akin to Earth, searching for signs of habitable environments and even life itself.

NESSI is one the first ground-based instruments specifically crafted to study the atmospheres of exoplanets that transit, or eclipse, their stars, from our point of view on Earth. It uses a technique called transit spectroscopy, in which a planet is observed as it crosses in front of, then behind, its parent star. The instrument, called a spectrometer, breaks apart the light of the star and planet, ultimately exposing chemicals that make up the planet’s atmosphere. The technique is challenging because a planet’s atmospheric signal accounts for only one part in 1,000 of the star’s light. It’s like looking for a firefly in a searchlight.

NASA’s Spitzer and Hubble Space Telescopes, though not designed for studying exoplanets, have used the same method from space, gathering data on far-off worlds. Because space is above the blurring and attenuation effects of Earth’s atmosphere, it is a better place than our planet to collect an exoplanet’s chemical or spectral information. But ground-based studies have advantages, too. They can be developed at lower costs and allow researchers to update instruments more easily.

To work around Earth’s atmospheric blurring problem, the NESSI instrument has a relatively wide field of view, covering a patch of sky about half the size of the full moon. This allows it to place two or more stars in its sight at once — both the star it is analyzing as the target planet circles around, and other control stars. When the atmosphere moves around during an observation, it affects both stars similarly. This allows the researchers to isolate and remove the blurring distortions.

NESSI will be able to see a wide range of wavelengths in the near-infrared region of the light spectrum. “We can probe multiple signatures of molecules all at the same time, a special feature of NESSI,” said Mark Swain, an astronomer on the NESSI project from NASA’s Jet Propulsion Laboratory, Pasadena, Calif.

The instrument includes a cryogenic dewar that will keep it super-cooled with liquid nitrogen. That’s an important factor for infrared-seeing telescopes, which are sensitive to heat.

Ten undergraduate students helped to make NESSI happen. “We’re watching the next generation of scientists and engineers get excited about exoplanets,” said Creech-Eakman. “Who knows what they will be able to see when they’re older — perhaps the atmospheres of potentially habitable worlds.”

The first exoplanet observations are expected to begin in the summer of 2014.

More information on NASA’s EPSCoR is at:
https://www.nasa.gov/offices/education/programs/national/epscor/home

More information about exoplanets is at: http://planetquest.jpl.nasa.gov

Whitney Clavin Jet Propulsion Laboratory, Pasadena, Calif. 818-354-4673
whitney.clavin@jpl.nasa.gov 2014-117

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NESSI – a new exoplanet finder in New Mexico

4 min read

NASA Science Editorial Team

The New Mexico Exoplanet Spectroscopic Survey Instrument (NESSI) will soon get its first "taste" of exoplanets, helping astronomers decipher their chemical composition. Exoplanets are planets that orbit stars beyond our sun.

NESSI got its first peek at the sky on April 3, 2014. It looked at Pollux, a star in the Gemini constellation, and Arcturus, in the Boötes constellation, confirming that all modes of the instrument are working.

"After five years of development, it's really exciting to turn on our instrument and see its first light," said Michele Creech-Eakman, the principal investigator of the project at the New Mexico Institute of Mining and Technology in Socorro, N.M. "Planet hunters have found thousands of exoplanets, but what do we know about them? NESSI will help us find out more about their atmospheres and compositions."

Partly funded by NASA's EPSCoR (Experimental Program to Stimulate Competitive Research), in partnership with the New Mexico Institute of Mining and Technology, the NESSI instrument is located on the institute's 2.4-meter Magdalena Ridge Observatory in Socorro County, N.M.

NESSI will focus on about 100 exoplanets, ranging from massive versions of Earth, called super-Earths, to scorching gas giants known as "hot Jupiters." All of the instrument's targets orbit closely to their stars. Future space telescopes will use similar technology to probe planets more akin to Earth, searching for signs of habitable environments and even life itself.

NESSI is one the first ground-based instruments specifically crafted to study the atmospheres of exoplanets that transit, or eclipse, their stars, from our point of view on Earth. It uses a technique called transit spectroscopy, in which a planet is observed as it crosses in front of, then behind, its parent star. The instrument, called a spectrometer, breaks apart the light of the star and planet, ultimately exposing chemicals that make up the planet's atmosphere. The technique is challenging because a planet's atmospheric signal accounts for only one part in 1,000 of the star's light. It's like looking for a firefly in a searchlight.

NASA's Spitzer and Hubble Space Telescopes, though not designed for studying exoplanets, have used the same method from space, gathering data on far-off worlds. Because space is above the blurring and attenuation effects of Earth's atmosphere, it is a better place than our planet to collect an exoplanet's chemical or spectral information. But ground-based studies have advantages, too. They can be developed at lower costs and allow researchers to update instruments more easily.

To work around Earth's atmospheric blurring problem, the NESSI instrument has a relatively wide field of view, covering a patch of sky about half the size of the full moon. This allows it to place two or more stars in its sight at once -- both the star it is analyzing as the target planet circles around, and other control stars. When the atmosphere moves around during an observation, it affects both stars similarly. This allows the researchers to isolate and remove the blurring distortions.

NESSI will be able to see a wide range of wavelengths in the near-infrared region of the light spectrum. "We can probe multiple signatures of molecules all at the same time, a special feature of NESSI," said Mark Swain, an astronomer on the NESSI project from NASA's Jet Propulsion Laboratory, Pasadena, Calif.

The instrument includes a cryogenic dewar that will keep it super-cooled with liquid nitrogen. That's an important factor for infrared-seeing telescopes, which are sensitive to heat.

Ten undergraduate students helped to make NESSI happen. "We're watching the next generation of scientists and engineers get excited about exoplanets," said Creech-Eakman. "Who knows what they will be able to see when they're older -- perhaps the atmospheres of potentially habitable worlds."

The first exoplanet observations are expected to begin in the summer of 2014.

More information on NASA's EPSCoR is at:
http://www.nasa.gov/offices/education/programs/national/epscor/home.

- By Whitney Clavin

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Odd Tilts Could Make More Worlds Habitable

4 min read

Pivoting planets that lean one way and then change orientation within a short geological time period might be surprisingly habitable, according to new modeling by NASA and university scientists affiliated with the NASA Astrobiology Institute.

The climate effects generated on these wobbling worlds could prevent them from turning into glacier-covered ice lockers, even if those planets are somewhat far from their stars. And with some water remaining liquid on the surface long-term, such planets could maintain favorable conditions for life.

“Planets like these are far enough from their stars that it would be easy to write them off as frozen, and poor targets for exploration, but in fact, they might be well-suited to supporting life,” said Shawn Domagal-Goldman, an astrobiologist at NASA’s Goddard Space Flight Center in Greenbelt, Md. “This could expand our idea of what a habitable planet looks like and where habitable planets might be found.”

The new modeling considers planets that have the same mass as Earth, orbit a sun-like star and have one or two gas giants orbiting nearby. In some cases, gravitational pulls from those massive planets could change the orientation of the terrestrial world’s axis of rotation within tens to hundreds of thousands of years – a blink of an eye in geologic terms.

Though it might seem far-fetched for a world to experience such see-sawing action, scientists have already spotted an arrangement of planets where this could happen, in orbit around the star Upsilon Andromedae. There, the orbits of two enormous planets were found to be inclined at an angle of 30 degrees relative to each other. (One planet was, as usual, farther from the star than the other planet.)

Compared to our solar system, that arrangement looks extreme. The orbits of Earth and its seven neighboring planets differ by 7 degrees at most. Even the tilted orbit of the dwarf planet Pluto, which really stands out, is offset by a relatively modest 17 degrees.

“Knowing that this kind of planetary system existed raised the question of whether a world could be habitable under such conditions,” said Rory Barnes, a scientist at the University of Washington in Seattle who was part of the team that studied the orbits of the two Andromedae planets.

The habitability concept is explored in a paper published in the April 2014 issue of Astrobiology and available online now. John Armstrong of Weber State University in Ogden, Utah, led the team, which includes Barnes, Domagal-Goldman, and other colleagues.

The team ran thousands of simulations for planets in 17 varieties of simplified planetary systems. The models the researchers built allowed them to adjust the tilt of the planetary orbits, the lean in the axes of rotation, and the ability of the terrestrial planet’s atmosphere to let in light.

In some cases, tilted orbits can cause a planet to wobble like a top that’s almost done spinning – and that wobbling should have a big impact on the planet’s glaciers and climate. Earth’s history indicates that the amount of sunlight glaciers receive strongly affects how much they grow and melt. Extreme wobbling, like that seen in some models in this study, would cause the poles to point directly at the sun from time to time, melting the glaciers. As a result, some planets would be able to maintain liquid water on the surface despite being located nearly twice as far from their stars as Earth is from the sun.

“In those cases, the habitable zone could be extended much farther from the star than we normally expect,” said Armstrong, the lead author of the paper. “Rather than working against habitability, the rapid changes in the orientation of the planet could turn out be a real boon sometimes.”

Elizabeth ZubritskyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

That’s no moon, that’s a…oh wait, maybe it is!

5 min read

NASA Science Editorial Team

Titan, Europa, Io and Phobos are just a few members of our solar system's pantheon of moons. Are there are other moons out there, orbiting planets beyond our sun?

NASA-funded researchers have spotted the first signs of an "exomoon," and though they say it's impossible to confirm its presence, the finding is a tantalizing first step toward locating others. The discovery was made by watching a chance encounter of objects in our galaxy, which can be witnessed only once.

"We won't have a chance to observe the exomoon candidate again," said David Bennett of the University of Notre Dame, Ind., lead author of a new paper on the findings appearing in the Astrophysical Journal. "But we can expect more unexpected finds like this."

The international study is led by the joint Japan-New Zealand-American Microlensing Observations in Astrophysics (MOA) and the Probing Lensing Anomalies NETwork (PLANET) programs, using telescopes in New Zealand and Tasmania. Their technique, called gravitational microlensing, takes advantage of chance alignments between stars. When a foreground star passes between us and a more distant star, the closer star can act like a magnifying glass to focus and brighten the light of the more distant one. These brightening events usually last about a month.

If the foreground star -- or what astronomers refer to as the lens -- has a planet circling around it, the planet will act as a second lens to brighten or dim the light even more. By carefully scrutinizing these brightening events, astronomers can figure out the mass of the foreground star relative to its planet.

In some cases, however, the foreground object could be a free-floating planet, not a star. Researchers might then be able to measure the mass of the planet relative to its orbiting companion: a moon. While astronomers are actively looking for exomoons -- for example, using data from NASA's Kepler mission - so far, they have not found any.

In the new study, the nature of the foreground, lensing object is not clear. The ratio of the larger body to its smaller companion is 2,000 to 1. That means the pair could be either a small, faint star circled by a planet about 18 times the mass of Earth -- or a planet more massive than Jupiter coupled with a moon weighing less than Earth.

The problem is that astronomers have no way of telling which of these two scenarios is correct.

"One possibility is for the lensing system to be a planet and its moon, which if true, would be a spectacular discovery of a totally new type of system," said Wes Traub, the chief scientist for NASA's Exoplanet Exploration Program office at NASA's Jet Propulsion Laboratory, Pasadena, Calif., who was not involved in the study. "The researchers' models point to the moon solution, but if you simply look at what scenario is more likely in nature, the star solution wins."

The answer to the mystery lies in learning the distance to the circling duo. A lower-mass pair closer to Earth will produce the same kind of brightening event as a more massive pair located farther away. But once a brightening event is over, it's very difficult to take additional measurements of the lensing system and determine the distance. The true identity of the exomoon candidate and its companion, a system dubbed MOA-2011-BLG-262, will remain unknown.

In the future, however, it may be possible to obtain these distance measurements during lensing events. For example, NASA's Spitzer and Kepler space telescopes, both of which revolve around the sun in Earth-trailing orbits, are far enough away from Earth to be great tools for the parallax-distance technique.

The basic principle of parallax can be explained by holding your finger out, closing one eye after the other, and watching your finger jump back and forth. A distant star, when viewed from two telescopes spaced really far apart, will also appear to move. When combined with a lensing event, the parallax effect alters how a telescope will view the resulting magnification of starlight. Though the technique works best using one telescope on Earth and one in space, such as Spitzer or Kepler, two ground-based telescopes on different sides of our planet can also be used.

Meanwhile, surveys like MOA and the Polish Optical Gravitational Experiment Lensing Experiment, or OGLE, are turning up more and more planets. These microlensing surveys have discovered dozens of exoplanets so far, in orbit around stars and free-floating. A previous NASA-funded study, also led by the MOA team, was the first to find strong evidence for planets the size of Jupiter roaming alone in space, presumably after they were kicked out of forming planetary systems. (See http://www.jpl.nasa.gov/news/news.php?release=2011-147).

The new exomoon candidate, if real, would orbit one such free-floating planet. The planet may have been ejected from the dusty confines of a young planetary system, while keeping its companion moon in tow.

The ground-based telescopes used in the study are the Mount John University Observatory in New Zealand and the Mount Canopus Observatory in Tasmania.

Additional observations were obtained with the W.M. Keck Observatory in Mauna Kea, Hawaii; European Southern Observatory's VISTA telescope in Chile; the Optical Gravitational Lens Experiment (OGLE) using the Las Campanas Observatory in Chile; the Microlensing Follow-Up Network (MicroFUN) using the Cerro Tololo Interamerican Observatory in Chile; and the Robonet Collaboration using the Faulkes Telescope South in Siding Spring, Australia.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Faraway Moon or Faint Star? Possible Exomoon Found

5 min read

Titan, Europa, Io and Phobos are just a few members of our solar system's pantheon of moons. Are there are other moons out there, orbiting planets beyond our sun?

NASA-funded researchers have spotted the first signs of an "exomoon," and though they say it's impossible to confirm its presence, the finding is a tantalizing first step toward locating others. The discovery was made by watching a chance encounter of objects in our galaxy, which can be witnessed only once.

"We won't have a chance to observe the exomoon candidate again," said David Bennett of the University of Notre Dame, Ind., lead author of a new paper on the findings appearing in the Astrophysical Journal. "But we can expect more unexpected finds like this."

The international study is led by the joint Japan-New Zealand-American Microlensing Observations in Astrophysics (MOA) and the Probing Lensing Anomalies NETwork (PLANET) programs, using telescopes in New Zealand and Tasmania. Their technique, called gravitational microlensing, takes advantage of chance alignments between stars. When a foreground star passes between us and a more distant star, the closer star can act like a magnifying glass to focus and brighten the light of the more distant one. These brightening events usually last about a month.

If the foreground star — or what astronomers refer to as the lens — has a planet circling around it, the planet will act as a second lens to brighten or dim the light even more. By carefully scrutinizing these brightening events, astronomers can figure out the mass of the foreground star relative to its planet.

In some cases, however, the foreground object could be a free-floating planet, not a star. Researchers might then be able to measure the mass of the planet relative to its orbiting companion: a moon. While astronomers are actively looking for exomoons — for example, using data from NASA's Kepler mission – so far, they have not found any.

In the new study, the nature of the foreground, lensing object is not clear. The ratio of the larger body to its smaller companion is 2,000 to 1. That means the pair could be either a small, faint star circled by a planet about 18 times the mass of Earth — or a planet more massive than Jupiter coupled with a moon weighing less than Earth.

The problem is that astronomers have no way of telling which of these two scenarios is correct.

"One possibility is for the lensing system to be a planet and its moon, which if true, would be a spectacular discovery of a totally new type of system," said Wes Traub, the chief scientist for NASA's Exoplanet Exploration Program office at NASA's Jet Propulsion Laboratory, Pasadena, Calif., who was not involved in the study. "The researchers' models point to the moon solution, but if you simply look at what scenario is more likely in nature, the star solution wins."

The answer to the mystery lies in learning the distance to the circling duo. A lower-mass pair closer to Earth will produce the same kind of brightening event as a more massive pair located farther away. But once a brightening event is over, it's very difficult to take additional measurements of the lensing system and determine the distance. The true identity of the exomoon candidate and its companion, a system dubbed MOA-2011-BLG-262, will remain unknown.

In the future, however, it may be possible to obtain these distance measurements during lensing events. For example, NASA's Spitzer and Kepler space telescopes, both of which revolve around the sun in Earth-trailing orbits, are far enough away from Earth to be great tools for the parallax-distance technique.

The basic principle of parallax can be explained by holding your finger out, closing one eye after the other, and watching your finger jump back and forth. A distant star, when viewed from two telescopes spaced really far apart, will also appear to move. When combined with a lensing event, the parallax effect alters how a telescope will view the resulting magnification of starlight. Though the technique works best using one telescope on Earth and one in space, such as Spitzer or Kepler, two ground-based telescopes on different sides of our planet can also be used.

Meanwhile, surveys like MOA and the Polish Optical Gravitational Experiment Lensing Experiment, or OGLE, are turning up more and more planets. These microlensing surveys have discovered dozens of exoplanets so far, in orbit around stars and free-floating. A previous NASA-funded study, also led by the MOA team, was the first to find strong evidence for planets the size of Jupiter roaming alone in space, presumably after they were kicked out of forming planetary systems. (See http://www.jpl.nasa.gov/news/news.php?release=2011-147).

The new exomoon candidate, if real, would orbit one such free-floating planet. The planet may have been ejected from the dusty confines of a young planetary system, while keeping its companion moon in tow.

The ground-based telescopes used in the study are the Mount John University Observatory in New Zealand and the Mount Canopus Observatory in Tasmania.

Additional observations were obtained with the W.M. Keck Observatory in Mauna Kea, Hawaii; European Southern Observatory's VISTA telescope in Chile; the Optical Gravitational Lens Experiment (OGLE) using the Las Campanas Observatory in Chile; the Microlensing Follow-Up Network (MicroFUN) using the Cerro Tololo Interamerican Observatory in Chile; and the Robonet Collaboration using the Faulkes Telescope South in Siding Spring, Australia.

Whitney Clavin 818-354-4673 Jet Propulsion Laboratory, Pasadena, Calif.
whitney.clavin@jpl.nasa.gov 2014-109

Nearby Star’s Icy Debris Suggests ‘Shepherd’ Planet

5 min read

An international team of astronomers exploring the disk of gas and dust around a nearby star have uncovered a compact cloud of poisonous gas formed by ongoing rapid-fire collisions among a swarm of icy, comet-like bodies. The researchers suggest the comet swarm is either the remnant of a crash between two icy worlds the size of Mars or frozen debris trapped and concentrated by the gravity of an as-yet-unseen planet.

Using the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile, the researchers mapped millimeter-wavelength light from dust and carbon monoxide (CO) molecules in a disk surrounding the bright star Beta Pictoris. Located about 63 light-years away and only 20 million years old, the star hosts one of the closest, brightest and youngest debris disks known, making it an ideal laboratory for studying the early development of planetary systems.

“Although toxic to us, carbon monoxide is one of many gases found in comets and other icy bodies,” said team member Aki Roberge, an astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Md. “In the rough-and-tumble environment around a young star, these objects frequently collide and generate fragments that release dust, icy grains and stored gases.”

The ALMA images reveal a vast belt of carbon monoxide located at the fringes of the Beta Pictoris system. Much of the gas is concentrated in a single clump located about 8 billion miles (13 billion kilometers) from the star, or nearly three times the distance between the planet Neptune and the sun. The total amount of CO observed, the scientists say, exceeds 200 million billion tons, equivalent to about one-sixth the mass of Earth’s oceans.

The presence of all this gas is a clue that something interesting is going on because ultraviolet starlight breaks up CO molecules in about 100 years, much faster than the main cloud can complete a single orbit around the star. “So unless we are observing Beta Pictoris at a very unusual time, then the carbon monoxide we observed must be continuously replenished,” said Bill Dent, a researcher at the Joint ALMA Office in Santiago, Chile, and the lead author of a paper published by Science Express on March 6.

Dent and his team calculate that to offset the destruction of CO molecules around Beta Pictoris, a large comet must be completely destroyed every five minutes. Only an unusually massive and compact swarm of comets could support such an astonishingly high collision rate.

Because we view the disk nearly edge-on, the ALMA data cannot determine whether the carbon monoxide belt has a single concentration of gas or two on opposite sides of the star. Further studies of the gas cloud’s orbital motion will clarify the situation, but current evidence favors a two-clump scenario.

In our own solar system, Jupiter’s gravity has trapped thousands of asteroids in two groups, one leading and one following the planet as it travels around the sun. A giant planet located in the outer reaches of the Beta Pictoris system likewise could corral comets into a pair of tight, massive swarms.

“Detailed dynamical studies are now under way, but at the moment we think this shepherding planet would be around Saturn’s mass and positioned near the inner edge of the CO belt,” said coauthor Mark Wyatt, an astronomer at the University of Cambridge in England.

Astronomers have directly imaged one giant planet, Beta Pictoris b, with a mass several times greater than Jupiter, orbiting much closer to the star. While it would be unusual for a giant planet to form up to 10 times farther away, as required to shepherd the massive comet clouds, the hypothetical planet could have formed near the star and migrated outward as the young disk underwent changes.

“We think the Beta Pictoris comet swarms formed when the hypothetical planet migrated outward, sweeping icy bodies into resonant orbits,” explained Wyatt. When the orbital periods of the comets matched the planet’s in some simple ratio – say, two orbits for every three of the planet – the comets received a nudge from the planet at the same location every orbit. Like regular pushes on a child’s swing, these accelerations amplify over time and work to confine the comets in a small region.

If, however, the gas actually turns out to reside in a single clump, the researchers suggest an alternative scenario. A crash between two Mars-sized icy planets about half a million years ago would account for the comet swarm, with frequent ongoing collisions among the fragments gradually releasing carbon monoxide gas.

Either way, Beta Pictoris clearly has a fascinating story to tell, and ALMA’s keen vision will help astronomers delve ever deeper into the tale.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers make the first Earth-based CCD images of an exoplanet

6 min read

NASA Science Editorial Team

From the University of Arizona

University of Arizona researchers snapped images of a planet outside our solar system with an Earth-based telescope using essentially the same type of imaging sensor found in digital cameras instead of an infrared detector. Although the technology still has a very long way to go, the accomplishment takes astronomers a small step closer to what will be needed to image earth-like planets around other stars.

"This is an important next step in the search for exoplanets because imaging in visible light instead of infrared is what we likely have to do if we want to detect planets that might be suitable for harboring life," said Jared Males, a NASA Sagan Fellow in the UA's Department of Astronomy and Steward Observatory and lead author on a report to be published in The Astrophysical Journal.

An image of the exoplanet Beta Pictoris b taken with the Magellan Adaptive Optics VisAO camera. This image was made using a CCD camera, which is essentially the same technology as a digital camera. The planet is nearly 100,000 times fainter than its star, and orbits its star at roughly the same distance as Saturn from our Sun. (Image: Jared Males/UA)

An image of the exoplanet Beta Pictoris b taken with the Magellan Adaptive Optics VisAO camera. This image was made using a CCD camera, which is essentially the same technology as a digital camera. The planet is nearly 100,000 times fainter than its star, and orbits its star at roughly the same distance as Saturn from our Sun. (Image: Jared Males/UA)

An image of the exoplanet Beta Pictoris b taken with the Magellan Adaptive Optics VisAO camera. This image was made using a CCD camera, which is essentially the same technology as a digital camera. The planet is nearly 100,000 times fainter than its star, and orbits its star at roughly the same distance as Saturn from our Sun. (Image: Jared Males/UA)

Even though the image was taken at a wavelength that is just shy of being visible to the human eye, the use of a digital camera-type imaging sensor – called a charge-coupled device or CCD – opens up the possibility of imaging planets in visible light, which has not been possible previously with Earth-based telescopes.

"This is exciting to astronomers because it means we now are a small step closer to being able to image planets outside our solar system in visible light," said Laird Close, a professor in the Department of Astronomy, who co-authored the paper.

He explained that all the other Earth-based images taken of exoplanets close to their stars are infrared images, which detect the planets' heat. This limits the technology to Gas Giants – massive, hot planets young enough to still shed heat. In contrast, older, possibly habitable planets that have cooled since their formation don't show up in infrared images as readily, and to image them, astronomers will have to rely on cameras capable of detecting visible light.

"Our ultimate goal is to be able to image what we call pale blue dots," Close said. "After all, the Earth is blue. And that's where you want to look for other planets: in reflected blue light."

The Magellan Telescope with the MagAO's Adaptive Secondary Mirror mounted at the top looking down some 30 feet onto the 21-foot diameter primary mirror, which is encased inside the blue mirror cell. (Photo: Yuri Beletsky, Las Campanas Observatory)

The photographed planet, called Beta Pictoris b, orbits its star at only nine times the Earth-Sun distance, making its orbit smaller than Saturn's. In the team's CCD images, Beta Pictoris b appears about 100,000 times fainter than its host star, making it the faintest object imaged so far at such high contrast and at such relative proximity to its star. The new images of this planet helped confirm that its atmosphere is at a temperature of roughly 2600 degrees Fahrenheit (1700 Kelvin). The team estimates that Beta Pictoris b weighs in at about 12 times the mass of Jupiter.

"Because the Beta Pictoris system is 63.4 light years from Earth, the scenario is equivalent to imaging a dime next right next to a lighthouse beam from more than four miles away," Males said. "Our image has the highest contrast ever achieved on an exoplanet that is so close to its star."

The contrast in brightness between the bright star and the faint planet is similar to the height of a 4-inch molehill next to Mount Everest, Close explained.

In addition to the host star's overwhelming brightness, the astronomers had to overcome the turbulence in Earth's atmosphere, which causes stars to twinkle and telescope images to blur. The success reported here is mostly due to an adaptive optics system developed by Close and his team that eliminates much of the atmosphere's effect. The Magellan Adaptive Optics technology is very good at removing this turbulence, or blurring, by means of a deformable mirror changing shape 1,000 times each second in real time.

Adaptive optics have been used for more than 20 years at observatories in Arizona, most recently at the Large Binocular Telescope, and the latest version has now been deployed in the high desert of Chile at the Magellan 6.5-meter telescope.

The team also imaged the planet with both of MagAO's cameras, giving the scientists two completely independent simultaneous images of the same object in infrared as well as bluer light to compare and contrast.

"An important part of the signal processing is proving that the tiny dot of light is really the planet and not a speckle of noise," said Katie Morzinski, who is also a Sagan Fellow and member of the MagAO team. "I obtained the second image in the infrared spectrum – at which the hot planet shines brightly – to serve as an unequivocal control that we are indeed looking at the planet. Taking the two images simultaneously helps to prove the planet image on the CCD is real and not just noise."

Males added: "In our case, we were able to record the planet's own glow because it is still young and hot enough so that its signal stood out against the noise introduced by atmospheric blurring."

"But when you go yet another 100,000 times fainter to spot much cooler and truly earthlike planets," Males said, "we reach a situation in which the residual blurring from the atmosphere is too large and we may have to resort to a specialized space telescope instead."

Development of the MagAO system was made possible through the strong support of the National Science Foundation MRI, TSIP and ATI grant programs. The Magellan telescopes are operated by a partnership of the Carnegie institute, the University of Arizona, Harvard University, Massachusetts Institute of Technology and the University of Michigan. The work of NASA Sagan Fellows Jared Males and Katie Morzinski was performed in part under contract with the California Institute of Technology funded by NASA through the Sagan Fellowship Program executed by the NASA Exoplanet Science Institute.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing.

Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Earth-like planets have Earth-like interiors

2 min read

NASA Science Editorial Team

Every school kid learns the basic structure of the Earth: a thin outer crust, a thick mantle, and a Mars-sized core. But is this structure universal? Will rocky exoplanets orbiting other stars have the same three layers? New research suggests that the answer is yes - they will have interiors very similar to Earth.

"We wanted to see how Earth-like these rocky planets are. It turns out they are very Earth-like," says lead author Li Zeng of the Harvard-Smithsonian Center for Astrophysics (CfA).

To reach this conclusion Zeng and his co-authors applied a computer model known as the Preliminary Reference Earth Model (PREM), which is the standard model for Earth's interior. They adjusted it to accommodate different masses and compositions, and applied it to six known rocky exoplanets with well-measured masses and physical sizes.

They found that the other planets, despite their differences from Earth, all should have a nickel/iron core containing about 30 percent of the planet's mass. In comparison, about a third of the Earth's mass is in its core. The remainder of each planet would be mantle and crust, just as with Earth.

"We've only understood the Earth's structure for the past hundred years. Now we can calculate the structures of planets orbiting other stars, even though we can't visit them," adds Zeng.

The new code also can be applied to smaller, icier worlds like the moons and dwarf planets in the outer solar system. For example, by plugging in the mass and size of Pluto, the team finds that Pluto is about one-third ice (mostly water ice but also ammonia and methane ices).

The model assumes that distant exoplanets have chemical compositions similar to Earth. This is reasonable based on the relevant abundances of key chemical elements like iron, magnesium, silicon, and oxygen in nearby systems. However, planets forming in more or less metal-rich regions of the galaxy could show different interior structures. The team expects to explore these questions in future research.

The paper detailing this work, authored by Li Zeng, Dimitar Sasselov, and Stein Jacobsen (Harvard University), has been accepted for publication in The Astrophysical Journal and is available online.

Headquartered in Cambridge, Mass., the Harvard-Smithsonian Center for Astrophysics (CfA) is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Message from Paul Hertz

3 min read

NASA Science Editorial Team

January 2014

Message from the Astrophysics Division Director

As astrophysicists, we are fortunate that our most compelling science questions – how does the universe work, how did the familiar sky of galaxies and stars come to be, are we alone – resonate with the American public and Government policy makers who support us. At this time, we are poised to answer these questions scientifically using the suite of large and small space-based observatories spanning the electromagnetic spectrum.

As I described during the NASA Town Hall at the 223rd meeting of the American Astronomical Society in National Harbor, MD, we have made progress towards addressing the priorities of the 2010 Decadal Survey for Astronomy and Astrophysics.•Preformulation and focused technology development for a 2.4m version of the Wide-Field Infrared Survey Telescope (WFIRST), a mission concept referred to as the Astrophysics Focused Telescope Assets (AFTA), are underway to enable a new start when funding becomes available as the James Webb Space Telescope approaches launch, no earlier than FY 2017. Reports from the Science Definition Team and other WFIRST information is available at http://wfirst.gsfc.nasa.gov/.•An augmentation has been made to the Explorer program to enable more frequent flight opportunities, including a planned SMEX AO later this year (see the community announcement at http://explorers.larc.nasa.gov/APSMEX/).•Strategic technology investments are being made and partnerships are being discussed with the European Space Agency in their gravitational wave and X-ray observatories.•Strategic technology investments are being made to advance the medium scale programs.•Modest augmentations have been made to small programs including the selection of six Theory and Computation Networks (co-funded by NSF). A goal of the Astrophysics Division is to be prepared to start a new strategic NASA Astrophysics mission to follow JWST as soon as funding becomes available, while continuing to advance Decadal Survey science during the interim.

The FY 2014 appropriations bill for NASA (being voted on as this message is being written) provides $658M for continued development of JWST toward its launch in 2018 and $668M for the rest of NASA astrophysics, including funding for continued preformulation of WFIRST. The FY 2014 budget also includes funding for several new missions including the Transiting Exoplanet Survey Satellite (TESS), the next Astrophysics Explorer mission, the Neutron Star Interior Explorer (NICER), the next Astrophysics Explorer Mission of Opportunity, and the NASA contribution to the European Space Agency’s Euclid mission.

The major impacts of the October 2013 Government shutdown included the cancellation of the 2013-2014 Antarctic balloon campaign including three long duration balloon flights; the cancellation of nine SOFIA science flights and a delay in the beginning of Cycle 2; a stand down in ASTRO-H soft x-ray spectrometer (SXS) integration and test that will result in a ~5 week delivery delay to JAXA; and delays in sending out research funding for those grantees whose awards were scheduled to start or be funded at the beginning of FY 2014.

Major activities planned for 2014 include the Astrophysics Senior Review of flight missions and release of a Small Explorer Announcement of Opportunity targeted for Fall 2014. A task force of the Astrophysics Subcommittee has completed a 30 year visionary roadmap, Enduring Quests, Daring Visions, to address enduring questions in Astrophysics.

My entire Town Hall Presentation from the January AAS meeting, as well as Enduring Quests, Daring Visions, is available at http://science.nasa.gov/astrophysics/documents/.

Paul HertzDirector, Astrophysics DivisionNASA Science Mission Directorate

NASA astronaut Nick Hague and Roscosmos cosmonaut Aleksandr Gorbunov will soon dock with the International Space Station as part of the agency's SpaceX Crew-9 mission, a venture which will enhance scientific research and bolster the knowledge about how people can live and work in space. During the planned five-month mission, Hague's mission tasks will include […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Powerful Planet Finder Turns Its Eye to the Sky

2 min read

After nearly a decade of development, construction and testing, the world's most advanced instrument for directly imaging and analyzing planets around other stars is pointing skyward and collecting light from distant worlds.

The instrument, called the Gemini Planet Imager (GPI), was designed, built, and optimized for imaging giant planets next to bright stars, in addition to studying dusty disks around young stars. It is the most advanced instrument of its kind to be deployed on one of the world's biggest telescopes – the 26-foot (8-meter) Gemini South telescope in Chile.

Imaging a planet next to a star is a tricky task. The planet is much fainter than its star, and also appears very close. These challenges make the act of separating the planet's light from the glare of the star difficult. NASA's Jet Propulsion Laboratory in Pasadena, Calif., contributed to the project by designing and building an ultra-precise infrared sensor to measure small distortions in starlight that might mask a planet.

"Our tasks were two-fold," said Kent Wallace, JPL's subsystem technical lead for the project. "First, keep the star centered on the instrument so that its glare is blocked as much as possible. Second, ensure the instrument itself is stable during the very long exposures required to image faint companions."

GPI detects infrared, or heat, radiation from young Jupiter-like planets in wide orbits around other stars. Those are equivalent to the giant planets in our own solar system not long after their formation. Every planet GPI sees can be studied in detail, revealing components of their atmospheres.

Although GPI was designed to look at distant planets, it can also observe objects in our solar system. Test images of Jupiter's moon Europa, for example, can allow scientists to map changes in the satellite's surface composition. The images were released today at the 223rd meeting of the American Astronomical Society in Washington.

Read the full news release from Gemini Observatory at http://www.gemini.edu/node/12113 .

Whitney Clavin 818-354-4673 Jet Propulsion Laboratory, Pasadena, Calif.
whitney.clavin@jpl.nasa.gov 2014-008

NASA-Sponsored ‘Disk Detective’ Lets Public Search for New Planetary Nurseries

5 min read

NASA is inviting the public to help astronomers discover embryonic planetary systems hidden among data from the agency’s Wide-field Infrared Survey Explorer (WISE) mission through a new website, DiskDetective.org.

Disk Detective is NASA’s largest crowdsourcing project whose primary goal is to produce publishable scientific results. It exemplifies a new commitment to crowdsourcing and open data by the United States government.

“Through Disk Detective, volunteers will help the astronomical community discover new planetary nurseries that will become future targets for NASA’s Hubble Space Telescope and its successor, the James Webb Space Telescope,” said James Garvin, the chief scientist for NASA Goddard’s Sciences and Exploration Directorate.

WISE was designed to survey the entire sky at infrared wavelengths. From a perch in Earth orbit, the spacecraft completed two scans of the entire sky between 2010 and 2011. It took detailed measurements on more than 745 million objects, representing the most comprehensive survey of the sky at mid-infrared wavelengths currently available.

Astronomers have used computers to search this haystack of data for planet-forming environments and narrowed the field to about a half-million sources that shine brightly in infrared, indicating they may be “needles”: dust-rich disks that are absorbing their star’s light and reradiating it as heat.

“Planets form and grow within disks of gas, dust and icy grains that surround young stars, but many details about the process still elude us,” said Marc Kuchner, an astrophysicist at NASA’s Goddard Space Flight Center in Greenbelt, Md. “We need more examples of planet-forming habitats to better understand how planets grow and mature.”

But galaxies, interstellar dust clouds and asteroids also glow in infrared, which stymies automated efforts to identify planetary habitats. There may be thousands of nascent solar systems in the WISE data, but the only way to know for sure is to inspect each source by eye, which poses a monumental challenge.

Public participation in scientific research is a type of crowdsourcing known as citizen science. It allows the public to make critical contributions to the fields of science, technology, engineering and mathematics by collecting, analyzing and sharing a wide range of data. NASA uses citizen science to engage the public in problem-solving.

Kuchner recognized that spotting planetary nurseries is a perfect opportunity for crowdsourcing. He arranged for NASA to team up with the Zooniverse, a collaboration of scientists, software developers and educators who collectively develop and manage citizen science projects on the Internet. The result of their combined effort is Disk Detective.

Disk Detective incorporates images from WISE and other sky surveys in brief animations the website calls flip books. Volunteers view a flip book and classify the object based on simple criteria, such as whether the image is round or includes multiple objects. By collecting this information, astronomers will be able to assess which sources should be explored in greater detail, for example, to search for planets outside our solar system.

“Disk Detective’s simple and engaging interface allows volunteers from all over the world to participate in cutting-edge astronomy research that wouldn’t even be possible without their efforts,” said Laura Whyte, director of citizen science at Adler Planetarium in Chicago, Ill., a founding partner of the Zooniverse collaboration.

The project aims to find two types of developing planetary environments. The first, known as a young stellar object disk, typically is less than 5 million years old, contains large quantities of gas, and often is found in or near young star clusters. For comparison, our own solar system is 4.6 billion years old. The second planetary environment, known as a debris disk, tends to be older than 5 million years, possesses little or no gas, and contains belts of rocky or icy debris that resemble the asteroid and Kuiper belts found in our own solar system. Vega and Fomalhaut, two of the brightest stars in the sky, host debris disks.

WISE was shut down in 2011 after its primary mission was completed. But in September 2013, it was reactivated, renamed Near-Earth Object Wide-field Infrared Survey Explorer (NEOWISE), and given a new mission, which is to assist NASA’s efforts to identify the population of potentially hazardous near-Earth objects (NEOs). NEOWISE also can assist in characterizing previously detected asteroids that could be considered potential targets for future exploration missions.

NASA’s Jet Propulsion Laboratory in Pasadena, Calif., manages and operates WISE for NASA’s Science Mission Directorate. The WISE mission was selected competitively under NASA’s Explorers Program managed by the agency’s Goddard Space Flight Center. The science instrument was built by the Space Dynamics Laboratory in Logan, Utah. The spacecraft was built by Ball Aerospace & Technologies Corp. in Boulder, Colo. Science operations and data processing take place at the Infrared Processing and Analysis Center at the California Institute of Technology, which manages JPL for NASA.

For more information about Disk Detective, please visit: http://www.diskdetective.org .

For more information about NASA’s WISE mission, visit: https://www.nasa.gov/wise .

Whitney Clavin 818-354-4673 Jet Propulsion Laboratory, Pasadena, Calif.
whitney.clavin@jpl.nasa.gov J.D. Harrington 202-358-5241 Headquarters, Washington
j.d.harrington@nasa.gov 2014-032

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Enigma of an exoplanet

5 min read

NASA Science Editorial Team

From University of Arizona

An international team of astronomers has discovered the most distantly orbiting planet found to date around a single, sun-like star.

Weighing in at 11 times Jupiter’s mass and orbiting its star at 650 times the average Earth-Sun distance, planet HD 106906 b is unlike anything in our own Solar System and throws a wrench in planet formation theories.

"This system is especially fascinating because no model of either planet or star formation fully explains what we see," said Vanessa Bailey, who led the research. Bailey is a fifth-year graduate student in the UA's Department of Astronomy.

It is thought that planets close to their stars, like Earth, coalesce from small asteroid-like bodies born in the primordial disk of dust and gas that surrounds a forming star. However, this process acts too slowly to grow giant planets far from their star. Another proposed mechanism is that giant planets can form from a fast, direct collapse of disk material. However, primordial disks rarely contain enough mass in their outer reaches to allow a planet like HD 106906 b to form. Several alternative hypotheses have been put forward, including formation like a mini binary star system.

"A binary star system can be formed when two adjacent clumps of gas collapse more or less independently to form stars, and these stars are close enough to each other to exert a mutual gravitation attraction and bind them together in an orbit," Bailey explained. "It is possible that in the case of the HD 106906 system the star and planet collapsed independently from clumps of gas, but for some reason the planet's progenitor clump was starved for material and never grew large enough to ignite and become a star."

According to Bailey, one problem with this scenario is that the mass ratio of the two stars in a binary system is typically no more than 10-to-1.

"In our case, the mass ratio is more than 100-to-1," she explained. "This extreme mass ratio is not predicted from binary star formation theories – just like planet formation theory predicts that we cannot form planets so far from the host star."

This system is also of particular interest because researchers can still detect the remnant “debris disk” of material left over from planet and star formation.

“Systems like this one, where we have additional information about the environment in which the planet resides, have the potential to help us disentangle the various formation models,” Bailey added. "Future observations of the planet's orbital motion and the primary star's debris disk may help answer that question."

At only 13 million years old, this young planet still glows from the residual heat of its formation. Because at 2,700 Fahrenheit (about 1,500 degrees Celsius) the planet is much cooler than its host star, it emits most of its energy as infrared rather than visible light. Earth, by comparison, formed 4.5 billion years ago and is thus about 350 times older than HD 106906 b.

Direct imaging observations require exquisitely sharp images, akin to those delivered by the Hubble Space Telescope. To reach this resolution from the ground requires a technology called Adaptive

Optics, or AO. The team used the new Magellan Adaptive Optics (MagAO) system and Clio2 thermal infrared camera – both technologies developed at the UA – mounted on the 6.5 meter-diameter Magellan telescope in the Atacama Desert in Chile to take the discovery image.

UA astronomy professor and MagAO principal investigator Laird Close said: “MagAO was able to utilize its special Adaptive Secondary Mirror, with 585 actuators, each moving 1,000 times a second, to remove the blurring of the atmosphere. The atmospheric correction enabled the detection of the weak heat emitted from this exotic exoplanet without confusion from the hotter parent star."

“Clio was optimized for thermal infrared wavelengths, where giant planets are brightest compared to their host stars, meaning planets are most easily imaged at these wavelengths,” explained UA astronomy professor and Clio principal investigator Philip Hinz, who directs the UA Center for Astronomical Adaptive Optics.

The team was able to confirm that the planet is moving together with its host star by examining Hubble Space Telescope data taken eight years prior for another research program. Using the FIRE spectrograph, also installed at the Magellan telescope, the team confirmed the planetary nature of the companion. “Images tell us an object is there and some information about its properties but only a spectrum gives us detailed information about its nature and composition,” explained co-investigator Megan Reiter, a graduate student in the UA Department of Astronomy. "Such detailed information is rarely available for directly imaged exoplanets, making HD 106906 b a valuable target for future study."

“Every new directly detected planet pushes our understanding of how and where planets can form," said co-investigator Tiffany Meshkat, a graduate student at Leiden Observatory in the Netherlands. "This planet discovery is particularly exciting because it is in orbit so far from its parent star. This leads to many intriguing questions about its formation history and composition. Discoveries like HD 106906 b provide us with a deeper understanding of the diversity of other planetary systems.”

The research paper, “HD 106906 b: A Planetary-mass Companion Outside a Massive Debris Disk,” has been accepted for publication in The Astrophysical Journal Letters and will appear in a future issue.

MagAO's development was funded by the National Science Foundation's Major Research Instrumentation program, and its Telescope System Instrumentation Program and an Advanced Technologies and Instrumentation Award.

The members of the discovery team are Vanessa Bailey (UA), Tiffany Meshkat (Leiden Observatory [LO]), Megan Reiter (UA), Katie Morzinski (UA), Jared Males (UA), Kate Y. L. Su (UA), Philip M. Hinz (UA), Matthew Kenworthy (LO), Daniel Stark (UA), Eric Mamajek (University of Rochester), Runa Briguglio (Arcetri Observatory [AO]), Laird M. Close (UA), Katherine B. Follette (UA), Alfio Puglisi (AO), Timothy Rodigas (UA, Carnegie Institute of Washington [CIW]), Alycia J. Weinberger (CIW), and Marco Xompero (AO).

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Traces Subtle Signals of Water on Hazy Worlds

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Using the powerful eye of NASA's Hubble Space Telescope, two teams of scientists have found faint signatures of water in the atmospheres of five distant planets.

The presence of atmospheric water was reported previously on a few exoplanets orbiting stars beyond our solar system, but this is the first study to conclusively measure and compare the profiles and intensities of these signatures on multiple worlds.

The five planets -- WASP-17b, HD209458b, WASP-12b, WASP-19b and XO-1b -- orbit nearby stars. The strengths of their water signatures varied. WASP-17b, a planet with an especially puffed-up atmosphere, and HD209458b had the strongest signals. The signatures for the other three planets, WASP-12b, WASP-19b and XO-1b, also are consistent with water.

"We're very confident that we see a water signature for multiple planets," said Avi Mandell, a planetary scientist at NASA's Goddard Space Flight Center in Greenbelt, Md., and lead author of an Astrophysical Journal paper, published today, describing the findings for WASP-12b, WASP-17b and WASP-19b. "This work really opens the door for comparing how much water is present in atmospheres on different kinds of exoplanets, for example hotter versus cooler ones."

The studies were part of a census of exoplanet atmospheres led by L. Drake Deming of the University of Maryland in College Park. Both teams used Hubble's Wide Field Camera 3 to explore the details of absorption of light through the planets' atmospheres. The observations were made in a range of infrared wavelengths where the water signature, if present, would appear. The teams compared the shapes and intensities of the absorption profiles, and the consistency of the signatures gave them confidence they saw water. The observations demonstrate Hubble's continuing exemplary performance in exoplanet research.

"To actually detect the atmosphere of an exoplanet is extraordinarily difficult. But we were able to pull out a very clear signal, and it is water," said Deming, whose team reported results for HD209458b and XO-1b in a Sept. 10 paper in the same journal. Deming's team employed a new technique with longer exposure times, which increased the sensitivity of their measurements.

The water signals were all less pronounced than expected, and the scientists suspect this is because a layer of haze or dust blankets each of the five planets. This haze can reduce the intensity of all signals from the atmosphere in the same way fog can make colors in a photograph appear muted. At the same time, haze alters the profiles of water signals and other important molecules in a distinctive way.

The five planets are hot Jupiters, massive worlds that orbit close to their host stars. The researchers were initially surprised that all five appeared to be hazy. But Deming and Mandell noted that other researchers are finding evidence of haze around exoplanets.

"These studies, combined with other Hubble observations, are showing us that there are a surprisingly large number of systems for which the signal of water is either attenuated or completely absent," said Heather Knutson of the California Institute of Technology, a co-author on Deming's paper. "This suggests that cloudy or hazy atmospheres may in fact be rather common for hot

Jupiters."

Hubble's high-performance Wide Field Camera 3 is one of few capable of peering into the atmospheres of exoplanets many trillions of miles away. These exceptionally challenging studies can be done only if the planets are spotted while they are passing in front of their stars. Researchers can identify the gases in a planet's atmosphere by determining which wavelengths of the star's light are transmitted and which are partially absorbed.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Storms galore

3 min read

NASA Science Editorial Team

Swirling, stormy clouds may be ever-present on cool celestial orbs called brown dwarfs. New observations from NASA's Spitzer Space Telescope suggest that most brown dwarfs are roiling with one or more planet-size storms akin to Jupiter's "Great Red Spot."

"As the brown dwarfs spin on their axis, the alternation of what we think are cloud-free and cloudy regions produces a periodic brightness variation that we can observe," said Stanimir Metchev of Western University, Ontario, Canada. "These are signs of patchiness in the cloud cover."

Metchev is principal investigator of the brown dwarf research. The results were presented at a news conference today at the 223rd annual meeting of the American Astronomical Society in Washington by Metchev's colleague, Aren Heinze, of Stony Brook University, New York.

Brown dwarfs form as stars do, but lack the mass to fuse atoms continually and blossom into full-fledged stars. They are, in some ways, the massive kin to Jupiter.

Scientists think that the cloudy regions on brown dwarfs take the form of torrential storms, accompanied by winds and, possibly, lightning more violent than that at Jupiter or any other planet in our solar system. However, the brown dwarfs studied so far are too hot for water rain; instead, astronomers believe the rain in these storms, like the clouds themselves, is made of hot sand, molten iron or salts.

In a Spitzer program named "Weather on Other Worlds," astronomers used the infrared space telescope to watch 44 brown dwarfs as they rotated on their axis for up to 20 hours. Previous results had suggested that some brown dwarfs have turbulent weather, so the scientists had expected to see a small fraction vary in brightness over time. However, to their surprise, half of the brown dwarfs showed the variations. When you take into account that half of the objects would be oriented in such a way that their storms would be either hidden or always in view and unchanging, the results indicate that most, if not all, brown dwarfs are racked by storms.

"We needed Spitzer to do this," said Metchev. "Spitzer is in space, above the thermal glow of the Earth's atmosphere, and it has the sensitivity required to see variations in the brown dwarfs' brightness."

The results led to another surprise as well. Some of the brown dwarfs rotated much more slowly than any previously measured, a finding that could not have been possible without Spitzer's long, uninterrupted observations from space. Astronomers had thought that brown dwarfs sped up to very fast rotations when they formed and contracted, and that this rotation didn't wind down with age.

"We don't yet know why these particular brown dwarfs spin so slowly, but several interesting possibilities exist," said Heinze. "A brown dwarf that rotates slowly may have formed in an unusual way -- or it may even have been slowed down by the gravity of a yet-undiscovered planet in a close orbit around it."

The work may lead to a better understanding of not just brown dwarfs but their "little brothers": the gas-giant planets. Researchers say that studying the weather on brown dwarfs will open new windows onto weather on planets outside our solar system, which are harder to study under the glare of their stars. Brown dwarfs are weather laboratories for planets, and, according to the new results, those laboratories are everywhere.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Residential Candidates

4 min read

NASA Science Editorial Team

Scientists from around the world are gathered this week at NASA's Ames Research Center in Moffett Field, Calif., for the second Kepler Science Conference, where they will discuss the latest findings resulting from the analysis of Kepler Space Telescope data.

Included in these findings is the discovery of 833 new candidate planets, which will be announced today by the Kepler team. Ten of these candidates are less than twice the size of Earth and orbit in their sun's habitable zone, which is defined as the range of distance from a star where the surface temperature of an orbiting planet may be suitable for liquid water.

At this conference two years ago, the Kepler team announced its first confirmed habitable zone planet, Kepler-22b. Since then, four more habitable zone candidates have been confirmed, including two in a single system.

New Kepler data analysis and research also show that most stars in our galaxy have at least one planet. This suggests that the majority of stars in the night sky may be home to planetary systems, perhaps some like our solar system.

"The impact of the Kepler mission results on exoplanet research and stellar astrophysics is illustrated by the attendance of nearly 400 scientists from 30 different countries at the Kepler Science Conference," said William Borucki, Kepler science principal investigator at Ames. "We gather to celebrate and expand our collective success at the opening of a new era of astronomy."

From the first three years of Kepler data, more than 3,500 potential worlds have emerged. Since the last update in January, the number of planet candidates identified by Kepler increased by 29 percent and now totals 3,538. Analysis led by Jason Rowe, research scientist at the SETI Institute in Mountain View, Calif., determined that the largest increase of 78 percent was found in the category of Earth-sized planets, based on observations conducted from May 2009 to March 2012. Rowe's findings support the observed trend that smaller planets are more common.

An independent statistical analysis of nearly all four years of Kepler data suggests that one in five stars like the sun is home to a planet up to twice the size of Earth, orbiting in a temperate environment. A research team led by Erik Petigura, doctoral candidate at University of California, Berkeley, used publicly accessible data from Kepler to derive this result.

Kepler data also fueled another field of astronomy dubbed asteroseismology -- the study of the interior of stars. Scientists examine sound waves generated by the boiling motion beneath the surface of the star. They probe the interior structure of a star just as geologists use seismic waves generated by earthquakes to probe the interior structure of Earth.

"Stars are the building blocks of the galaxy, driving its evolution and providing safe harbors for planets. To study the stars, one truly explores the galaxy and our place within it," said William Chaplin, professor for astrophysics at the University of Birmingham in the United Kingdom. "Kepler has revolutionized asteroseismology by giving us observations of unprecedented quality, duration and continuity for thousands of stars. These are data we could only have dreamt of a few years ago."

Kepler's mission is to determine what percentage of stars like the sun harbor small planets the approximate size and temperature of Earth. For four years, the space telescope simultaneously and continuously monitors the brightness of more than 150,000 stars, recording a measurement every

30 minutes. More than a year of the collected data remains to be fully reviewed and analyzed.

For more information about the second Kepler Science Conference, visit:http://nexsci.caltech.edu/conferences/KeplerII/index.shtml

For more information about the Kepler mission and to view the digital press kit, visit:http://www.nasa.gov/kepler

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exoplanet hunter says discovery of another Earth is within our reach

3 min read

NASA Science Editorial Team

What does it take to find life in the universe? Dr. Sara Seager of MIT is working hard to find out. Seager was recently interviewed by NPR's Science Friday at NASA's Jet Propulsion Laboratory in Pasadena, Calif. Sara believes the current search for exoplanets has broader implications for our future. “It's a special time for us here on Earth. It's the first time in human history that we actually have the technological capability to find other Earths, to identify them as Earths, and to hope to look for signs of life on the first handful or the first dozens or hundreds of exoplanets, and that's a special time in history. So I'm trying to do what I can to make sure that happens now.”

Where are we in the search for exoplanets?

Recently teams of scientists determined that one in five sun-like stars likely have an Earth-sized planet in the habitable zone. According to Seager, “all evidence points to the fact that small planets are extremely common, they are literally everywhere.” How many planets have we found? It depends on how you count them, but, Seager said, “the better statement for everyone is we're confident that every single star in our Milky Way galaxy has at least one planet.”

How do we look for life on other planets?

We will look for life by peering into the atmospheres of exoplanets in an effort to find gases that don't belong. For example, on Earth oxygen is 20 percent of our atmosphere. If we didn't have photosynthetic processes (used by plants and other organisms to convert sunlight into energy) then the level of oxygen in our atmosphere would be almost zero. There are a variety of gases the scientific community is considering as important in the search for extraterrestrial life.

One way in which Seager thinks we could accomplish this is through direct imaging with a starshade, "a big, big 30 meter shade that will fly tens of thousands of kilometers from a telescope … it would search nearby stars directly for an Earth and it would be able to get the spectrum and to see if there's life there.” The starshade allows us to image planets by blocking out the bright light of the parent star. It is one concept currently being studied by NASA to image the atmospheres of exoplanets. Another is a coronagraph that is internal to the telescope.

What do we do if we find a planet with life?

Even if we find evidence indicating that life may exist on another planet, we won't be able to tell if life is basic, complex, or intelligent. But it will give us a start on answering the question of whether there is intelligent life.

Additionally, Seager said we could feasibly communicate with another planet (SETI for example), but that it would be a slow conversation. If a planet is ten light-years away, it would take ten years for our message to be delivered and then another ten years for a reply if they answer right away.

For more discussion on these topics and more, listen to the entire Science Friday interview here: http://www.sciencefriday.com/segment/11/15/2013/searching-for-earth-2-0.html

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's

other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Odds are on Oodles of Earths

7 min read

NASA Science Editorial Team

From Keck Observatory

Scientists from University of California, Berkeley, and University of Hawaii, Manoa, have statistically determined that twenty percent of Sun-like stars in our galaxy have Earth-sized planets that could host life. The findings, gleaned from data collected from NASA’s Kepler spacecraft and the W. M. Keck Observatory, now satisfy Kepler's primary mission: to determine how many of the 100 billion stars in our galaxy have potentially habitable planets. The results are being published November 4 in the journal Proceedings of the National Academy of Sciences.

"What this means is, when you look up at the thousands of stars in the night sky, the nearest sun-like star with an Earth-size planet in its habitable zone is probably only 12 light years away and can be seen with the naked eye. That is amazing," said UC Berkeley graduate student Erik Petigura, who led the analysis of the Kepler and Keck Observatory data.

"For NASA, this number – that every fifth star has a planet somewhat like Earth – is really important, because successor missions to Kepler will try to take an actual picture of a planet, and the size of the telescope they have to build depends on how close the nearest Earth-size planets are," said Andrew Howard, astronomer with the Institute for Astronomy at the University of Hawaii. "An abundance of planets orbiting nearby stars simplifies such follow-up missions."

The team, which also included planet hunter Geoffrey Marcy, UC Berkeley professor of astronomy, cautioned that Earth-size planets in Earth-size orbits are not necessarily hospitable to life, even if they orbit in the habitable zone of a star where the temperature is not too hot and not too cold.

"Some may have thick atmospheres, making it so hot at the surface that DNA-like molecules would not survive. Others may have rocky surfaces that could harbor liquid water suitable for living organisms," Marcy said. "We don't know what range of planet types and their environments are suitable for life."

Just last week, Howard, Marcy and their colleagues provided hope that many such planets actually are rocky. They reported that one Earth-sized planet discovered – albeit, a planet with a likely temperature of 2,000 Kelvin, which is far too hot for life as we know it – is the same density as Earth and most likely composed of rock and iron, like Earth.

"This gives us some confidence that when we look out into the habitable zone, the planets Erik is describing may be Earth-size, rocky planets," Howard said.

NASA launched the now crippled Kepler space telescope in 2009 to look for planets that cross in front of, or transit, their stars, which causes a slight diminution – about one hundredth of one percent – in the star's brightness. From among the 150,000 stars photographed every 30 minutes for four years, NASA's Kepler team reported more than 3,000 planet candidates. Many of these are much larger than Earth – ranging from large planets with thick atmospheres, like Neptune, to gas giants like Jupiter – or in orbits so close to their stars that they are roasted.

To sort them out, Petigura and his colleagues are using the twin, 10-meter telescopes of the Keck Observatory on the summit of Mauna Kea, Hawaii to obtain HIRES spectra of as many stars as possible. This will help them determine each star's true brightness and calculate the diameter of each transiting planet, with an emphasis on Earth-diameter planets.

HIRES (the High-Resolution Echelle Spectrometer) produces spectra of single objects at very high spectral resolution, yet covering a wide wavelength range. It does this by separating the light into many "stripes" of spectra stacked across a mosaic of three large CCD detectors. HIRES is famous for finding planets orbiting other stars. Astronomers also use HIRES to study distant galaxies and quasars, finding clues to the Big Bang.

The team focused on the 42,000 stars that are like the sun or slightly cooler and smaller, and found 603 candidate planets orbiting them. Only 10 of these were Earth-size, that is, one to two times the diameter of Earth and orbiting their star at a distance where they are heated to lukewarm temperatures suitable for life. The team's definition of habitable is that a planet receives between four times and one-quarter the amount of light that Earth receives from the sun.

The analysis subjected Petigura's planet-finding algorithms to a battery of tests in order to measure how many habitable zone, Earth-size planets they missed. Petigura actually introduced fake planets into the Kepler data in order to determine which ones his software could detect and which it couldn't.

"What we're doing is taking a census of extrasolar planets, but we can't knock on every door. Only after injecting these fake planets and measuring how many we actually found, could we really pin down the number of real planets that we missed," Petigura said.

Accounting for missed planets, as well as the fact that only a small fraction of planets are oriented so that they cross in front of their host star as seen from Earth, allowed them to estimate that 22 percent of all sun-like stars in the galaxy have Earth-size planets in their habitable zones.

"The primary goal of the Kepler mission was to answer the question, When you look up in the night sky, what fraction of the stars that you see have Earth-size planets at lukewarm temperatures so that water would not be frozen into ice or vaporized into steam, but remain a liquid, because liquid water is now understood to be the prerequisite for life," Marcy said. "Until now, no one knew exactly how common potentially habitable planets were around Sun-like stars in the galaxy."

All of the potentially habitable planets found in their survey are around K stars, which are cooler and slightly smaller than the sun, Petigura said. But the team's analysis shows that the result for K stars can be extrapolated to G stars like the sun. Had Kepler survived for an extended mission, it would have obtained enough data to directly detect a handful of Earth-size planets in the habitable zones of G-type stars.

If the stars in the Kepler field are representative of stars in the solar neighborhood, then the nearest (Earth-size) planet is expected to orbit a star that is less than 12 light-years from Earth and can be seen by the unaided eye. Future instrumentation to image and take spectra of these Earths need only observe a few dozen nearby stars to detect a sample of Earth-size planets residing in the habitable zones of their host stars.

In January, the team reported a similar analysis of Kepler data for scorched planets that orbit close to their stars. The new, more complete analysis shows that "nature makes about as many planets in hospitable orbits as in close-in orbits," Howard said.

The W. M. Keck Observatory operates the largest, most scientifically productive telescopes on Earth. The two, 10-meter optical/infrared telescopes on the summit of Mauna Kea on the Island of Hawaii feature a suite of advanced instruments including imagers, multi-object spectrographs, high-resolution spectrographs, integral-field spectroscopy and world-leading laser guide star adaptive optics systems. The Observatory is a private 501(c) 3 non-profit organization and a scientific partnership of the California Institute of Technology, the University of California and NASA.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing.

Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Rare Snapshot of a Planetary Construction Site

4 min read

NASA Science Editorial Team

From the Max Planck Institute for Astronomy

Planets are formed in disks of gas and dust around nascent stars. Now, combined observations with the compound telescope ALMA and the Herschel Space Observatory have produced a rare view of a planetary construction site in an intermediate state of evolution: Contrary to expectations, the disk around the star HD 21997 appears to contain both primordial gas left over from the formation of the star itself and dust that appears to have been produced in collisions between planetesimals – small rocks that are the building blocks for the much larger planets. This is the first direct observation of such a "hybrid disk", and likely to require a revision of current models of planet formation.

When a star similar to our Sun is born, it is surrounded by a disk of dust and gas. Within that disk, the star's planetary system begins to form: The dust grains stick together to build larger, solid, kilometer-sized bodies known as planetesimals. Those either survive in the form of asteroids and comets, or clump together further to form solid planets like our Earth, or the cores of giant gas planets.

Current models of planet formation predict that, as a star reaches the planetesimal stage, the original gas should quickly be depleted. Some of the gas falls into the star, some is caught up by what will later become giant gas planets like Jupiter, and the rest is dispersed into space, driven by the young star's intense radiation. After 10 million years or so, all the original gas should be gone.

But now a team of astronomers from the Netherlands, Hungary, Germany, and the US has found what appears to be a rare hybrid disk, which contains plenty of original gas, but also dust produced much later in the collision of planetesimals. As such, it qualifies as a link between an early and a late phase of disk evolution: the primordial disk and a later debris phase.

The astronomers used both ESA's Herschel Space Observatory and the compound telescope ALMA in Chile to study the disk around the star HD 21997, which lies in the Southern constellation Fornax, at a distance of 235 light-years from Earth. HD 21997 has 1.8 times the mass of our Sun and is around 30 million years old.

The Herschel and ALMA observations show a broad dust ring surrounding the star at distances between about 55 and 150 astronomical units (one astronomical unit is the average Earth-Sun distance). But the ALMA observations also show a gas ring. Surprisingly, the two do not coincide: "The gas ring starts closer to the central star than the dust," explains Ágnes Kóspál from ESA, principal investigator of the ALMA proposal. "If the dust and the gas had been produced by the same physical mechanism, namely by the erosion of planetesimals, we would have expected them to be at the same location. This is clearly not the case in the inner disk."

Attila Moór from Konkoly Observatory adds: "Our observations also showed that previous studies had grossly underestimated the amount of gas present in the disk. Using carbon monoxide as a tracer molecule, we find that the total gas mass is likely to amount to between 30 and 60 times the mass of the Earth." That value is another indication that the gas disk is made of primordial material – gas set free in collisions between planetesimals could never explain this substantial quantity.

Thomas Henning from the Max-Planck Institute for Astronomy says: "The presence of primordial gas around the 30 million-year-old star HD 21997 is puzzling. Both model predictions and previous observations show that the gas in this kind of disk around a young star should be depleted within about 10 million years."

The team is currently working on finding more systems like HD 21997 for further studies of hybrid disks, and to find out how they fit within the current paradigm of planet formation – or the ways in which the models need to be changed.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Patchy and Puffy

4 min read

NASA Science Editorial Team

Astronomers using data from NASA's Kepler and Spitzer space telescopes have created the first cloud map of a planet beyond our solar system, a sizzling, Jupiter-like world known as Kepler-7b.

The planet is marked by high clouds in the west and clear skies in the east. Previous studies from Spitzer have resulted in temperature maps of planets orbiting other stars, but this is the first look at cloud structures on a distant world.

"By observing this planet with Spitzer and Kepler for more than three years, we were able to produce a very low-resolution 'map' of this giant, gaseous planet," said Brice-Olivier Demory of Massachusetts Institute of Technology in Cambridge. Demory is lead author of a paper accepted for publication in the Astrophysical Journal Letters. "We wouldn't expect to see oceans or continents on this type of world, but we detected a clear, reflective signature that we interpreted as clouds."

Kepler has discovered more than 150 exoplanets, which are planets outside our solar system, and Kepler-7b was one of the first. The telescope's problematic reaction wheels prevent it from hunting planets any more, but astronomers continue to pore over almost four years' worth of collected data.

Kepler's visible-light observations of Kepler-7b's moon-like phases led to a rough map of the planet that showed a bright spot on its western hemisphere. But these data were not enough on their own to decipher whether the bright spot was coming from clouds or heat. The Spitzer Space Telescope played a crucial role in answering this question.

Like Kepler, Spitzer can fix its gaze at a star system as a planet orbits around the star, gathering clues about the planet's atmosphere. Spitzer's ability to detect infrared light means it was able to measure Kepler-7b's temperature, estimating it to be between 1,500 and 1,800 degrees Fahrenheit (1,100 and 1,300 Kelvin). This is relatively cool for a planet that orbits so close to its star -- within 0.06 astronomical units (one astronomical unit is the distance from Earth and the sun) -- and, according to astronomers, too cool to be the source of light Kepler observed. Instead, they determined, light from the planet's star is bouncing off cloud tops located on the west side of the planet.

"Kepler-7b reflects much more light than most giant planets we've found, which we attribute to clouds in the upper atmosphere," said Thomas Barclay, Kepler scientist at NASA's Ames Research Center in Moffett Field, Calif. "Unlike those on Earth, the cloud patterns on this planet do not seem to change much over time -- it has a remarkably stable climate."

The findings are an early step toward using similar techniques to study the atmospheres of planets more like Earth in composition and size.

"With Spitzer and Kepler together, we have a multi-wavelength tool for getting a good look at planets that are trillions of miles away," said Paul Hertz, director of NASA's Astrophysics Division in Washington. "We're at a point now in exoplanet science where we are moving beyond just detecting exoplanets, and into the exciting science of understanding them."

Kepler identified planets by watching for dips in starlight that occur as the planets transit, or pass in front of their stars, blocking the light. This technique and other observations of Kepler-7b previously revealed that it is one of the puffiest planets known: if it could somehow be placed in a tub of water, it would float. The planet was also found to whip around its star in just less than five days.

Explore all 900-plus exoplanet discoveries with NASA's "Eyes on Exoplanets," a fully rendered 3D visualization tool, available for download at http://eyes.nasa.gov/exoplanets. The program is updated daily with the latest findings from NASA's Kepler mission and ground-based observatories around the world as they search for planets like our own.

Other authors include: Julien de Wit, Nikole Lewis, Andras Zsom and Sara Seager of Massachusetts Institute of Technology; Jonathan Fortney of the University of California, Santa Cruz; Heather Knutson and Jean-Michel Desert of the California Institute of Technology, Pasadena; Kevin Heng of the University of Bern, Switzerland; Nikku Madhusudhan of Yale University, New Haven, Conn.; Michael Gillon of the University of Liège, Belgium; Vivien Parmentier of the French National Center for Scientific Research, France; and Nicolas Cowan of Northwestern University, Evanston, Ill. Lewis is also a NASA Sagan Fellow.

The technical paper is online at http://iopscience.iop.org/article/10.1088/2041-8205/776/2/L25.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Earth first

3 min read

NASA Science Editorial Team

Astronomers have discovered the first Earth-size planet outside the solar system that has a rocky composition like that of Earth. Kepler-78b whizzes around its host star every 8.5 hours, making it a blazing inferno and not suitable for life as we know it. The results are published in two papers in the journal Nature.

"The news arrived in grand style with the message: 'Kepler-10b has a baby brother,'" said Natalie Batalha, Kepler mission scientist at NASA's Ames Research Center in Moffett Field, Calif. Batalha led the team that discovered Kepler-10b, a larger but also rocky planet identified by the Kepler spacecraft.

"The message expresses the joy of knowing that Kepler's family of exoplanets is growing," Batalha reflects. "It also speaks of progress. The Doppler teams are attaining higher precision, measuring masses of smaller planets at each turn. This bodes well for the broader goal of one day finding evidence of life beyond Earth."

Kepler-78b was discovered using data from NASA’s Kepler space telescope, which for four years simultaneously and continuously monitored more than 150,000 stars looking for telltale dips in their brightness caused by crossing, or transiting, planets.

Two independent research teams then used ground-based telescopes to confirm and characterize Kepler-78b. To determine the planet's mass, the teams employed the radial velocity method to measure how much the gravitation tug of an orbiting planet causes its star to wobble. Kepler, on the other hand, determines the size or radius of a planet by the amount of starlight blocked when it passes in front of its host star.

A handful of planets the size or mass of Earth have been discovered. Kepler-78b is the first to have both a measured mass and size. With both quantities known, scientists can calculate a density and determine what the planet is made of.

Kepler-78b is 1.2 times the size of Earth and 1.7 times more massive, resulting in a density that is the same as Earth's. This suggests that Kepler-78b is also made primarily of rock and iron. Its star is slightly smaller and less massive than the sun and is located about 400 light-years from Earth in the constellation Cygnus.

One team led by Andrew Howard from the University of Hawaii in Honolulu, made follow-up observations using the W. M. Keck Observatory atop Mauna Kea in Hawaii. More information on their research can be found here.

The other team led by Francesco Pepe from the University of Geneva, Switzerland, did their ground-base work at the Roque de los Muchachos Observatory on La Palma in the Canary Islands. More information on their research can be found here.

This result will be one of many discussed next week at the second Kepler science conference Nov. 4-8 at Ames. More than 400 astrophysicists from Australia, China, Europe, Latin America and the US will convene to present their latest results using publicly accessible data from Kepler. To learn more about the conference, please visit the website.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing.

Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Super Time for Super-Earths

12 min read

NASA Science Editorial Team

From Astrobiology Magazine

The headlines have been coming thick and fast – a trio of super-Earths in the habitable zone of Gliese 667C, two probably rocky planets in the Goldilocks zone around Kepler-62 and possible super-Earths orbiting Tau Ceti and HD 40307 at just the right distance for liquid water to exist on their surfaces, albeit under certain conditions. These are all just from the past twelve months. Should those exoplanet hunters who are seeking out Earth 2, a planet where life as we know it could possibly exist, start to feel excited?

Not yet. Our knowledge of these planets is woefully incomplete. However, the times may be changing. While we cannot yet determine whether a planet is hospitable to life, David Kipping of the Harvard–Smithsonian Center for Astrophysics has led a team of astronomers to develop a new theoretical model that can tell us with one swift glance whether a super-Earth – a world with two to ten times the mass of our planet and up to twice the diameter – has an atmosphere that might not be suitable for life. Consequently we could rule such worlds out of our search for analogs to Earth. It's all about whether a planet has an atmosphere and how that atmosphere is connected to the relationship between a planet's mass and diameter.

The two main exoplanet detecting techniques are beautifully complementary. When a planet transits its star – that is, passes in front of its star, blocking a fraction of the starlight – we can determine the diameter of the planet from the size of the transit. Meanwhile, that orbiting planet also exerts a gravitational tug on its parent star. If we can detect that tug we can calculate the planet's mass based on the extent by which the planet is pulling on the star.

The only problem is that not all planets orbit their star at an appropriate angle for us to see a transit, while some exoplanets and their stars are too distant and faint for us to accurately measure their 'radial velocity' tug (many of the Kepler spacecraft's candidate planets fall into this category). However, for those worlds where we are fortunate to know both properties, we can work out a planet's volume and then divide the mass by the calculated volume to determine the planet's density, which tells us whether it is likely rocky, gaseous or icy.

The model that Kipping has developed, along with Harvard's Dimitar Sasselov and Princeton's David Spiegel, allows an astronomer to plug in these numbers for mass and radius and, with the knowledge of the density, figure out if a planet – in particular a super-Earth – has a light but extended atmosphere or a relatively thin, heavy atmosphere.

That's important because Earth's atmosphere is the latter kind – a hundred kilometer layer filled with the likes of nitrogen, oxygen, carbon dioxide, argon, water vapor and neon that contributes just 1.5 percent of Earth's radius. We don't know if an extended atmosphere of mostly hydrogen and helium – similar to Uranus' or Neptune's atmospheres but warmer – could support life, and so searches for Earth's twin may want to avoid such worlds.

Solid, liquid or gas

The way Kipping, Sasselov and Spiegel's model makes use of a graph that plots a planet's mass against its radius, and where a world falls on that graph, tells us whether it is solid rock, partly watery or has a significant fraction of gas.

“There’s a full range of models that we think a super-Earth can be built out of,” says Kipping. “You can make them out of iron, or out of silicate, or out of water, or some mixture of those things.”

However, when a planet transits a star, not only does the solid body of the planet block some of the starlight, but so too does its atmosphere. By simply detecting the planet’s silhouette we cannot automatically figure out which part is solid and which part is gaseous atmosphere. The mass-radius diagram, however, offers a way around this problem.

Kipping and his cohorts have calculated theoretical limits – boundary conditions – for each type of planet. The lower boundary condition denotes a super-Earth made of solid rock with an iron core and lacking an atmosphere. The top boundary signifies a planet made entirely of water that, says Kipping, is probably impossible – there needs to be a solid core in there somewhere – and thus you cannot get a super-Earth less dense than a water-world (purely gaseous planets, it is thought, cannot exist as small as super-Earths and even Neptune-type worlds have a large rocky core lurking inside them). Therefore, if you discover a planet and plot its mass against its radius only to discover that it resides on the graph above the impossible pure-water line, then the only way to explain its apparent density given its radius is that it must have a large atmosphere.

Such mass-radius models have been around for a while, but what makes Kipping’s different is that they are based on a new understanding of the physics of materials placed under the enormous amounts of pressure that the interior of a super-Earth would impose on them. Dimitar Sasselov, along with his student Li Zeng, was able to create superior models of the interior of super-Earths using new laboratory technology that is able to simulate those pressures. They published their work in the March 2013 issue of the Publications of the Astronomical Society of the Pacific and Kipping’s mass-radius diagram, itself to be published in the Monthly Notices of the Royal Astronomical Society, is modeled around those interior structures derived by Sasselov and Zeng.

What does the model tell us about super-Earths we have already discovered? Kipping, Spiegel and Sasselov concentrated on GJ 1214b, a world with six and a half times the mass and two and a half times the diameter of our planet that is orbiting a red dwarf star 47 light years away. Prior to now the planet had been a puzzle – no matter what wavelength it was observed in, the size of the planet was always the same, which shouldn’t happen because an atmosphere should be more opaque to some wavelengths than others. Was its atmosphere extended and topped with thick, opaque clouds, or was its atmosphere thin enough not to be noticed? Employing the mass–radius diagram settles the matter.

“Our method says that 20 percent of this planet’s radius is pure atmosphere, which strongly favors the idea of a very light, extended hydrogen-helium atmosphere with clouds on top,” says Kipping. “So we are able to come into this discussion with these two possibilities and say which is more likely, just based on the simple measurement of the mass and the radius of the planet.”

Uncertain data

Another intriguing world is Kepler-22b, which was the first habitable zone planet to be discovered by NASA’s Kepler spacecraft. Around 620 light years from Earth, it orbits a Sun-like star at a distance of 0.85 astronomical units (one astronomical unit is the average distance between Earth and the Sun, 149.6 million kilometers) and has a diameter two and a half times that of our planet.

“We tried to apply our technique to this planet but unfortunately the mass measurement is very poor because it is a very distant star,” says Kipping. “What we found was that the data was unable to say one way or another what kind of planet it is; it sits right on the blue [water-world] line, so we can’t tell whether it is a rocky planet with an extended atmosphere or a water-world with very little atmosphere.”

Unfortunately that’s also the story for the rest of the potentially habitable planets discovered so far, a list of which is maintained by Professor Abel Mendez of the Planetary Habitability Laboratory at the University of Puerto Rico at Arecibo, in the form of the Habitable Exoplanets Catalog. A dozen planets currently reside on the list, meeting the criteria of being (probably) rocky and existing within their star's habitable zone. However, as we found with Kepler-22b, in most cases either the mass or the radius is little more than an estimate, and as such the majority tend to sit on that boundary condition.

"Astronomers estimate mass or radius from the assumption that smaller planets are more rocky in composition and those larger planets close to two Earth radii are water-worlds," says Mendez. "This seems to be a good estimate for most cases but there is a lot of uncertainty; for example, Kepler-11f has just over two Earth masses but it is a gas planet, while Kepler-20b with about nine Earth masses is rocky."

Kipping's mass–radius diagram is only half the job. Without good data the new mass-radius relationship is limited in what it can tell us. For Kepler planets, better mass measurements from radial velocities are required, but this is tricky given that most of the stars around which Kepler discovers planets are faint and distant. For those worlds discovered by radial velocity, we need more luck in observing transits to give us their diameter. The approval of the Transiting Exoplanet Survey Satellite (TESS), which is scheduled to launch in 2017 and will systematically survey all the brightest stars in the sky for transiting planets, will be a massive boon to the field.

"The TESS mission promises to dramatically change this picture," says Heather Knutson, a planetary astronomer at the California Institute of Technology whose research is focused in the area of exoplanet atmospheres. "At the moment there are currently only three transiting super-Earths that are suitable for detailed characterization and all three have been observed with either the Spitzer or Hubble space telescopes, or both. In the era of TESS we will have far more super-Earths than we can reasonably study and Kipping's criterion will provide a useful means to select targets that are likely to have detectable atmospheric signatures."

The launch of the James Webb Space Telescope (JWST) a year after TESS will also dramatically boost the nascent science of exoplanetary atmospheric investigations. JWST, with its 6.5-meter mirror, will extend its observations well into the near-infrared, perfect for picking up the tenuous signatures of water, methane, oxygen, carbon monoxide and carbon dioxide in atmospheres, which could be interpreted as biosignatures depending upon their concentrations. TESS will identify the planets, the mass-radius model will decide which ones we want to observe, and JWST will tell us about them. It is going to be an exciting time and the wait will be excruciating for scientists.

"At this point almost anything is possible!" enthuses Knutson.

Finding a potentially habitable planet

There are many factors that go into making a planet habitable, from the presence of a magnetic field to protect its atmosphere to the question of whether it has plate tectonics to recycle carbon. A stable rotational axis, a moderate impact rate and sufficient gravity are also plausible necessities. Yet, the possession of an atmosphere, especially one that contains some form of greenhouse gas, is one of the most crucial factors, essential for maintaining cosily warm temperatures that permit all-important liquid water to exist on its surface. That said, the range of suitable atmospheres may not be as narrow as we may think.

"I don't think that thick hydrogen–helium atmospheres will rule out the potential for life on these planets as long as the pressure at the surface/water transition allows for liquid water," says Mendez.

So a super-Earth, with a thick envelope of hydrogen swathing a rocky core deep down could still have watery conditions at depths where the pressure, according to Mendez, drops below 10,000 atmospheres, although of course temperature will also have a say where and if this transition point occurs.

There is one more intriguing possibility. On Earth, convection currents and air flows are strongly influenced by what is on the surface, be it oceans, continents or mountains. Could a careful study of the atmosphere of a super-Earth tell us things about the terrain below that are otherwise beyond the capabilities of our telescopes?

“Yes, potentially, but the atmosphere would need to be thin enough for our observations to detect the atmosphere flows from the region close to the surface,” says Knutson, who also points out that a thin atmosphere will be transparent enough for us to spectroscopically measure the surface of the planet and determine whether there are oceans, desert or even plant life.

“When we get these new super telescopes in the future [such as the Thirty Meter Telescope, the Giant Magellan Telescope and the European Extremely Large Telescope] we’ll be able to go down to sort of Earth-like atmospheres,” adds Kipping. “In special cases we could probably go down to these very small atmospheres that are potentially life-harboring.”

But we’re getting ahead of ourselves; the new mass–radius model only provides us with a way of saying which planets don’t have a thin atmosphere. If we come to the conclusion that a super-Earth does not have an extended atmosphere, then it might be worth pointing JWST at it to measure the spectrum of any atmosphere present and see whether it is analogous to Earth’s atmosphere.

“If you are really hunting Earth-like planets and our method tells you it has a big extended atmosphere, then you are probably wasting your time,” says Kipping. “So it’s a way of making our searches for Earth-analogues more efficient.”

With TESS and JWST and the next generation of extremely large telescopes on the horizon, Kipping’s new model is timely indeed. The way things are going, the next decade might be the decade of the super-Earth. All the hints are it is going to be an exciting time.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Detecting biomarkers on faraway exoplanets

3 min read

NASA Science Editorial Team

From EPSC

On Earth, life leaves tell-tale signals in the atmosphere. Photosynthesis is ultimately responsible for the high oxygen levels and the thick ozone layer. Microbes emit methane and nitrous oxide into the atmosphere, and seaweeds emit chloromethane gas. These chemicals, when present in sufficient quantities, are indicators of life and are known as atmospheric biomarkers. Detecting them in the atmosphere of an exoplanet should, in theory, be a means of discovering whether life exists on any alien worlds.

While biomarkers have never been spotted in observations of an exoplanet, because their signal is so faint, the new generation of telescopes being planned today, such as the European Extremely Large Telescope, may be sensitive enough to detect them. New research presented to the European Planetary Science Congress at UCL by Lee Grenfell (DLR) aims to explore how such biomarkers might be detected in future.

“The main aim of our work is to assess the possible range of biomarker signals that might be detected by future telescopes,” Grenfell explains. “To do this, we developed computer models of exoplanets which simulate the abundances of different biomarkers and the way they affect the light shining through a planet’s atmosphere.”

Chemicals in a planet’s atmosphere affect light that passes through it, leaving characteristic chemical fingerprints in the star’s spectrum. Using this technique, astronomers have already deduced a wealth of information about the conditions present in (large, hot) exoplanets. Biomarkers would be detected in much the same way, but here the signal is expected to be so weak that scientists will need a solid understanding based on theoretical models before they can hope to decipher the actual data.

“In our simulations, we modelled an exoplanet similar to the Earth, which we then placed in different orbits around stars, calculating how the biomarker signals respond to differing conditions,” Grenfell explains. “We focused on red-dwarf stars, which are smaller and fainter than our Sun, since we expect any biomarker signals from planets orbiting such stars to be easier to detect.”

For detections of the biomarker ozone, the team confirms that there appears to be a ‘Goldilocks’ effect when it comes to the amount of ultraviolet radiation from the star to which the planet is exposed. With weak UV radiation, less ozone is produced in the atmosphere and its detection is challenging. Too much UV leads to increased heating in the middle atmosphere that weakens the vertical gradient and destroys the signal. At intermediate UV, the conditions are ‘just right’ for detecting ozone.

“We find that variations in the UV emissions of red-dwarf stars have a potentially large impact on atmospheric biosignatures in simulations of Earth-like exoplanets. Our work emphasizes the need for future missions to characterise the UV emissions of this type of star,” said Grenfell.

There are other limitations on using this method to detect signs of life. For example, it is assuming that any life-bearing planets would be identical to Earth, which is not guaranteed. Moreover, scientists will have to be certain that apparent biomarker signals they find truly arose from life, and not from other, non-living processes. Finally, dim red dwarf stars may not be the most suitable for the onset and maintenance of life. Nevertheless, this technique is an extremely promising one for detecting potential signs of life on alien worlds.

Grenfell concludes: “For the first time we are reaching a point where serious scientific debate can be applied to address the age-old question: are we alone?”

This research has been submitted to the journal Planetary & Space Science (2013) “Planetary Evolution and Life” Special Issue.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Tamer in twos: Binary Stars May Be Havens for Habitability

4 min read

Pat Brennan

It’s a classic moment in sci-fi history: Luke Skywalker ponders his future as two blazing suns sink beneath the horizon of the desert planet Tatooine.

Astronomers have found exoplanets orbiting multiple stars before, but research from a team led by Paul Mason of New Mexico State University including researchers of the Universidad de Antioquia (Colombia) has found that life among binary stars, as envisioned in Star Wars, might be more feasible than originally thought.

In fact, being part of a stellar pair might help turn otherwise tempestuous and unruly stars into good hosts for Earth-like worlds.

Comprising some three-quarters of all the stars in the galaxy, red dwarfs are thought to be great places to search for Earth-size planets. Their small size and cool temperature may make it easier for astronomers to find planets that would otherwise be lost in the glare of larger stars.

But while red dwarfs may be small, they’re anything but demure. Red dwarfs appear to blast their planets with massive pulses of radiation, which over time can strip away planet atmospheres and cause life-sustaining liquid water to evaporate away.

A major reason for these outbursts is the fact that red dwarfs spin much more rapidly than larger and more languid stars like our sun. While the sun completes one rotation every month, red dwarfs take only a few days. “When a star spins quickly, it creates a magnetic field with a large corona - giving it a really powerful solar wind,” Mason said. And while stars rotate more slowly as they age, red dwarfs have incredibly long lifespans -- by the time they begin to relax, it may be too late for life to form in that solar system.

These findings have dampened some of astronomers’ enthusiasm that red dwarf stars may harbor a bonanza of Earth-like planets.

But there may be hope for the unruly red dwarf. Mason and his team have found that being part of a binary star system may tame some of these stars’ more destructive tendencies.

“When stars orbit closely to one another, their gravitational forces interact,” Mason said. “The tidal effect between two stars in a binary system can slow down a star that would otherwise be spinning too fast.”

This process can reign in an otherwise rapidly spinning star, an effect that Mason calls “premature aging.” In the period of just a few hundred million years, a dangerously active red dwarf star could “age” into a one much more accommodating to an Earth-like world. “The star’s not actually getting older, it just seems older, as its spin and radiation are reduced earlier in its lifetime.”

Even for larger stars, like our sun, being part of a binary system might be a boon for the formation of Earth-like worlds, reducing the amount of time the star spends as a rapidly-spinning, highly-radioactive youth and easing it more quickly into the relative quiescence of middle-age, giving potential habitable planets a chance of surviving with atmospheres and liquid water intact.

“The advantage to this setup is that you could have a wetter habitable zone with multiple planets in it than you’d see with a single star,” Mason said. “A planet like Venus, which is outside the habitable zone of our sun, might be more Earth-like in the right kind of binary system.”

Of course, Mason warns, not all binary stars are friendly places for Earth-like planets. “If the stars are too close together and have a period of less than ten days, they’ll keep spinning quickly and have a strong solar wind ... they’ll stay ‘forever young’ and that’s very bad for a habitable planet.

“And stars that are too far away from each other won’t affect each other’s spin, so the slowdown effect won’t happen.”

Still, the findings suggest new hope for the habitability of exoplanets orbiting otherwise hostile red dwarfs and tantalize with the possibility of a new and improved “Goldilocks zone” lurking around certain binary stars.

Mason’s findings were published under the title “Rotational Synchronization May Enhance Habitability for Circumbinary Planets: Kepler Binary Case Studies”. The paper can be viewed here:

http://arxiv.org/abs/1307.4624

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Seeing Blue: Exoplanet With Water-Rich Atmosphere Observed

4 min read

NASA Science Editorial Team

From National Astronomical Observatory of Japan

A Japanese research team of astronomers and planetary scientists has used Subaru Telescope's two optical cameras, Suprime-Cam and the Faint Object Camera and Spectrograph (FOCAS), with a blue transmission filter to observe planetary transits of super-Earth GJ 1214 b (Gilese 1214 b). The team investigated whether this planet has an atmosphere rich in water or hydrogen. The Subaru observations show that the sky of this planet does not show a strong Rayleigh scattering feature, which a cloudless hydrogen-dominated atmosphere would predict. When combined with the findings of previous observations in other colors, this new observational result implies that GJ 1214 b is likely to have a water-rich atmosphere.

Super-Earths are emerging as a new type of exoplanet (i.e., a planet orbiting a star outside of our Solar System) with a mass and radius larger than the Earth's but less than those of ice giants in our Solar System, such as Uranus or Neptune. Whether super-Earths are more like a "large Earth" or a "small Uranus" is unknown, since scientists have yet to determine their detailed properties. The current Japanese research team of astronomers and planetary scientists focused their efforts on investigating the atmospheric features of one super-Earth, GJ 1214 b, which is located 40 light years from Earth in the constellation Ophiuchus, northwest of the center of our Milky Way galaxy. This planet is one of the well-known super-Earths discovered by Charbonneau et. al. (2009) in the MEarth Project, which focuses on finding habitable planets around nearby small stars. The current team's research examined features of light scattering of GJ 1214 b's transit around its star.

Current theory posits that a planet develops in a disk of dense gas surrounding a newly formed star (i.e., a protoplanetary disk). The element hydrogen is a major component of a protoplanetary disk, and water ice is abundant in an outer region beyond a so-called "snow line." Findings about where super-Earths have formed and how they have migrated to their current orbits point to the prediction that hydrogen or water vapor is a major atmospheric component of a super-Earth. If scientists can determine the major atmospheric component of a super-Earth, they can then infer the planet's birthplace and formation history.

Planetary transits enable scientists to investigate changes in the wavelength in the brightness of the star (i.e., transit depth), which indicate the planet's atmospheric composition. Strong Rayleigh scattering in the optical wavelength is powerful evidence for a hydrogen-dominated atmosphere. Rayleigh scattering occurs when light particles scatter in a medium without a change in wavelength. Such scattering strongly depends on wavelength and enhances short wavelengths; it causes greater transit depth in the blue rather than in the red wavelength.

The current team used the two optical cameras Suprime-Cam and FOCAS on the Subaru Telescope fitted with a blue transmission filter to search for the Rayleigh scattering feature of GJ 1214 b's atmosphere. This planetary system's very faint host star in blue light poses a challenge for researchers seeking to determine whether or not the planet's atmosphere has strong Rayleigh scattering. The large, powerful light-collecting 8.2 m mirror of the Subaru Telescope allowed the team to achieve the highest-ever sensitivity in the bluest region.

The team's observations showed that GJ 1214 b's atmosphere does not display strong Rayleigh scattering. This finding implies that the planet has a water-rich or a hydrogen-dominated atmosphere with extensive clouds.

Although the team did not completely discount the possibility of a hydrogen-dominated atmosphere, the new observational result combined with findings from previous research in other colors suggests that GJ 1214 b is likely to have a water-rich atmosphere. The team plans to conduct follow-up observations in the near future to reinforce their conclusion. Although there are only a small number of super-Earths that scientists can observe in the sky now, this situation will dramatically change when the Transiting Exoplanet Survey Satellite (TESS) begins its whole sky survey of small transiting exoplanets in our solar neighborhood. When new targets become available, scientists can study the atmospheres of many super-Earths with the Subaru Telescope and next generation, large telescopes such as the Thirty Meter Telescope (TMT). Such observations will allow scientists to learn even more about the nature of various super-Earths.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Blurred lines: exoplanet or star?

4 min read

NASA Science Editorial Team

From NASA Jet Propulsion Laboratory

In 2011, astronomers on the hunt for the coldest star-like celestial bodies discovered a new class of such objects using NASA's Wide-Field Infrared Survey Explorer (WISE) space telescope. But until now, no one knew exactly how cool the bodies' surfaces really are. In fact, some evidence suggested they could be at room temperature.

A new study using data from NASA's Spitzer Space Telescope shows that while these so-called brown dwarfs are indeed the coldest known free-floating celestial bodies, they are warmer than previously thought, with surface temperatures ranging from about 250 to 350 degrees Fahrenheit (125 to 175 degrees Celsius). By comparison, the sun has a surface temperature of about 10,340 degrees Fahrenheit (5,730 degrees Celsius).

To reach these surface temperatures after cooling for billions of years, these objects would have to have masses of only five to 20 times that of Jupiter. Unlike the sun, the only source of energy for these coldest of brown dwarfs is from their gravitational contraction, which depends directly on their mass. The sun is powered by the conversion of hydrogen to helium; these brown dwarfs are not hot enough for this type of "nuclear burning" to occur.

The findings help researchers understand how planets and stars form.

"If one of these objects were found orbiting a star, there is a good chance that it would be called a planet," said Trent Dupuy, a Hubble Fellow at the Harvard-Smithsonian Center for Astrophysics and a co-author of the study, appearing online Sept. 5 in the journal Science Express. But because they probably formed on their own and not in a planet-forming disk orbiting a more massive star, astronomers still call these objects brown dwarfs even if their mass is of planetary size.

Characterizing these cold brown dwarfs is challenging because they emit most of their light at infrared wavelengths and are very faint due to their small size and low temperature.

To get accurate temperatures, astronomers need to know the distances to these objects. "We wanted to find out if they were colder, fainter and nearby, or if they were warmer, brighter and more distant," explains Dupuy.

Using Spitzer, the team determined that the brown dwarfs in question are located at distances 20 to 50 light-years away.

To determine the distances to these objects, the team measured their parallax -- the apparent change in position against background stars over time. As Spitzer orbits the sun, its perspective changes and nearby objects appear to shift back and forth slightly. The same effect occurs if you hold up a finger in front of your face and close one eye and then the other. The position of your finger seems to shift when viewed against the distant background.

But even for these relatively nearby brown dwarfs, the parallax motion is small. "To be able to determine accurate distances, our measurements had to be the same precision as knowing the position of a firefly to within 1 inch (2.5 centimeters) from 200 miles (320 kilometers) away," explained Adam Kraus, professor at the University of Texas at Austin and the study's other co-author.

The new data also present new puzzles to astronomers who study cool, planet-like atmospheres. Unlike warmer brown dwarfs and stars, the observable properties of these objects don't seem to correlate as strongly with temperature. This suggests increased roles for other factors, such as convective mixing, in driving the chemistry at the surface.

This study examined the initial sample of the coldest brown dwarfs discovered in the WISE survey data. Additional objects discovered in the past two years remain to be studied, and scientists hope they will shed light on some of these outstanding issues.

NASA's Jet Propulsion Laboratory, Pasadena, Calif., manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology in Pasadena. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

For more information about Spitzer, visit http://spitzer.caltech.edu and http://www.nasa.gov/spitzer.

Whitney Clavin 818-354-4673Jet Propulsion Laboratory, Pasadena, Calif.whitney.clavin@jpl.nasa.gov

2013-271

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Identification of oldest solar twin may help locate rocky exoplanets

7 min read

NASA Science Editorial Team

From ESO

An international team led by astronomers in Brazil has used ESO’s Very Large Telescope to identify and study the oldest solar twin known to date. Located 250 light-years from Earth, the star HIP 102152 is more like the Sun than any other solar twin — except that it is nearly four billion years older. This older, but almost identical, twin gives us an unprecedented chance to see how the Sun will look when it ages. The new observations also provide an important first clear link between a star’s age and its lithium content, and in addition suggest that HIP 102152 may be host to rocky terrestrial planets.

Astronomers have only been observing the Sun with telescopes for 400 years — a tiny fraction of the Sun’s age of 4.6 billion years. It is very hard to study the history and future evolution of our star, but we can do this by hunting for rare stars that are almost exactly like our own, but at different stages of their lives. Now astronomers have identified a star that is essentially an identical twin to our Sun, but 4 billion years older — almost like seeing a real version of the twin paradox in action.

Jorge Melendez (Universidade de São Paulo, Brazil), the leader of the team and co-author of the new paper explains: “For decades, astronomers have been searching for solar twins in order to know our own life-giving Sun better. But very few have been found since the first one was discovered in 1997. We have now obtained superb-quality spectra from the VLT and can scrutinise solar twins with extreme precision, to answer the question of whether the Sun is special.”

The team studied two solar twins — one that was thought to be younger than the Sun (18 Scorpii) and one that was expected to be older (HIP 102152). They used the UVES spectrograph on the Very Large Telescope (VLT) at ESO's Paranal Observatory to split up the light into its component colours so that the chemical composition and other properties of these stars could be studied in great detail.

They found that HIP 102152 in the constellation of Capricornus (The Sea Goat) is the oldest solar twin known to date. It is estimated to be 8.2 billion years old, compared to 4.6 billion years for our own Sun. On the other hand 18 Scorpii was confirmed to be younger than the Sun — about 2.9 billion years old.

Studying the ancient solar twin HIP 102152 allows scientists to predict what may happen to our own Sun when it reaches that age, and they have already made one significant discovery. “One issue we wanted to address is whether or not the Sun is typical in composition,” says Melendez. “Most importantly, why does it have such a strangely low lithium content?”

Lithium, the third element in the periodic table, was created in the Big Bang along with hydrogen and helium. Astronomers have pondered for years over why some stars appear to have less lithium than others. With the new observations of HIP 102152, astronomers have taken a big step towards solving this mystery by pinning down a strong correlation between a Sun-like star’s age and its lithium content.

Our own Sun now has just 1% of the lithium content that was present in the material from which it formed. Examinations of younger solar twins have hinted that these younger siblings contain significantly larger amounts of lithium, but up to now scientists could not prove a clear correlation between age and lithium content.

TalaWanda Monroe (Universidade de São Paulo), the lead author on the new paper, concludes: “We have found that HIP 102152 has very low levels of lithium. This demonstrates clearly for the first time that older solar twins do indeed have less lithium than our own Sun or younger solar twins. We can now be certain that stars somehow destroy their lithium as they age, and that the Sun's lithium content appears to be normal for its age.”

A final twist in the story is that HIP 102152 has an unusual chemical composition pattern that is subtly different to most other solar twins, but similar to the Sun. They both show a deficiency of the elements that are abundant in meteorites and on Earth. This is a strong hint that HIP 102152 may host terrestrial rocky planets.

If a star contains less of the elements that we commonly find in rocky bodies, this indicates that it is likely to host rocky terrestrial planets because such planets lock up these elements as they form from a large disc surrounding the star. The suggestion that HIP 102152 may host such planets is further reinforced by the radial velocity monitoring of this star with ESO's HARPS spectrograph, which indicates that inside the star’s habitable zone there are no giant planets. This would allow the existence of potential Earth-like planets around HIP 102152; in systems with giant planets existing close in to their star, the chances of finding terrestrial planets are much less as these small rocky bodies are disturbed and disrupted.

More informationThis research was presented in a paper to appear in “High precision abundances of the old solar twin HIP 102152: insights on Li depletion from the oldest Sun”, by TalaWanda Monroe et al. in the Astrophysical Journal Letters.

The team is composed of TalaWanda R. Monroe, Jorge Meléndez (Universidade de São Paulo, Brazil [USP]), Iván Ramírez (The University of Texas at Austin, USA), David Yong (Australian National University, Australia [ANU]), Maria Bergemann (Max Planck Institute for Astrophysics, Germany), Martin Asplund (ANU), Jacob Bean, Megan Bedell (University of Chicago, USA), Marcelo Tucci Maia (USP), Karin Lind (University of Cambridge, UK), Alan Alves-Brito, Luca Casagrande (ANU), Matthieu Castro, José-Dias do Nascimento (Universidade Federal do Rio Grande do Norte, Brazil), Michael Bazot (Centro de Astrofísica da Universidade de Porto, Portugal) and Fabrício C. Freitas (USP).

ESO is the foremost intergovernmental astronomy organisation in Europe and the world’s most productive ground-based astronomical observatory by far. It is supported by 15 countries: Austria, Belgium, Brazil, the Czech Republic, Denmark, France, Finland, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom. ESO carries out an ambitious programme focused on the design, construction and operation of powerful ground-based observing facilities enabling astronomers to make important scientific discoveries. ESO also plays a leading role in promoting and organising cooperation in astronomical research. ESO operates three unique world-class observing sites in Chile: La Silla, Paranal and Chajnantor. At Paranal, ESO operates the Very Large Telescope, the world’s most advanced visible-light astronomical observatory and two survey telescopes. VISTA works in the infrared and is the world’s largest survey telescope and the VLT Survey Telescope is the largest telescope designed to exclusively survey the skies in visible light. ESO is the European partner of a revolutionary astronomical telescope ALMA, the largest astronomical project in existence. ESO is currently planning the 39-metre European Extremely Large optical/near-infrared Telescope, the E-ELT, which will become “the world’s biggest eye on the sky”.

ContactsTalaWanda R. MonroeUniversidade de São PauloSão Paulo, BrazilTel: +55 11 3091 2815Email: tmonroe - at - usp.br

Jorge MeléndezUniversidade de São PauloSão Paulo, BrazilTel: +55 11 3091 2840Email: jorge.melendez@iag.usp.br

Richard HookESO, Public Information OfficerGarching bei München, GermanyTel: +49 89 3200 6655Cell: +49 151 1537 3591Email: rhook@eso.org

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Good night, sweet prince

4 min read

NASA Science Editorial Team

Following months of analysis and testing, the Kepler Space Telescope team is ending its attempts to restore the spacecraft to full working order, and now is considering what new science research it can carry out in its current condition.

Two of Kepler's four gyroscope-like reaction wheels, which are used to precisely point the spacecraft, have failed. The first was lost in July 2012, and the second in May. Engineers' efforts to restore at least one of the wheels have been unsuccessful.

Kepler completed its prime mission in November 2012 and began its four-year extended mission at that time. However, the spacecraft needs three functioning wheels to continue its search for Earth-sized exoplanets, which are planets outside our solar system, orbiting stars like our sun in what's known as the habitable zone -- the range of distances from a star where the surface temperature of a planet might be suitable for liquid water. As scientists analyze previously collected data, the Kepler team also is looking into whether the space telescope can conduct a different type of science program, potentially including an exoplanet search, using the remaining two good reaction wheels and thrusters.

"Kepler has made extraordinary discoveries in finding exoplanets including several super-Earths in the habitable zone," said John Grunsfeld, associate administrator for NASA's Science Mission Directorate in Washington. "Knowing that Kepler has successfully collected all the data from its prime mission, I am confident that more amazing discoveries are on the horizon."

On Aug. 8, engineers conducted a system-level performance test to evaluate Kepler's current capabilities. They determined wheel 2, which failed last year, can no longer provide the precision pointing necessary for science data collection. The spacecraft was returned to its point rest state, which is a stable configuration where Kepler uses thrusters to control its pointing with minimal fuel use.

"At the beginning of our mission, no one knew if Earth-size planets were abundant in the galaxy. If they were rare, we might be alone," said William Borucki, Kepler science principal investigator at NASA's Ames Research Center in Moffett Field, Calif. "Now at the completion of Kepler observations, the data holds the answer to the question that inspired the mission: Are Earths in the habitable zone of stars like our sun common or rare?

An engineering study will be conducted on the modifications required to manage science operations with the spacecraft using a combination of its remaining two good reaction wheels and thrusters for spacecraft attitude control.

Informed by contributions from the broader science community in response to the call for scientific white papers announced Aug. 2, the Kepler project team will perform a study to identify possible science opportunities for a two-wheel Kepler mission.

Depending on the outcome of these studies, which are expected to be completed later this year, NASA will assess the scientific priority of a two-wheel Kepler mission. Such an assessment may include prioritization relative to other NASA astrophysics missions competing for operational funding at the NASA Senior Review board early next year.

From the data collected in the first half of its mission, Kepler has confirmed 135 exoplanets and identified over 3,500 candidates. The team continues to analyze all four years of collected data, expecting hundreds, if not thousands, of new discoveries including the long-awaited Earth-size planets in the habitable zone of sun-like stars. Though the spacecraft will no longer operate with its unparalleled precision pointing, scientists expect Kepler’s most interesting discoveries are still to come.

Ames is responsible for Kepler's ground system development, mission operations and science data analysis. NASA's Jet Propulsion Laboratory in Pasadena, Calif., managed Kepler mission development.

Ball Aerospace & Technologies Corp. in Boulder, Colo., developed the Kepler flight system and supports mission operations with the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder.

The Space Telescope Science Institute in Baltimore archives, hosts and distributes Kepler science data. Kepler is NASA's 10th Discovery Mission and was funded by the agency's Science Mission Directorate.

For more information about NASA's Kepler spacecraft, visit the mission website.

NASA's Ames Research Center hosted the second Kepler Science Conference Nov. 4-8, 2013. The event, co-sponsored by the Kepler Project and the NASA Exoplanet Science Institute, shared information about the investigations of the Kepler project team, and also those of the wider science community using publicly accessible data from Kepler. Information about the Kepler Science Conference is available at its legacy website: http://go.nasa.gov/13kz012 .

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Spitzer Telescope Celebrates 10 Years in Space

5 min read

NASA Science Editorial Team

From NASA's Jet Propulsion Laboratory

PASADENA, Calif. -- Ten years after a Delta II rocket launched NASA's Spitzer Space Telescope, lighting up the night sky over Cape Canaveral, Fla., the fourth of the agency's four Great Observatories continues to illuminate the dark side of the cosmos with its infrared eyes.

The telescope studied comets and asteroids, counted stars, scrutinized planets and galaxies, and discovered soccer-ball-shaped carbon spheres in space called buckyballs. Moving into its second decade of scientific scouting from an Earth-trailing orbit, Spitzer continues to explore the cosmos near and far. One additional task is helping NASA observe potential candidates for a developing mission to capture, redirect and explore a near-Earth asteroid.

"President Obama's goal of visiting an asteroid by 2025 combines NASA's diverse talents in a unified endeavor," said John Grunsfeld, NASA's associate administrator for science in Washington. "Using Spitzer to help us characterize asteroids and potential targets for an asteroid mission advances both science and exploration."

Spitzer's infrared vision lets it see the far, cold and dusty side of the universe. Close to home, the telescope has studied the comet dubbed Tempel 1, which was hit by NASA's Deep Impact mission in 2005. Spitzer showed the composition of Tempel 1 resembled that of solar systems beyond our own. Spitzer also surprised the world by discovering the largest of Saturn's many rings. The enormous ring, a wispy band of ice and dust particles, is very faint in visible light, but Spitzer's infrared detectors were able to pick up the glow from its heat.

Perhaps Spitzer's most astonishing finds came from beyond our solar system. The telescope was the first to detect light coming from a planet outside our solar system, a feat not in the mission's original design. With Spitzer's ongoing studies of these exotic worlds, astronomers have been able to probe their composition, dynamics and more, revolutionizing the study of exoplanet atmospheres.

Other discoveries and accomplishments of the mission include getting a complete census of forming stars in nearby clouds; making a new and improved map of the Milky Way's spiral-arm structure; and, with NASA's Hubble Space Telescope, discovering that the most distant galaxies known are more massive and mature than expected.

"I always knew Spitzer would work, but I had no idea that it would be as productive, exciting and long-lived as it has been," said Spitzer project scientist Michael Werner of NASA's Jet Propulsion Laboratory, Pasadena, Calif., who helped conceive the mission. "The spectacular images that it continues to return, and its cutting-edge science, go far beyond anything we could have imagined when we started on this journey more than 30 years ago."

In October, Spitzer will attempt infrared observations of a small near-Earth asteroid named 2009 DB to better determine its size, a study that will assist NASA in understanding potential candidates for the agency's asteroid capture and redirection mission. This asteroid is one of many candidates the agency is evaluating.

Spitzer, originally called the Space Infrared Telescope Facility, was renamed after its launch in honor of the late astronomer Lyman Spitzer. Considered the father of space telescopes, Lyman Spitzer began campaigning to put telescopes in space, away from the blurring effects of Earth's atmosphere, as early as the 1940s. His efforts also led to the development and deployment of NASA's Hubble Space Telescope, carried to orbit by the space shuttle in 1990.

In anticipation of the Hubble launch, NASA set up the Great Observatories program to fly a total of four space telescopes designed to cover a range of wavelengths: Hubble, Spitzer, the Chandra X-ray Observatory and the now-defunct Compton Gamma Ray Observatory.

"The majority of our Great Observatory fleet is still up in space, each with its unique perspective on the cosmos," said Paul Hertz, Astrophysics Division director at NASA headquarters in Washington. "The wisdom of having space telescopes that cover all wavelengths of light has been borne out by the spectacular discoveries made by astronomers around the world using Spitzer and the other Great Observatories."

Spitzer ran out of the coolant needed to chill its longer-wavelength instruments in 2009, and entered the so-called warm mission phase. Now, after its tenth year of peeling back the hidden layers of the cosmos, its journey continues.

"I get very excited about the serendipitous discoveries in areas we never anticipated," said Dave Gallagher, Spitzer's project manager at JPL from 1999 to 2004, reminding him of a favorite quote from Marcel Proust: "The real voyage of discovery consists not in seeking new landscapes, but in having new eyes."

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology in Pasadena. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA. For more information about Spitzer, visit http://spitzer.caltech.edu and http://www.nasa.gov/spitzer .

Whitney Clavin 818-354-4673Jet Propulsion Laboratory, Pasadena, Calif.whitney.clavin@jpl.nasa.gov

J.D. Harrington 202-358-5241Headquarters, Washingtonj.d.harrington@nasa.gov

Check out our gallery of Spitzer exoplanet discoveries by visiting our Facebook page: http://on.fb.me/1dJAgPa

As a radio frequency wireless engineer in NASA’s Johnson Space Center Avionic Systems Division in Houston, Melissa Moreno makes an impact in space exploration while proudly sharing her cultural heritage in the NASA community. Moreno works in the Electronic Systems Test Laboratory, developing communication systems critical to Gateway, NASA’s first lunar-orbiting space station. But her […]

Researchers found that long-duration spaceflight affected the mechanical properties of eye tissues, including reducing the stiffness of tissue around the eyeball. A better understanding of these changes could help researchers prevent, diagnose, and treat the vision impairment often seen in crew members. SANSORI, a Canadian Space Agency investigation, examined whether reduced stiffness of eye tissue contributes to […]

On Sept. 30, 1994, space shuttle Endeavour took to the skies on its 7th trip into space. During the 11-day mission, the STS-68 crew of Commander Michael A. Baker, Pilot Terrence “Terry” W. Wilcutt, and Mission Specialists Steven L. Smith, Daniel W. Bursch, Peter J.K. “Jeff” Wisoff, and Payload Commander Thomas “Tom” D. Jones operated […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Razor’s Edge

3 min read

NASA Science Editorial Team

By Joshua Rodriguez

When astronomers in the 1990s first started discovering massive, Jupiter-size worlds whipping around their stars in a matter of mere days, the rulebook for what kinds of planets were and weren’t possible had to be tossed out the window.

Now, thanks to data from the ever-prolific Kepler mission, an even more extreme class of exoplanets is causing scientists to once again redefine the rules.

When Carnegie Institution of Washington astronomer Brian Jackson and his team set out to find extremely close-orbiting exoplanets in Kepler’s treasure trove of data, he wasn’t optimistic that they’d find anything. “Most of the time, things like this don’t work out,” he said.

But his team hit pay dirt when they found strong evidence for planets with orbits of as little as three hours—the first such transiting planet ever discovered.

“These planets are nearly skimming the stellar surface, and if they’re confirmed, they’ll be some of the closest planets to their stars ever discovered,” Jackson said.

“The results were very surprising,” Jackson said. “The first hot Jupiters, with their several-day orbits, were completely unexpected, but these planets are even closer—almost touching the star itself.”

The discovery of such extreme worlds prompts new questions about how such a planet could form in the first place.

“They could be the carcasses of former gas giants that have had their atmospheres entirely ripped off by the gravity of their star, leaving behind an Earth-size solid core of ice and rock,” Jackson said. “But the reality is that at present, we don’t know where they came from.”

And just how long can a planet survive at such an incredibly cozy distance from its host star? “We know they have to survive long enough for us to see them,” Jackson said. “But at the same time, this is something that’s orbiting 50 times closer to its star than Mercury is to the sun ... it’s practically skimming the star's surface.”

Jackson and his team now turn to gathering the information needed to understand this enigmatic new class of planets. “We want to find some more, and view them closer with high-powered ground instruments so that we can try to understand them theoretically,” Jackson said.

“This discovery pushes the envelope even further,” Jackson said. “Now we’ve got to explain these amazing new planets.”

While Jackson is “surprised and gratified” by his team’s groundbreaking new find, he recognizes that the exoplanet field has a habit of confounding expectations. “It’s a huge challenge, understanding the vast menagerie of planets that are out there,” he said.

“Every time astronomers think we have a handle on where planets can and can’t live, nature surprises us.”

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Astronomers Image Lowest-Mass Exoplanet Around a Sun-like Star

4 min read

Using infrared data from the Subaru Telescope in Hawaii, an international team of astronomers has imaged a giant planet around the bright star GJ 504. Several times the mass of Jupiter and similar in size, the new world, dubbed GJ 504 b, is the lowest-mass planet ever detected around a star like the sun using direct imaging techniques.

“If we could travel to this giant planet, we would see a world still glowing from the heat of its formation with a color reminiscent of a dark cherry blossom, a dull magenta,” said Michael McElwain, a member of the discovery team at NASA’s Goddard Space Flight Center in Greenbelt, Md. “Our near-infrared camera reveals that its color is much more blue than other imaged planets, which may indicate that its atmosphere has fewer clouds.”

GJ 504 b orbits its star at nearly nine times the distance Jupiter orbits the sun, which poses a challenge to theoretical ideas of how giant planets form.

According to the most widely accepted picture, called the core-accretion model, Jupiter-like planets get their start in the gas-rich debris disk that surrounds a young star. A core produced by collisions among asteroids and comets provides a seed, and when this core reaches sufficient mass, its gravitational pull rapidly attracts gas from the disk to form the planet.

While this model works fine for planets out to where Neptune orbits, about 30 times Earth’s average distance from the sun (30 astronomical units, or AU), it’s more problematic for worlds located farther from their stars. GJ 504 b lies at a projected distance of 43.5 AU from its star; the actual distance depends on how the system tips to our line of sight, which is not precisely known.

“This is among the hardest planets to explain in a traditional planet-formation framework,” explained team member Markus Janson, a Hubble postdoctoral fellow at Princeton University in New Jersey. “Its discovery implies that we need to seriously consider alternative formation theories, or perhaps to reassess some of the basic assumptions in the core-accretion theory.”

The research is part of the Strategic Explorations of Exoplanets and Disks with Subaru (SEEDS), a project to directly image extrasolar planets and protoplanetary disks around several hundred nearby stars using the Subaru Telescope on Mauna Kea, Hawaii. The five-year project began in 2009 and is led by Motohide Tamura at the National Astronomical Observatory of Japan (NAOJ).

While direct imaging is arguably the most important technique for observing planets around other stars, it is also the most challenging.

“Imaging provides information about the planet’s luminosity, temperature, atmosphere and orbit, but because planets are so faint and so close to their host stars, it’s like trying to take a picture of a firefly near a searchlight,” explained Masayuki Kuzuhara at the Tokyo Institute of Technology, who led the discovery team.

The SEEDS project images at near-infrared wavelengths with the help of the telescope’s novel adaptive optics system, which compensates for the smearing effects of Earth’s atmosphere, and two instruments: the High Contrast Instrument for the Subaru Next Generation Adaptive Optics and the InfraRed Camera and Spectrograph. The combination allows the team to push the boundary of direct imaging toward fainter planets.

A paper describing the results has been accepted for publication in The Astrophysical Journal and will appear in a future issue.

The researchers find that GJ 504 b is about four times more massive than Jupiter and has an effective temperature of about 460 degrees Fahrenheit (237 Celsius).

It orbits the G0-type star GJ 504, which is slightly hotter than the sun and is faintly visible to the unaided eye in the constellation Virgo. The star lies 57 light-years away and the team estimates the system is about 160 million years old, based on methods that link the star’s color and rotation period to its age.

Young star systems are the most attractive targets for direct exoplanet imaging because their planets have not existed long enough to lose much of the heat from their formation, which enhances their infrared brightness.

“Our sun is about halfway through its energy-producing life, but GJ504 is only one-thirtieth its age,” added McElwain. “Studying these systems is a little like seeing our own planetary system in its youth.”

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Blink buddies

3 min read

NASA Science Editorial Team

Astronomers using NASA's Spitzer Space Telescope have spotted a young stellar system that "blinks" every 93 days. Called YLW 16A, the system likely consists of three developing stars, two of which are surrounded by a disk of material left over from the star-formation process.

As the two inner stars whirl around each other, they periodically peek out from the disk that girds them like a hula hoop. The hoop itself appears to be misaligned from the central star pair, probably due to the disrupting gravitational presence of the third star orbiting at the periphery of the system. The whole system cycles through bright and faint phases, with the central stars playing a sort of cosmic peek-a-boo as the tilted disk twirls around them. It is believed that this disk should go on to spawn planets and the other celestial bodies that make up a solar system.

Spitzer observed infrared light from YLW 16A, emitted by the warmed gas and dust in the disk that still swathes the young stars. Other observations came from the ground-based 2MASS survey, as well as from the NACO instrument at the European Southern Observatory's Very Large Telescope in Chile.

YLW 16A is the fourth example of a star system known to blink in such a manner, and the second in the same star-forming region Rho Ophiuchus. The finding suggests that these systems might be more common than once thought. Blinking star systems with warped disks offer scientists a way to study how planets form in these environments. The planets can orbit one or both of the stars in the binary star system. The famous science fictional planet Tatooine in "Star Wars" orbits two stars, hence its double sunsets. Such worlds are referred to as circumbinary planets. Astronomers can record how light is absorbed by planet-forming disks during the bright and faint phases of blinking stellar systems, which in turn reveals information about the materials that comprise the disk.

"These blinking systems offer natural probes of the binary and circumbinary planet formation process," said Peter Plavchan, a scientist at the NASA Exoplanet Science Institute and Infrared Processing and Analysis Center at the California Institute of Technology, Pasadena, Calif., and lead author of a new paper accepted for publication in Astronomy & Astrophysics.

NASA's Jet Propulsion Laboratory, Pasadena, Calif., manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate, Washington. Science operations are conducted at the Spitzer Science Center at Caltech. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center. Caltech manages JPL for NASA. For more information about Spitzer, visit http://spitzer.caltech.edu and http://www.nasa.gov/spitzer .

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Chandra Sees Eclipsing Planet in X-rays for First Time

4 min read

For the first time since exoplanets, or planets around stars other than the sun, were discovered almost 20 years ago, X-ray observations have detected an exoplanet passing in front of its parent star.

An advantageous alignment of a planet and its parent star in the system HD 189733, which is 63 light-years from Earth, enabled NASA’s Chandra X-ray Observatory and the European Space Agency’s XMM Newton Observatory to observe a dip in X-ray intensity as the planet transited the star.

“Thousands of planet candidates have been seen to transit in only optical light,” said Katja Poppenhaeger of Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Mass., who led a new study to be published in the Aug. 10 edition of The Astrophysical Journal. “Finally being able to study one in X-rays is important because it reveals new information about the properties of an exoplanet.”

The team used Chandra to observe six transits and data from XMM Newton observations of one.

The planet, known as HD 189733b, is a hot Jupiter, meaning it is similar in size to Jupiter in our solar system but in very close orbit around its star. HD 189733b is more than 30 times closer to its star than Earth is to the sun. It orbits the star once every 2.2 days.

HD 189733b is the closest hot Jupiter to Earth, which makes it a prime target for astronomers who want to learn more about this type of exoplanet and the atmosphere around it. They have used NASA’s Kepler space telescope to study it at optical wavelengths, and NASA’s Hubble Space Telescope to confirm it is blue in color as a result of the preferential scattering of blue light by silicate particles in its atmosphere.

The study with Chandra and XMM Newton has revealed clues to the size of the planet’s atmosphere. The spacecraft saw light decreasing during the transits. The decrease in X-ray light was three times greater than the corresponding decrease in optical light.

“The X-ray data suggest there are extended layers of the planet’s atmosphere that are transparent to optical light but opaque to X-rays,” said co-author Jurgen Schmitt of Hamburger Sternwarte in Hamburg, Germany. “However, we need more data to confirm this idea.”

The researchers also are learning about how the planet and the star can affect one another.

Astronomers have known for about a decade ultraviolet and X-ray radiation from the main star in HD 189733 are evaporating the atmosphere of HD 189733b over time. The authors estimate it is losing 100 million to 600 million kilograms of mass per second. HD 189733b’s atmosphere appears to be thinning 25 percent to 65 percent faster than it would be if the planet’s atmosphere were smaller.

“The extended atmosphere of this planet makes it a bigger target for high-energy radiation from its star, so more evaporation occurs,” said co-author Scott Wolk, also of CfA.

The main star in HD 189733 also has a faint red companion, detected for the first time in X-rays with Chandra. The stars likely formed at the same time, but the main star appears to be 3 billion to 3 1/2 billion years younger than its companion star because it rotates faster, displays higher levels of magnetic activity and is about 30 times brighter in X-rays than its companion.

“This star is not acting its age, and having a big planet as a companion may be the explanation,” said Poppenhaeger. “It’s possible this hot Jupiter is keeping the star’s rotation and magnetic activity high because of tidal forces, making it behave in some ways like a much younger star.”

The paper is available online at: http://arxiv.org/abs/1306.2311

For Chandra images, multimedia and related materials, visit: https://www.nasa.gov/chandra

For an additional interactive image, podcast, and video on the finding, visit:

http://chandra.si.edu

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cool star, warm planet

4 min read

NASA Science Editorial Team

From University of WashingtonBy Peter Kelley

In a bit of cosmic irony, planets orbiting cooler stars may be more likely to remain ice-free than planets around hotter stars. This artist’s concept illustrates a planet orbiting a red dwarf star.In a bit of cosmic irony, planets orbiting cooler stars may be more likely to remain ice-free than planets around hotter stars. This is due to the interaction of a star’s light with ice and snow on the planet’s surface.

Stars emit different types of light. Hotter stars emit high-energy visible and ultraviolet light, and cooler stars give off infrared and near-infrared light, which has a much lower energy.

It seems logical that the warmth of terrestrial or rocky planets should depend on the amount of light they get from their stars, all other things being equal. But new climate model research led by Aomawa Shields, a doctoral student in the University of Washington astronomy department, has added a surprising new twist to the story: Planets orbiting cool stars actually may be much warmer and less icy than their counterparts orbiting much hotter stars, even though they receive the same amount of light.

That’s because the ice absorbs much of the longer wavelength, near-infrared light predominantly emitted by these cooler stars. This is counter to what we experience on Earth, where ice and snow strongly reflect the visible light emitted by the Sun.

Around a cooler (M-dwarf) star, the more light the ice absorbs, the warmer the planet gets. The planet’s atmospheric greenhouse gases also absorb this near-infrared light, compounding the warming effect.

The researchers found that planets orbiting cooler stars, given similar amounts of light as those orbiting hotter stars, are therefore less likely to experience so-called “snowball states,” icing over from pole to equator.

However, around a hotter star such as an F-dwarf, the star’s visible and ultraviolet light is reflected by planetary ice and snow in a process called ice-albedo feedback. The more light the ice reflects, the cooler the planet gets.

This feedback can be so effective at cooling that terrestrial planets around hotter stars appear to be more susceptible than other planets to entering snowball states. That’s not necessarily a bad thing, in the scheme of time — Earth itself is believed to have experienced several snowball states during the course of its 4.6 billion year history.

Shields and co-authors found that this interaction of starlight with a planet’s surface ice is less pronounced near the outer edge of the habitable zone, where carbon dioxide is expected to build up as temperatures decrease. The habitable zone is the swath of space around a star that’s just right to allow an orbiting planet’s surface water to be in liquid form, thus giving life a chance.

That is the case because planets at that zone’s outer edge would likely have a thick atmosphere of carbon dioxide or other greenhouse gases, which blocks the absorption of radiation at the surface, causing the planet to lose any additional warming advantage due to the ice.

The researchers' findings are documented in a paper published in the August issue of the journal Astrobiology, and published online ahead of print July 15.

Shields said that astronomers hunting for possible life will prioritize planets less vulnerable to that snowball state — that is, planets other than those orbiting hotter stars. But that doesn't mean they will rule out the cooler planets.

"The last snowball episode on Earth has been linked to the explosion of multicellular life on our planet," Shields said. "If someone observed our Earth then, they might not have thought there was life here — but there certainly was.

"So though we'd look for the non-snowball planets first, we shouldn't entirely write off planets that may be ice-covered, or headed for total ice cover. There could be life there too, though it may be much harder to detect."

Shields' UW co-authors are Victoria Meadows, associate professor of astronomy; Cecilia Bitz, associate professor of atmospheric sciences; and Tyler Robinson, an astronomy research associate. Other co-authors are Raymond T. Pierrehumbert of the University of Chicago and Manoj Joshi of the University of East Anglia.

The work was funded by a National Science Foundation Graduate Research Fellowship and performed as part of the NASA Astrobiology Institute's Virtual Planetary Laboratory Lead Team.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

A Frosty Landmark for Planet and Comet Formation

8 min read

NASA Science Editorial Team

From European Southern Observatory

A snow line has been imaged in a far-off infant planetary system for the very first time. The snow line, located in the disc around the Sun-like star TW Hydrae, promises to tell us more about the formation of planets and comets, the factors that decide their composition, and the history of the Solar System. The results are published today in Science Express.

Astronomers using the Atacama Large Millimeter/submillimeter Array (ALMA) have taken the first ever image of the snow line in an infant planetary system. On Earth, snow lines form at high altitudes where falling temperatures turn the moisture in the air into snow. This line is clearly visible on a mountain, where the snow-capped summit ends and the rocky face begins.

The snow lines around young stars form in a similar way, in the distant, colder reaches of the dusty discs from which planetary systems form. Starting from the star and moving outwards, water (H_2O) is the first to freeze, forming the first snow line. Further out from the star, as temperatures drop, more exotic molecules can freeze and turn to snow, such as carbon dioxide (CO_2), methane (CH_4), and carbon monoxide (CO). These different snows give the dust grains a sticky outer coating and play an essential role in helping the grains to overcome their usual tendency to break up in collisions, allowing them to become the crucial building blocks of planets and comets. The snow also increases how much solid matter is available and may dramatically speed up the planetary formation process.

Each of these different snow lines — for water, carbon dioxide, methane and carbon monoxide — may be linked to the formation of particular kinds of planets [1]. Around a Sun-like star in a planetary system like our own, the water snow line would correspond to a distance between the orbits of Mars and Jupiter, and the carbon monoxide snow line would correspond to the orbit of Neptune.

The snow line spotted by ALMA is the first glimpse of the carbon monoxide snow line, around TW Hydrae, a young star 175 light-years away from Earth. Astronomers believe this budding planetary system shares many of the same characteristics of the Solar System when it was just a few million years old.

“ALMA has given us the first real picture of a snow line around a young star, which is extremely exciting because of what it tells us about the very early period in the history of the Solar System,” said Chunhua “Charlie” Qi (Harvard-Smithsonian Center for Astrophysics, Cambridge, USA) one of the two lead authors of the paper. “We can now see previously hidden details about the frozen outer reaches of another planetary system similar to our own.”

But the presence of a carbon monoxide snow line could have greater consequences than just the formation of planets. Carbon monoxide ice is needed to form methanol, which is a building block of the more complex organic molecules that are essential for life. If comets ferried these molecules to newly forming Earth-like planets, these planets would then be equipped with the ingredients necessary for life.

Before now, snow lines had never been imaged directly because they always form in the relatively narrow central plane of a protoplanetary disc, so their precise location and extent could not be determined. Above and below the narrow region where snow lines exist, the star’s radiation prevents ice formation. The dust and gas concentration in the central plane is necessary to insulate the area from the radiation so that carbon monoxide and other gases can cool and freeze.

This team of astronomers succeeded in peering inside this disc to where the snow has formed with the help of a clever trick. Instead of looking for the snow — as it cannot be observed directly — they searched for a molecule known as diazenylium (N2H+), which shines brightly in the millimetre portion of the spectrum, and so is a perfect target for a telescope such as ALMA. The fragile molecule is easily destroyed in the presence of carbon monoxide gas, so would only appear in detectable amounts in regions where carbon monoxide had become snow and could no longer destroy it. In essence, the key to finding carbon monoxide snow lies in finding diazenylium.

ALMA's unique sensitivity and resolution has allowed the astronomers to trace the presence and distribution of diazenylium and find a clearly defined boundary approximately 30 astronomical units from the star (30 times the distance between the Earth and the Sun). This gives, in effect, a negative image of the carbon monoxide snow in the disc surrounding TW Hydrae, which can be used to see the carbon monoxide snow line precisely where theory predicts it should be — the inner rim of the diazenylium ring.

"For these observations we used only 26 of ALMA's eventual full complement of 66 antennas. Indications of snow lines around other stars are already showing up in other ALMA observations, and we are convinced that future observations with the full array will reveal many more of these and provide further, exciting insights into the formation and evolution of planets. Just wait and see,” concludes Michiel Hogerheijde from Leiden Observatory, the Netherlands.

Notes[1] For instance dry rocky planets form on the inner side of the water snow line (nearest the star), where only dust can exist. At the other extreme are the icy giant planets which form beyond the carbon monoxide snow line.

More informationThe Atacama Large Millimeter/submillimeter Array (ALMA), an international astronomy facility, is a partnership of Europe, North America and East Asia in cooperation with the Republic of Chile. ALMA is funded in Europe by the European Southern Observatory (ESO), in North America by the U.S. National Science Foundation (NSF) in cooperation with the National Research Council of Canada (NRC) and the National Science Council of Taiwan (NSC) and in East Asia by the National Institutes of Natural Sciences (NINS) of Japan in cooperation with the Academia Sinica (AS) in Taiwan. ALMA construction and operations are led on behalf of Europe by ESO, on behalf of North America by the National Radio Astronomy Observatory (NRAO), which is managed by Associated Universities, Inc. (AUI) and on behalf of East Asia by the National Astronomical Observatory of Japan (NAOJ). The Joint ALMA Observatory (JAO) provides the unified leadership and management of the construction, commissioning and operation of ALMA.

This research was presented in a paper appearing in the 18 July 2013 issue of Science Express.

The team is composed of C. Qi (Harvard-Smithsonian Center for Astrophysics, USA), K. I. Öberg (Departments of Chemistry and Astronomy, University of Virginia, USA), D. J. Wilner (Harvard-Smithsonian Center for Astrophysics, USA), P. d’Alessio (Centro de Radioastronomía y Astro■sica, Universidad Nacional Autónoma de Mexico, Mexico), E. Bergin (Department of Astronomy, University of Michigan, USA), S. M. Andrews (Harvard-Smithsonian Center for Astrophysics, USA), G. A. Blake (Division of Geological and Planetary Sciences, California Institute of Technology, USA), M. R. Hogerheijde (Leiden Observatory, Leiden, Netherlands) and E. F. van Dishoeck (Leiden Observatory, Leiden, Netherlands; Max Planck Institute for Extraterrestrial Physics, Germany).

Qi and Öberg were joint lead authors of this work.

ESO is the foremost intergovernmental astronomy organisation in Europe and the world’s most productive ground-based astronomical observatory by far. It is supported by 15 countries: Austria, Belgium, Brazil, the Czech Republic, Denmark, France, Finland, Germany, Italy, the Netherlands, Portugal, Spain, Sweden, Switzerland and the United Kingdom. ESO carries out an ambitious programme focused on the design, construction and operation of powerful ground-based observing facilities enabling astronomers to make important scientific discoveries. ESO also plays a leading role in promoting and organising cooperation in astronomical research. ESO operates three unique world-class observing sites in Chile: La Silla, Paranal and Chajnantor. At Paranal, ESO operates the Very Large Telescope, the world's most advanced visible-light astronomical observatory and two survey telescopes. VISTA works in the infrared and is the world's largest survey telescope and the VLT Survey Telescope is the largest telescope designed to exclusively survey the skies in visible light. ESO is the European partner of a revolutionary astronomical telescope ALMA, the largest astronomical project in existence. ESO is currently planning the 39-metre European Extremely Large optical/near-infrared Telescope, the E-ELT, which will become "the world's biggest eye on the sky".

LinksMore about ALMAPhotos of ALMAPress release at NRAOCfA press release

ContactsChunhua QiHarvard-Smithsonian Center for AstrophysicsCambridge, Mass., USATel: +1 617 495 7087Email: cqi@cfa.harvard.edu

Michiel HogerheijdeLeiden ObservatoryLeiden, The NetherlandsTel: +31 6 4308 3291Email: michiel@strw.leidenuniv.nl

Richard HookESO, Public Information OfficerGarching bei München, GermanyTel: +49 89 3200 6655Cell: +49 151 1537 3591Email: rhook@eso.org

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Exo-eclipse in x-ray vision

4 min read

NASA Science Editorial Team

From NASA's Chandra X-Ray Observatory

For the first time since exoplanets, or planets around stars other than the sun, were discovered almost 20 years ago, X-ray observations have detected an exoplanet passing in front of its parent star.

An advantageous alignment of a planet and its parent star in the system HD 189733, which is 63 light-years from Earth, enabled NASA’s Chandra X-ray Observatory and the European Space Agency’s XMM Newton Observatory to observe a dip in X-ray intensity as the planet transited the star.

"Thousands of planet candidates have been seen to transit in only optical light," said Katja Poppenhaeger of Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Mass., who led a new study to be published in the Aug. 10 edition of The Astrophysical Journal. "Finally being able to study one in X-rays is important because it reveals new information about the properties of an exoplanet."

The team used Chandra to observe six transits and data from XMM Newton observations of one.

The planet, known as HD 189733b, is a hot Jupiter, meaning it is similar in size to Jupiter in our solar system but in very close orbit around its star. HD 189733b is more than 30 times closer to its star than Earth is to the sun. It orbits the star once every 2.2 days.

HD 189733b is the closest hot Jupiter to Earth, which makes it a prime target for astronomers who want to learn more about this type of exoplanet and the atmosphere around it. They have used NASA's Kepler space telescope to study it at optical wavelengths, and NASA's Hubble Space Telescope to confirm it is blue in color as a result of the preferential scattering of blue light by silicate particles in its atmosphere.

The study with Chandra and XMM Newton has revealed clues to the size of the planet's atmosphere. The spacecraft saw light decreasing during the transits. The decrease in X-ray light was three times greater than the corresponding decrease in optical light.

"The X-ray data suggest there are extended layers of the planet's atmosphere that are transparent to optical light but opaque to X-rays," said co-author Jurgen Schmitt of Hamburger Sternwarte in Hamburg, Germany. "However, we need more data to confirm this idea."

The researchers also are learning about how the planet and the star can affect one another.

Astronomers have known for about a decade ultraviolet and X-ray radiation from the main star in HD 189733 are evaporating the atmosphere of HD 189733b over time. The authors estimate it is losing 100 million to 600 million kilograms of mass per second. HD 189733b's atmosphere appears to be thinning 25 percent to 65 percent faster than it would be if the planet's atmosphere were smaller.

"The extended atmosphere of this planet makes it a bigger target for high-energy radiation from its star, so more evaporation occurs," said co-author Scott Wolk, also of CfA.

The main star in HD 189733 also has a faint red companion, detected for the first time in X-rays with Chandra. The stars likely formed at the same time, but the main star appears to be 3 billion to 3 1/2 billion years younger than its companion star because it rotates faster, displays higher levels of magnetic activity and is about 30 times brighter in X-rays than its companion.

"This star is not acting its age, and having a big planet as a companion may be the explanation," said Poppenhaeger. "It's possible this hot Jupiter is keeping the star's rotation and magnetic activity high because of tidal forces, making it behave in some ways like a much younger star."

The paper is available online at:http://arxiv.org/abs/1306.2311

For Chandra images, multimedia and related materials, visit:http://www.nasa.gov/chandra

For an additional interactive image, podcast, and video on the finding, visit:http://chandra.si.eduMedia contacts:J.D. HarringtonHeadquarters, Washington 202-358-5241j.d.harrington@nasa.gov

Megan WatzkeChandra X-ray Center, Cambridge, Mass.617-496-7998mwatzke@cfa.harvard.edu

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA Hubble Finds a True Blue Planet

3 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Astronomers making visible-light observations with NASA's Hubble Space Telescope have deduced the actual color of a planet orbiting another star 63 light-years away.

The planet is HD 189733b, one of the closest exoplanets that can be seen crossing the face of its star.

Hubble's Space Telescope Imaging Spectrograph measured changes in the color of light from the planet before, during and after a pass behind its star. There was a small drop in light and a slight change in the color of the light. "We saw the light becoming less bright in the blue but not in the green or red. Light was missing in the blue but not in the red when it was hidden," said research team member Frederic Pont of the University of Exeter in South West England. "This means that the object that disappeared was blue."

Earlier observations have reported evidence for scattering of blue light on the planet. The latest Hubble observation confirms the evidence.

If seen directly, this planet would look like a deep blue dot, reminiscent of Earth's color as seen from space. That is where the comparison ends.

On this turbulent alien world, the daytime temperature is nearly 2,000 degrees Fahrenheit, and it possibly rains glass – sideways – in howling, 4,500-mph winds. The cobalt blue color comes not from the reflection of a tropical ocean as it does on Earth, but rather a hazy, blow-torched atmosphere containing high clouds laced with silicate particles. Silicates condensing in the heat could form very small drops of glass that scatter blue light more than red light.

Hubble and other observatories have made intensive studies of HD 189733b and found its atmosphere to be changeable and exotic.

HD 189733b is among a bizarre class of planets called hot Jupiters, which orbit precariously close to their parent stars. The observations yield new insights into the chemical composition and cloud structure of the entire class.

Clouds often play key roles in planetary atmospheres. Detecting the presence and importance of clouds in hot Jupiters is crucial to astronomers' understanding of the physics and climatology of other planets.

HD 189733b was discovered in 2005. It is only 2.9 million miles from its parent star, so close that it is gravitationally locked. One side always faces the star and the other side is always dark.

In 2007, NASA's Spitzer Space Telescope measured the infrared light, or heat, from the planet, leading to one of the first temperature maps for an exoplanet. The map shows day side and night side temperatures on HD 189733b differ by about 500 degrees Fahrenheit. This should cause fierce winds to roar from the day side to the night side.

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Lightest exoplanet imaged so far?

3 min read

NASA Science Editorial Team

From European Southern Observatory

A team of astronomers using ESO’s Very Large Telescope has imaged a faint object moving near a bright star. With an estimated mass of four to five times that of Jupiter, it would be the least massive planet to be directly observed outside the Solar System. The discovery is an important contribution to our understanding of the formation and evolution of planetary systems.

Although nearly a thousand exoplanets have been detected indirectly — most using the radial velocity or transit methods — and many more candidates await confirmation, only a dozen exoplanets have been directly imaged. Nine years after ESO's Very Large Telescope captured the first image of an exoplanet, the planetary companion to the brown dwarf 2M1207 (eso0428), the same team has caught on camera what is probably the lightest of these objects so far.

“Direct imaging of planets is an extremely challenging technique that requires the most advanced instruments, whether ground-based or in space,” says Julien Rameau (Institut de Planetologie et d'Astrophysique de Grenoble, France), first author of the paper announcing the discovery. “Only a few planets have been directly observed so far, making every single discovery an important milestone on the road to understanding giant planets and how they form.”

In the new observations, the likely planet appears as a faint but clear dot close to the star HD 95086. A later observation also showed that it was slowly moving along with the star across the sky. This suggests that the object, which has been designated HD 95086 b, is in orbit around the star. Its brightness also indicates that it has a predicted mass of only four to five times that of Jupiter.

The team used NACO, the adaptive optics instrument mounted on one of the 8.2-metre Unit Telescopes of ESO's Very Large Telescope (VLT). This instrument allows astronomers to remove most of the blurring effects of the atmosphere and obtain very sharp images. The observations were made using infrared light and a technique called differential imaging, which improves the contrast between the planet and dazzling host star.

The newly discovered planet orbits the young star HD 95086 at a distance of around 56 times the distance from the Earth to the Sun, twice the Sun–Neptune distance. The star itself is a little more massive than the Sun and is surrounded by a debris disc. These properties allowed astronomers to identify it as an ideal candidate to harbour young massive planets. The whole system lies some 300 light-years away from us.

The youth of this star, just 10 to 17 million years, leads astronomers to believe that this new planet probably formed within the gaseous and dusty disc that surrounds the star. “Its current location raises questions about its formation process. It either grew by assembling the rocks that form the solid core and then slowly accumulated gas from the environment to form the heavy atmosphere, or started forming from a gaseous clump that arose from gravitational instabilities in the disc.” explains Anne-Marie Lagrange, another team member. “Interactions between the planet and the disc itself or with other planets may have also moved the planet from where it was born.”

Another team member, Gaël Chauvin, concludes, “The brightness of the star gives HD 95086 b an estimated surface temperature of about 700 degrees Celsius. This is cool enough for water vapour and possibly methane to exist in its atmosphere. It will be a great object to study with the forthcoming SPHERE instrument on the VLT. Maybe it can also reveal inner planets in the system — if they exist.”

You can read the full paper here.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Rings and a reality check

4 min read

NASA Science Editorial Team

From NASA's Jet Propulsion Laboratory

Many young stars known to host planets also possess disks containing dust and icy grains, particles produced by collisions among asteroids and comets also orbiting the star. These debris disks often show sharply defined rings or spiral patterns, features that could signal the presence of orbiting planets. Astronomers study the disk features as a way to better understand the physical properties of known planets and possibly uncover new ones.

But a new study by NASA scientists sounds a cautionary note in interpreting rings and spiral arms as signposts for new planets. Thanks to interactions between gas and dust, a debris disk may, under the right conditions, produce narrow rings on its own -- no planets needed.

"When the mass of gas is roughly equal to the mass of dust, the two interact in a way that leads to clumping in the dust and the formation of patterns," said lead researcher Wladimir Lyra, a Sagan Fellow at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "In essence, the gas shepherds the dust into the kinds of structures we would expect to be see if a planet were present."

A paper describing the findings was published in the July 11 issue of Nature.

The warm dust in debris disks is easy to detect at infrared wavelengths, but estimating the gas content of disks is a much greater challenge. As a result, theoretical studies tend to focus on the role of dust and ice particles, paying relatively little attention to the gas component. Yet icy grains evaporate and collisions produce both gas and dust, so at some level all debris disks must contain some amount of gas.

"All we need to produce narrow rings and other structures in our models of debris disks is a bit of gas, too little for us to detect today in most actual systems," said co-author Marc Kuchner, an astrophysicist at NASA's Goddard Space Flight Center in Greenbelt, Md.

Here's how it works. When high-energy ultraviolet light from the central star strikes a clump of dust and ice grains, it drives electrons off the particles. These high-speed electrons then collide with and heat nearby gas.

The rising gas pressure changes the drag force on the orbiting dust, causing the clump to grow and better heat the gas. This interaction, which the astronomers refer to as the photoelectric instability, continues to cascade. Clumps grow into arcs, rings and oval features in tens of thousands of years, a relatively short time compared to other forces at work in a young solar system.

A model developed by Lyra and Kuchner shows the process at work.

"We were fascinated to watch this structure form in the simulations," Lyra said. "Some of the rings begin to oscillate, and at any moment they have the offset appearance of dust rings we see around many stars, such as Fomalhaut."

In addition, dense clumps with many times the dust density elsewhere in the disk also form during the simulation. When a clump in a ring grows too dense, the ring breaks into arcs and the arcs gradually shrink until only a single compact clump remains. In actual debris disks, some of these dense clumps could reflect enough light to be directly observable.

"We would detect these clumps as bright moving sources of light, which is just what we're looking for when we search for planets," adds Kuchner.

The researchers conclude that the photoelectric instability provides a simple and plausible explanation for many of the features found in debris disks, making the job of planet-hunting astronomers just a little bit harder.

An abstract for the Nature paper, titled "Sharp Eccentric Rings in Planetless Hydrodynamical Models of Debris Disks," is online.

The Sagan Fellowship Program is administered by the NASA Exoplanet Science Institute at the California Institute of Technology in Pasadena. Its purpose is to advance the scientific and technical goals of NASA's Exoplanet Exploration Program, managed for NASA by JPL. Caltech manages JPL for NASA.

Whitney Clavin 818-354-4673Jet Propulsion Laboratory, Pasadena, Calif.whitney.clavin@jpl.nasa.gov

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cool confluence

1 min read

NASA Science Editorial Team

Awesome happenings in the sky March 17, as Kepler, Jupiter, the moon, and a comet will all be near the horns of the constellation Taurus.

After sunset look in the western sky and find the crescent moon. The bright white object to the upper right is the planet Jupiter, and to the left of the moon is the bright red star Aldebaran in the constellation of Taurus. Not visible to the eye is the NASA's planet-hunting Kepler spacecraft which is nearly 40 million miles away, located in the sky between the horns of Taurus the Bull. High above this collection of objects is the comet Pan-STARRS.

Image credit: Till Credner

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Small Stars Are a Big Deal and Could Be the Best Chance for Finding Life on an Exoplanet

4 min read

NASA Science Editorial Team

Of all the big discoveries the Kepler mission has notched in its over three illustrious years of service, there's one that excites Sarah Ballard more than the rest.

"What's inspired me most is that exoplanet size seems to be a function of star size. In other words, small stars are twice as likely to have Earth-size planets as ones the size of our sun. This is something brand new -- we've literally only known it for a few months."

A NASA Sagan Fellow at the University of Washington, Ballard's quest is to study and characterize exoplanets that orbit red dwarf (also known as M-dwarf) stars, which are smaller and cooler than the sun. "Nature just seems to make more little planets around these stars," she said. "Chances are that where you find a small, Earth-size planet, it orbits a small star."

It's a breakthrough discovery for astronomers looking for habitable worlds that are near our solar system. Our own stellar neighborhood is about 75 percent composed of red dwarf stars.

Planets orbiting close enough to a dwarf star for liquid water to exist on their surfaces would be tidally locked, with one side always facing towards the star.

Because red dwarf stars are so much cooler than the sun, any habitable planet that orbits one would have to be much, much closer to its star than the Earth. And that's when things get weird.

"It's really interesting to conceive of life on a planet orbiting a red dwarf star," Ballard said. "The planet would most likely be tidally locked, which means that it's parked so that one half always faces the star, like how the moon always faces the same way towards the Earth. You'd have a day side, a night side, and areas with eternal sunset. Or it might rotate, but very slowly - a single day could take an entire lifetime."

A habitable exoplanet would have to be so close to its host M-dwarf that it would loom huge in the sky. Two or more suns in the sky are also a possibility, as many small stars exist in binary configurations.

Creatures that evolved on the surface of these worlds would most likely look very different from what we're used to. "Most of the light that small stars put out is in the infrared spectrum," Ballard said. "Human eyes have evolved to the wavelengths that our sun emits, but a creature living on a planet orbiting a red dwarf would be sensitive to infrared light. Table salt shines like a mirror in the infrared and ice looks black ... their reality would be completely different from ours, totally a function of the wavelengths they can see."

Red dwarf stars may be the best place to look for potentially habitable worlds, but they are far from the easiest. "They are incredibly hard to characterize," Ballard said. "With sun-like stars, we have accurate models. We can generate an accurate fake spectrum and compare it to the spectrum of a real star to pick out which light is actually coming from the planet. It doesn't work for low-mass stars ... their atmospheres are full of grainy material and very hard to model."

To make up for these shortcomings, Ballard is looking to nearby red dwarfs that have been extensively studied by other astronomers. "By comparing the spectra of well-known low-mass stars with ones that Kepler has found that are similar, we can try to pick out planets in the Kepler data."

Already Ballard’s research has turned up one major discovery: the Kepler-19 system, with a pair of planets – one just over twice the size of Earth – orbiting an star slightly smaller than the sun. And with Kepler continuing to bring in mountains of data, Ballard hopes that she’ll be able to get even deeper into the world of small planets orbiting small stars.

Now that astronomers know red dwarfs are a great place to look for small, potentially habitable planets, Ballard hopes that future missions will enable her to hunt for these worlds in our own backyard. “Kepler’s data has been beyond my wildest dreams -- we have incredible data on low-mass stars and the planets that orbit them. The next step is to look for small planets around the nearest M-dwarf stars. In the future, possibly with the James Webb Space Telescope, we could analyze their atmospheres for signs of organic life.”

“I realize that I’m probably never going to visit the planets we find,” Ballard said. “But there’s something amazing about realize that these are real places, where you could walk around. It’s amazing and evocative to find another world, and I find it really inspiring.”

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Astronomers Directly Image Massive Star's 'Super-Jupiter'

5 min read

Astronomers using infrared data from the Subaru Telescope in Hawaii have discovered a "super-Jupiter" around the bright star Kappa Andromedae, which now holds the record for the most massive star known to host a directly imaged planet or lightweight brown dwarf companion.

Designated Kappa Andromedae b (Kappa And b, for short), the new object has a mass about 12.8 times greater than Jupiter's. This places it teetering on the dividing line that separates the most massive planets from the lowest-mass brown dwarfs. That ambiguity is one of the object's charms, say researchers, who call it a super-Jupiter to embrace both possibilities.

"According to conventional models of planetary formation, Kappa And b falls just shy of being able to generate energy by fusion, at which point it would be considered a brown dwarf rather than a planet," said Michael McElwain, a member of the discovery team at NASA's Goddard Space Flight Center in Greenbelt, Md. "But this isn't definitive, and other considerations could nudge the object across the line into brown dwarf territory."

Massive planets slowly radiate the heat leftover from their own formation. For example, the planet Jupiter emits about twice the energy it receives from the sun. But if the object is massive enough, it's able to produce energy internally by fusing a heavy form of hydrogen called deuterium. (Stars like the sun, on the other hand, produce energy through a similar process that fuses the lighter and much more common form of hydrogen.) The theoretical mass where deuterium fusion can occur – about 13 Jupiters – marks the lowest possible mass for a brown dwarf.

"Kappa And b, the previously imaged planets around HR 8799 and Beta Pictoris, and the most massive planets discovered by non-imaging techniques likely all represent a class of object that formed in much the same way as lower-mass exoplanets," said lead researcher Joseph Carson, an astronomer at the College of Charleston, S.C., and the Max Planck Institute for Astronomy in Heidelberg, Germany.

The discovery of Kappa And b also allows astronomers to explore another theoretical limit. Astronomers have argued that large stars likely produce large planets, but experts predict that this stellar scaling can only extend so far, perhaps to stars with just a few times the sun's mass. The more massive a young star is, the brighter and hotter it becomes, resulting in powerful radiation that could disrupt the formation of planets within a circumstellar disk of gas and dust.

"This object demonstrates that stars as large as Kappa And, with 2.5 times the sun's mass, remain fully capable of producing planets," Carson adds.

The research is part of the Strategic Explorations of Exoplanets and Disks with Subaru (SEEDS), a five-year effort to directly image extrasolar planets and protoplanetary disks around several hundred nearby stars using the Subaru Telescope on Mauna Kea, Hawaii. Direct imaging of exoplanets is rare because the dim objects are usually lost in the star's brilliant glare. The SEEDS project images at near-infrared wavelengths using the telescope's adaptive optics system, which compensates for the smearing effects of Earth's atmosphere, in concert with its High Contrast Instrument for the Subaru Next Generation Adaptive Optics and Infrared Camera and Spectrograph.

Young star systems are attractive targets for direct exoplanet imaging because young planets have not been around long enough to lose much of the heat from their formation, which enhances their brightness in the infrared. The team focused on the star Kappa And because of its relative youth –

estimated at the tender age of 30 million years, or just 0.7 percent the age of our solar system, based on its likely membership in a stellar group known as the Columba Association. The B9-type star is located 170 light-years away in the direction of the constellation Andromeda and is visible to the unaided eye.

Kappa And b orbits its star at a projected distance of 55 times Earth's average distance from the sun and about 1.8 times as far as Neptune; the actual distance depends on how the system is oriented to our line of sight, which is not precisely known. The object has a temperature of about 2,600 degrees Fahrenheit (1,400 Celsius) and would appear bright red if seen up close by the human eye.

Carson's team detected the object in independent observations at four different infrared wavelengths in January and July of this year. Comparing the two images taken half a year apart showed that Kappa And b exhibits the same motion across the sky as its host star, which proves that the two objects are gravitationally bound and traveling together through space. Comparing the brightness of the super-Jupiter between different wavelengths revealed infrared colors similar to those observed in the handful of other gas giant planets successfully imaged around stars.

A paper describing the results has been accepted for publication in The Astrophysical Journal Letters and will appear in a future issue.

The SEEDS research team is continuing to study Kappa And b to better understand the chemistry of its atmosphere, constrain its orbit, and search for possible secondary planets.

Coincidentally, the stellar association that hosts Kappa And also includes another famous high-mass star, HR 8799, which is one of the first where astronomers directly imaged an extrasolar planet. The system hosts several gas giant planets with masses and infrared colors similar to Kappa And b.

Download high-resolution image from NASA Goddard's Scientific Visualization Studio.

By Francis ReddyNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Q & A with a “genius”

4 min read

NASA Science Editorial Team

PQ: How did you find out that you’d been named a MacArthur Fellow?

Olivier Guyon: I got a call on September 13th telling me that I was one of the people who had been awarded. It was a huge surprise. The nomination process is completely secret, so I was totally in the dark about having been nominated until I got the phone call. Then I had to keep it secret from everyone else until the official announcement.

PQ: What kinds of feelings did you experience after you found out?OG: I was thrilled and surprised. At first, I was in disbelief, but that didn’t last long.

I felt very grateful that people trust in my work enough to have nominated me for this grant. It was also a great validation of the work I have done so far. It’s also a huge encouragement to do more significant work in the future. It’s also a pretty major financial prize, so it comes with a bit of responsibility as well.

It all boils down to genuine curiosity, looking for answers, and pushing limits. In order to do something new, you have to question where those limits come from.

PQ: What kinds of things have you thought about doing with the fellowship money?OG: Well, all my plans are just preliminary at the moment, but I really want to engage the public more with exoplanets. I’m interested in helping amateur astronomers look for planets and make their own discoveries.

One of my ideas is to build a remote telescope station that can look for exoplanet transits. Amateur astronomers could get time with the telescope and control it from afar to discover new planets.

PQ: Why is reaching out to the public such a priority for you?OG: I think it’s a main thing for me because it’s how I got into the field. When I was ten years old I read a book on astronomy, and from then on I was very interested in looking at the sky…I started with binoculars, then eventually got a small telescope, and the rest is history. I’ve always had a lot of fun with astronomy, from the time I was young.

I think a big thing was that I found that book at an age when I was curious. I think it’s important that young people are exposed to science at that age, when they are still curious about the world. I want to look for ways to do more reaching out to people in that age group.

PQ: Can you tell us a little bit about the work you do for NASA?OG: I work for the NASA Exoplanet Exploration Program’s tech lab, developing new technology that could be used in future space-based exoplanet-finding missions.

In particular, I work on a project called the PIAA (Phase-induced amplitude apodization) coronagraph. A coronagraph is a device that blocks out the light of a star so that astronomers can capture light from orbiting exoplanets, which are millions of times fainter.

The advantages of the PIAA coronagraph are that it can make more efficient use of a telescope. Thus we can use a smaller, less expensive telescope to get images of exoplanets that are close to their stars. This coronagraph could potentially be used to directly image Earth-like exoplanets orbiting other stars. I work on this technology at testbeds at JPL, Ames Research Center, and the Subaru Telescope.

PQ: What motivates you to come to work each day?OG: Looking back, the path I have followed is motivated by curiosity. That has made it a lot of fun.

It all boils down to genuine curiosity, looking for answers, and pushing limits. In order to do something new, you have to question where those limits come from.

What's helped me a lot is that I never accept limits to what can be done, or assume that they are true, without understanding them myself. Finding a workaround can be a challenge, and the details can add up to something very complicated, and it's hard work, but the result is extremely satisfying.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

New Study Brings a Doubted Exoplanet ‘Back from the Dead’

4 min read

A second look at data from NASA’s Hubble Space Telescope is reanimating the claim that the nearby star Fomalhaut hosts a massive exoplanet. The study suggests that the planet, named Fomalhaut b, is a rare and possibly unique object that is completely shrouded by dust.

Fomalhaut is the brightest star in the constellation Piscis Austrinus and lies 25 light-years away. In November 2008, Hubble astronomers announced the exoplanet, named Fomalhaut b, as the first one ever directly imaged in visible light around another star. The object was imaged just inside a vast ring of debris surrounding but offset from the host star. The planet’s location and mass – no more than three times Jupiter’s – seemed just right for its gravity to explain the ring’s appearance.

Recent studies have claimed that this planetary interpretation is incorrect. Based on the object’s apparent motion and the lack of an infrared detection by NASA’s Spitzer Space Telescope, they argue that the object is a short-lived dust cloud unrelated to any planet.

A new analysis, however, brings the planet conclusion back to life.

“Although our results seriously challenge the original discovery paper, they do so in a way that actually makes the object’s interpretation much cleaner and leaves intact the core conclusion, that Fomalhaut b is indeed a massive planet,” said Thayne Currie, an astronomer formerly at NASA’s Goddard Space Flight Center in Greenbelt, Md., and now at the University of Toronto.

The discovery study reported that Fomalhaut b’s brightness varied by about a factor of two and cited this as evidence that the planet was accreting gas. Follow-up studies then interpreted this variability as evidence that the object actually was a transient dust cloud instead.

In the new study, Currie and his team reanalyzed Hubble observations of the star from 2004 and 2006. They easily recovered the planet in observations taken at visible wavelengths near 600 and 800 nanometers, and made a new detection in violet light near 400 nanometers. In contrast to the earlier research, the team found that the planet remained at constant brightness.

The team attempted to detect Fomalhaut b in the infrared using the Subaru Telescope in Hawaii, but was unable to do so. The non-detections with Subaru and Spitzer imply that Fomalhaut b must have less than twice the mass of Jupiter.

Another contentious issue has been the object’s orbit. If Fomalhaut b is responsible for the ring’s offset and sharp interior edge, then it must follow an orbit aligned with the ring and must now be moving at its slowest speed. The speed implied by the original study appeared to be too fast. Additionally, some researchers argued that Fomalhaut b follows a tilted orbit that passes through the ring plane.

Using the Hubble data, Currie’s team established that Fomalhaut b is moving with a speed and direction consistent with the original idea that the planet’s gravity is modifying the ring.

“Given what we know about the behavior of dust and the environment where the planet is located, we think that we’re seeing a planetary object that is completely embedded in dust rather than a free-floating dust cloud,” said team member John Debes, an astronomer at the Space Telescope Science Institute in Baltimore, Md.

A paper describing the findings has been accepted for publication in The Astrophysical Journal Letters.

Because astronomers detect Fomalhaut b by the light of surrounding dust and not by light or heat emitted by its atmosphere, it no longer ranks as a “directly imaged exoplanet.” But because it’s the right mass and in the right place to sculpt the ring, Currie’s team thinks it should be considered a “planet identified from direct imaging.”

Fomalhaut was targeted with Hubble most recently in May by another team. Those observations are currently under scientific analysis and are expected to be published soon.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

A Change in the Air

1 min read

NASA Hubble Mission Team

Goddard Space Flight Center

An international team of astronomers using data from NASA's Hubble Space Telescope made an unparalleled observation, detecting significant changes in the atmosphere of a planet located beyond our solar system.

Exoplanet HD 189733b lies so near its star that it completes an orbit every 2.2 days. In late 2011, NASA's Hubble Space Telescope found that the planet's upper atmosphere was streaming away at speeds exceeding 300,000 mph. Just before the Hubble observation, NASA's Swift detected the star blasting out a strong X-ray flare, one powerful enough to blow away part of the planet's atmosphere.

The exoplanet is a gas giant similar to Jupiter, but about 14 percent larger and more massive. The planet circles its star at a distance of only 3 million miles, or about 30 times closer than Earth's distance from the sun. Its star, named HD 189733A, is about 80 percent the size and mass of our sun.

This artist's rendering illustrates the evaporation of HD 189733b's atmosphere in response to a powerful eruption from its host star.

Image Credit: NASA

Alien Light Forms

4 min read

NASA Science Editorial Team

NASA's Spitzer Space Telescope has detected light emanating from a "super-Earth" planet beyond our solar system for the first time. While the planet is not habitable, the detection is a historic step toward the eventual search for signs of life on other planets.

"Spitzer has amazed us yet again," said Bill Danchi, Spitzer program scientist at NASA Headquarters in Washington. "The spacecraft is pioneering the study of atmospheres of distant planets and paving the way for NASA's upcoming James Webb Space Telescope to apply a similar technique on potentially habitable planets."

The planet, called 55 Cancri e, falls into a class of planets termed super Earths, which are more massive than our home world but lighter than giant planets like Neptune. The planet is about twice as big and eight times as massive as Earth. It orbits a bright star, called 55 Cancri, in a mere 18 hours.

Previously, Spitzer and other telescopes were able to study the planet by analyzing how the light from 55 Cancri changed as the planet passed in front of the star. In the new study, Spitzer measured how much infrared light comes from the planet itself. The results reveal the planet is likely dark, and its sun-facing side is more than 2,000 Kelvin (3,140 degrees Fahrenheit), hot enough to melt metal.

The new information is consistent with a prior theory that 55 Cancri e is a water world: a rocky core surrounded by a layer of water in a "supercritical" state where it is both liquid and gas, and topped by a blanket of steam.

"It could be very similar to Neptune, if you pulled Neptune in toward our sun and watched its atmosphere boil away," said Michaël Gillon of Université de Liège in Belgium, principal investigator of the research, which appears in the Astrophysical Journal. The lead author is Brice-Olivier Demory of the Massachusetts Institute of Technology in Cambridge. The 55 Cancri system is relatively close to Earth, at 41 light-years away. It has five planets, with 55 Cancri e the closest to the star and tidally locked, so one side always faces the star. Spitzer discovered the sun-facing side is extremely hot, indicating the planet probably does not have a substantial atmosphere to carry the sun's heat to the unlit side.

NASA's James Webb Space Telescope, scheduled to launch in 2018, likely will be able to learn even more about the planet's composition. The telescope might be able to use a similar infrared method to Spitzer to search other potentially habitable planets for signs of molecules possibly related to life.

"When we conceived of Spitzer more than 40 years ago, exoplanets hadn't even been discovered," said Michael Werner, Spitzer project scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "Because Spitzer was built very well, it's been able to adapt to this new field and make historic advances such as this."

In 2005, Spitzer became the first telescope to detect light from a planet beyond our solar system. To the surprise of many, the observatory saw the infrared light of a "hot Jupiter," a gaseous planet much larger than the solid 55 Cancri e. Since then, other telescopes, including NASA's Hubble and Kepler space telescopes, have performed similar feats with gas giants using the same method.

In this method, a telescope gazes at a star as a planet circles behind it. When the planet disappears from view, the light from the star system dips ever so slightly, but enough that astronomers can determine how much light came from the planet itself. This information reveals the temperature of a planet, and, in some cases, its atmospheric components. Most other current planet-hunting methods obtain indirect measurements of a planet by observing its effects on the star.

During Spitzer's ongoing extended mission, steps were taken to enhance its unique ability to see exoplanets, including 55 Cancri e. Those steps, which included changing the cycling of a heater and using an instrument in a new way, led to improvements in how precisely the telescope points at targets.

JPL manages the Spitzer Space Telescope mission for NASA's Science Mission Directorate in Washington. Science operations are conducted at the Spitzer Science Center at the California Institute of Technology (Caltech) in Pasadena. Data are archived at the Infrared Science Archive housed at the Infrared Processing and Analysis Center at Caltech. Caltech manages JPL for NASA.

For more information about Spitzer, visit: http://www.nasa.gov/spitzer and http://spitzer.caltech.edu.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble, Swift Detect First-Ever Changes in an Exoplanet Atmosphere

4 min read

NASA Hubble Mission Team

Goddard Space Flight Center

An international team of astronomers using data from NASA's Hubble Space Telescope has made an unparalleled observation, detecting significant changes in the atmosphere of a planet located beyond our solar system.

The scientists conclude the atmospheric variations occurred in response to a powerful eruption on the planet's host star, an event observed by NASA's Swift satellite.

"The multiwavelength coverage by Hubble and Swift has given us an unprecedented view of the interaction between a flare on an active star and the atmosphere of a giant planet," said lead researcher Alain Lecavelier des Etangs at the Paris Institute of Astrophysics (IAP), part of the French National Scientific Research Center located at Pierre and Marie Curie University in Paris.

The exoplanet is HD 189733b, a gas giant similar to Jupiter, but about 14 percent larger and more massive. The planet circles its star at a distance of only 3 million miles, or about 30 times closer than Earth's distance from the sun, and completes an orbit every 2.2 days. Its star, named HD 189733, is about 80 percent the size and mass of our sun.

Astronomers classify the planet as a "hot Jupiter." Previous Hubble observations show that the planet's deep atmosphere reaches a temperature of about 1,900 degrees Fahrenheit (1,030 C).

HD 189733b periodically passes across, or transits, its parent star, and these events give astronomers an opportunity to probe its atmosphere and environment. In a previous study, a group led by Lecavelier des Etangs used Hubble to show that hydrogen gas was escaping from the planet's upper atmosphere. The finding made HD 189733b only the second-known "evaporating" exoplanet at the time.

The system is just 63 light-years away, so close that its star can be seen with binoculars near the famous Dumbbell Nebula. This makes HD 189733b an ideal target for studying the processes that drive atmospheric escape.

"Astronomers have been debating the details of atmospheric evaporation for years, and studying HD 189733b is our best opportunity for understanding the process," said Vincent Bourrier, a doctoral student at IAP and a team member on the new study.

When HD 189733b transits its star, some of the star's light passes through the planet's atmosphere. This interaction imprints information on the composition and motion of the planet's atmosphere into the star's light.

In April 2010, the researchers observed a single transit using Hubble's Space Telescope Imaging Spectrograph (STIS), but they detected no trace of the planet's atmosphere. Follow-up STIS observations in September 2011 showed a surprising reversal, with striking evidence that a plume of gas was streaming away from the exoplanet.

The researchers determined that at least 1,000 tons of gas was leaving the planet's atmosphere every second. The hydrogen atoms were racing away at speeds greater than 300,000 mph. The findings will appear in an upcoming issue of the journal Astronomy & Astrophysics.

Because X-rays and extreme ultraviolet starlight heat the planet's atmosphere and likely drive its escape, the team also monitored the star with Swift's X-ray Telescope (XRT). On Sept. 7, 2011, just eight hours before Hubble was scheduled to observe the transit, Swift was monitoring the star when it unleashed a powerful flare. It brightened by 3.6 times in X-rays, a spike occurring atop emission levels that already were greater than the sun's.

"The planet's close proximity to the star means it was struck by a blast of X-rays tens of thousands of times stronger than the Earth suffers even during an X-class solar flare, the strongest category," said co-author Peter Wheatley, a physicist at the University of Warwick in England.

After accounting for the planet's enormous size, the team notes that HD 189733b encountered about 3 million times as many X-rays as Earth receives from a solar flare at the threshold of the X class.

Hubble is a project of international cooperation between NASA and the European Space Agency. Swift is operated in collaboration with several U.S. institutions and partners in the United Kingdom, Italy, Germany and Japan. NASA's Goddard Space Flight Center in Greenbelt, Md., manages both missions.

For more information about Swift, visit:http://www.nasa.gov/swiftFor more information about Hubble, visit:http://www.nasa.gov/hubble

Text issued as NASA Headquarters Release No. 12-217

Scientists and engineers tested NASA’s LEMS (Lunar Environment Monitoring Station) instrument suite in a “sandbox” of simulated Moon "soil."

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble, Swift Detect First-Ever Changes in an Exoplanet Atmosphere

4 min read

An international team of astronomers using data from NASA’s Hubble Space Telescope has made an unparalleled observation, detecting significant changes in the atmosphere of a planet located beyond our solar system.

The scientists conclude the atmospheric variations occurred in response to a powerful eruption on the planet’s host star, an event observed by NASA’s Swift satellite.

“The multiwavelength coverage by Hubble and Swift has given us an unprecedented view of the interaction between a flare on an active star and the atmosphere of a giant planet,” said lead researcher Alain Lecavelier des Etangs at the Paris Institute of Astrophysics (IAP), part of the French National Scientific Research Center located at Pierre and Marie Curie University in Paris.

The exoplanet is HD 189733b, a gas giant similar to Jupiter, but about 14 percent larger and more massive. The planet circles its star at a distance of only 3 million miles, or about 30 times closer than Earth’s distance from the sun, and completes an orbit every 2.2 days. Its star, named HD 189733, is about 80 percent the size and mass of our sun.

Astronomers classify the planet as a “hot Jupiter.” Previous Hubble observations show that the planet’s deep atmosphere reaches a temperature of about 1,900 degrees Fahrenheit (1,030 C).

HD 189733b periodically passes across, or transits, its parent star, and these events give astronomers an opportunity to probe its atmosphere and environment. In a previous study, a group led by Lecavelier des Etangs used Hubble to show that hydrogen gas was escaping from the planet’s upper atmosphere. The finding made HD 189733b only the second-known “evaporating” exoplanet at the time.

The system is just 63 light-years away, so close that its star can be seen with binoculars near the famous Dumbbell Nebula. This makes HD 189733b an ideal target for studying the processes that drive atmospheric escape.

“Astronomers have been debating the details of atmospheric evaporation for years, and studying HD 189733b is our best opportunity for understanding the process,” said Vincent Bourrier, a doctoral student at IAP and a team member on the new study.

When HD 189733b transits its star, some of the star’s light passes through the planet’s atmosphere. This interaction imprints information on the composition and motion of the planet’s atmosphere into the star’s light.

In April 2010, the researchers observed a single transit using Hubble’s Space Telescope Imaging Spectrograph (STIS), but they detected no trace of the planet’s atmosphere. Follow-up STIS observations in September 2011 showed a surprising reversal, with striking evidence that a plume of gas was streaming away from the exoplanet.

The researchers determined that at least 1,000 tons of gas was leaving the planet’s atmosphere every second. The hydrogen atoms were racing away at speeds greater than 300,000 mph. The findings will appear in an upcoming issue of the journal Astronomy & Astrophysics.

Because X-rays and extreme ultraviolet starlight heat the planet’s atmosphere and likely drive its escape, the team also monitored the star with Swift’s X-ray Telescope (XRT). On Sept. 7, 2011, just eight hours before Hubble was scheduled to observe the transit, Swift was monitoring the star when it unleashed a powerful flare. It brightened by 3.6 times in X-rays, a spike occurring atop emission levels that already were greater than the sun's.

“The planet's close proximity to the star means it was struck by a blast of X-rays tens of thousands of times stronger than the Earth suffers even during an X-class solar flare, the strongest category,” said co-author Peter Wheatley, a physicist at the University of Warwick in England.

After accounting for the planet's enormous size, the team notes that HD 189733b encountered about 3 million times as many X-rays as Earth receives from a solar flare at the threshold of the X class.

Hubble is a project of international cooperation between NASA and the European Space Agency. Swift is operated in collaboration with several U.S. institutions and partners in the United Kingdom, Italy, Germany and Japan. NASA's Goddard Space Flight Center in Greenbelt, Md., manages both missions.

For more information about Swift, visit: https://www.nasa.gov/swift

For more information about Hubble, visit: https://www.nasa.gov/hubble

Text issued as NASA Headquarters Release No. 12-217

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Tiny Trio of Exoplanets Found Orbiting a Red Star

4 min read

NASA Science Editorial Team

Astronomers using data from NASA's Kepler mission have discovered the three smallest planets yet detected orbiting a star beyond our sun. The planets orbit a single star, called KOI-961, and are 0.78, 0.73 and 0.57 times the radius of Earth. The smallest is about the size of Mars.

All three planets are thought to be rocky like Earth but orbit close to their star, making them too hot to be in the habitable zone, which is the region where liquid water could exist. Of the more than 5,500 planets confirmed to orbit other stars, called exoplanets, only a handful are known to be rocky.

"Astronomers are just beginning to confirm the thousands of planet candidates uncovered by Kepler so far," said Doug Hudgins, Kepler program scientist at NASA Headquarters in Washington. "Finding one as small as Mars is amazing, and hints that there may be a bounty of rocky planets all around us."

Kepler searches for planets by continuously monitoring more than 150,000 stars, looking for telltale dips in their brightness caused by crossing, or transiting, planets. At least three transits are required to verify a signal as a planet. Follow-up observations from ground-based telescopes also are needed to confirm the discoveries.

The latest discovery comes from a team led by astronomers at the California Institute of Technology in Pasadena. The team used data publicly released by the Kepler mission, along with follow-up observations from the Palomar Observatory, near San Diego, and the W.M. Keck Observatory atop Mauna Kea in Hawaii. Their measurements dramatically revised the sizes of the planets from what was originally estimated, revealing their small nature.

The three planets are very close to their star, taking less than two days to orbit around it. The KOI-961 star is a red dwarf with a diameter one-sixth that of our sun, making it just 70 percent bigger than Jupiter.

"This is the tiniest solar system found so far," said John Johnson, the principal investigator of the research from NASA's Exoplanet Science Institute at the California Institute of Technology in Pasadena. "It's actually more similar to Jupiter and its moons in scale than any other planetary system. The discovery is further proof of the diversity of planetary systems in our galaxy."

Red dwarfs are the most common kind of star in our Milky Way galaxy. The discovery of three rocky planets around one red dwarf suggests that the galaxy could be teeming with similar rocky planets.

"These types of systems could be ubiquitous in the universe," said Phil Muirhead, lead author of the new study from Caltech. "This is a really exciting time for planet hunters."

The discovery follows a string of recent milestones for the Kepler mission. In December 2011, scientists announced the mission's first confirmed planet in the habitable zone of a sun-like star: a planet 2.4 times the size of Earth called Kepler-22b. Later in the month, the team announced the discovery of the first Earth-size planets orbiting a sun-like star outside our solar system, called Kepler-20e and Kepler-20f.

For the latest discovery, the team obtained the sizes of the three planets (called KOI-961.01, KOI-961.02 and KOI-961.03) with the help of a well-studied twin star to KOI-961, Barnard's Star. By better understanding the KOI-961 star, they could then determine how big the planets must be to have caused the observed dips in starlight. In addition to the Kepler observations and ground-based telescope measurements, the team used modeling techniques to confirm the planet discoveries.

Prior to these confirmed planets, only six other planets had been confirmed using the Kepler public data.

NASA's Ames Research Center in Moffett Field, Calif., manages Kepler's ground system development, mission operations and science data analysis. NASA’s Jet Propulsion Laboratory, Pasadena, Calif., managed the Kepler mission's development.

For information about the Kepler mission, visit: http://www.nasa.gov/kepler.

JPL is managed for NASA by the California Institute of Technology in Pasadena.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Free-Floating Planets May be More Common Than Stars

4 min read

NASA Science Editorial Team

Astronomers, including a NASA-funded team member, have discovered a new class of Jupiter-sized planets floating alone in the dark of space, away from the light of a star. The team believes these lone worlds were probably ejected from developing planetary systems.

The discovery is based on a joint Japan-New Zealand survey that scanned the center of the Milky Way galaxy during 2006 and 2007, revealing evidence for up to 10 free-floating planets roughly the mass of Jupiter. The isolated orbs, also known as orphan planets, are difficult to spot, and had gone undetected until now. The newfound planets are located at an average approximate distance of 10,000 to 20,000 light-years from Earth.

"Although free-floating planets have been predicted, they finally have been detected, holding major implications for planetary formation and evolution models," said Mario Perez, exoplanet program scientist at NASA Headquarters in Washington.

The discovery indicates there are many more free-floating Jupiter-mass planets that can't be seen. The team estimates there are about twice as many of them as stars. In addition, these worlds are thought to be at least as common as planets that orbit stars. This would add up to hundreds of billions of lone planets in our Milky Way galaxy alone.

"Our survey is like a population census," said David Bennett, a NASA and National Science Foundation-funded co-author of the study from the University of Notre Dame in South Bend, Indiana. "We sampled a portion of the galaxy, and based on these data, can estimate overall numbers in the galaxy."

The study, led by Takahiro Sumi from Osaka University in Japan, appears in the May 19 issue of the journal Nature.

The survey is not sensitive to planets smaller than Jupiter and Saturn, but theories suggest lower-mass planets like Earth should be ejected from their stars more often. As a result, they are thought to be more common than free-floating Jupiters.

Previous observations spotted a handful of free-floating, planet-like objects within star-forming clusters, with masses three times that of Jupiter. But scientists suspect the gaseous bodies form more like stars than planets. These small, dim orbs, called brown dwarfs, grow from collapsing balls of gas and dust, but lack the mass to ignite their nuclear fuel and shine with starlight. It is thought the smallest brown dwarfs are approximately the size of large planets.

On the other hand, it is likely that some planets are ejected from their early, turbulent solar systems, due to close gravitational encounters with other planets or stars. Without a star to circle, these planets would move through the galaxy as our sun and other stars do, in stable orbits around the galaxy's center. The discovery of 10 free-floating Jupiters supports the ejection scenario, though it's possible both mechanisms are at play.

"If free-floating planets formed like stars, then we would have expected to see only one or two of them in our survey instead of 10," Bennett said. "Our results suggest that planetary systems often become unstable, with planets being kicked out from their places of birth."

The observations cannot rule out the possibility that some of these planets may have very distant orbits around stars, but other research indicates Jupiter-mass planets in such distant orbits are rare.

The survey, the Microlensing Observations in Astrophysics (MOA), is named in part after a giant wingless, extinct bird family from New Zealand called the moa. A 5.9-foot (1.8-meter) telescope at Mount John University Observatory in New Zealand is used to regularly scan the copious stars at the center of our galaxy for gravitational microlensing events. These occur when something, such as a star or planet, passes in front of another, more distant star. The passing body's gravity warps the light of the background star, causing it to magnify and brighten. Heftier passing bodies, like massive stars, will warp the light of the background star to a greater extent, resulting in brightening events that can last weeks. Small planet-size bodies will cause less of a distortion, and brighten a star for only a few days or less.

A second microlensing survey group, the Optical Gravitational Lensing Experiment (OGLE), contributed to this discovery using a 4.2-foot (1.3 meter) telescope in Chile. The OGLE group also observed many of the same events, and their observations independently confirmed the analysis of the MOA group.

NASA's Jet Propulsion Laboratory, Pasadena,Calif., manages NASA's Exoplanet Exploration program office. JPL is a division of the California Institute of Technology in Pasadena.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Students Build Planet-Hunting Miniature Satellite

3 min read

NASA Science Editorial Team

(PLANETQUEST) -- Most college finals end up in a stack on a professor's desk. For one group of MIT students, however, their three-semester long project has a slightly different destination - outer space.

The final in this case is an exoplanet-finding "CubeSat" - a small, rectangular satellite that's about as long as a skateboard and as heavy as a bowling ball. Over the course of three semesters, MIT students have developed parts of the mission from initial concepts to functioning hardware, aiming for launch in 2012.

Because CubeSats are so small, they can piggyback on the rockets that take much larger satellites to space, giving educational institutions like MIT the chance to test new technology and perform experiments in space more easily and cheaply. "We had the idea of using a CubeSat to look for exoplanets a few years ago," said Sara Seager, the astronomer and expert in exoplanet atmospheres who teaches the class. "The beauty of the project is that it's a prototype--low risk and low cost means we can move quickly to get the satellite built and launched."

Unlike the recent planet-finding focus to search for signs of exoplanets orbiting stars smaller and dimmer than the sun, the MIT prototype space telescope will focus on a single star like our own during its mission, looking for the telltale dimming of light that occurs when a planet passes in front of its star. This way of planet-finding is called the "transit" method, and though many exoplanets have been discovered this way, few have been found orbiting stars like our own.

"Astronomers have found it hard to find exoplanets orbiting bright, sun-like stars because the brightness overwhelms their very sensitive detectors," said Rebecca Jensen-Clem, a fourth-year undergraduate. "If this prototype mission is successful, we could someday launch a whole constellation of small, planet-finding telescopes that could potentially find Earth-like planets orbiting stars close by."

In addition to its potential scientific bounty, the CubeSat project went a long way toward helping prepare students for the challenges of someday working on a large-scale space mission.

"There were a lot of lessons learned in time-management and communication, because the project moved on a pretty quick timeline, and because we had both science and engineering students," said Joseph McCarter, also a fourth-year undergraduate. "But knowing that what we were working on was a real mission that was going to space was a real motivating factor."

That motivation will turn into anticipation as the CubeSat project is finished up and the students wait for a confirmed launch date. Both Seager and Jensen-Clem are optimistic that this first prototype could yield significant future dividends. "Nature gives us so much to find - we just have to look," Seager said.

Jensen-Clem sums it up in a different way: "Someday, I might be able to point to a star in the sky and tell people that there's a planet like ours out there. I'll be proud to have been a part of that search."

The CubeSat project was partially supported by a Strategic University Research Partnership grant from NASA's Jet Propulsion Laboratory. The ExoplanetSat CubeSat project is jointly run by MIT and Draper Labs.

Written by Joshua Rodriguez/PlanetQuest

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Winter thaws out with hot exoplanet news

2 min read

NASA Science Editorial Team

Kepler's big announcement of over 1,000 exoplanet candidates in early February 2011 continues to reverberate in the astronomy world. Here are some other news stories that are heating things up in the realm of exoplanets.

Could habitable, Earth-like planets exist around tiny, dying stars? Astronomer Eric Algol, of the University of Washington, thinks so. He recently published research showing that white dwarfs - cooling stars that have run out of nuclear fuel - could indeed harbor Earth-like planets. Such planets would be tidally locked, with one side permanently night and the other permanently day, and would orbit very close to their stars. Because white dwarfs are typically no bigger than the average terrestrial planet, Algol says that such worlds would be easy to spot with ground based telescopes.

The Milky Way may be packed with planets. Kepler Science Chief Bill Borucki says that the mission's latest results indicate that there are at least 50 billion planets in the Milky Way galaxy, with some 500 million in their host star's habitable zone. These figures were extrapolated from the Kepler mission's current haul of over 1,000 possible exoplanet discoveries. As the mission moves into its third year, scientists anticipate that Kepler will begin to discover planets with longer orbits similar to Earth's, which means that Kepler's greatest discoveries could be yet to come.

While Kepler quickly racked up new exoplanet candidates for astronomers to study, the process of confirming and understanding these finds remains tricky. When Kepler released its list of candidates in early February, the candidate KOI 326.01 got a lot of attention for being one of the most Earth-like planets yet discovered, due to its size and the fact that it was the right distance from its star to have liquid water. (NASA's Kepler Space Telescope was retired in 2020.)

However, further research revealed that KOI 326.01 isn't quite as promising as previously thought. Discover Magazine fact-checkers found that KOI 326.01 may actually be orbiting one of two nearby stars, and that it's very likely that the planet is much larger and hotter than previously thought, a finding verified by the Kepler science team, which has warned scientists and the media against jumping to conclusions about unconfirmed exoplanet candidates. Read more...

Planet Count Tops 500

1 min read

NASA Science Editorial Team

By Joshua Rodriguez / PlanetQuest

A big year for exoplanet exploration came to a fitting end in December when astronomers announced new exoplanet discoveries that brought the total number of known worlds outside our solar system to over 500.

The milestone number indicates the breakneck speed with which astronomers have made new exoplanet discoveries in just the past few years. Just a few decades ago, finding planets orbiting stars besides our sun was considered a distant, unlikely possibility.

Over 450 new planets have been discovered in the past decade, and the Kepler mission is poised to dramatically increase that count in the coming years, as it scours 100,000 distant stars for evidence of exoplanets. With a massive roster of candidate planets already being sorted through by scientists, don't expect the planet count to remain near 500 for long.

The graphic below illustrates the sheer number of exoplanets discovered so far - and the increasing speed with which they are being found.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Kepler changes the planetary scorecard

2 min read

NASA Science Editorial Team

Kepler's latest data release included the discovery of an exotic six-planet solar system and five Earth-size worlds, but the bigger story may be in the hundreds of new "candidate planets" that were announced, The list, now at 1,235, is providing astronomers with tantalizing clues about what kinds of planets are out there and in what quantities.

"The size spread of the planet candidates is intriguing," said Steve Edberg, an astronomer with NASA's Jet Propulsion Laboratory. Though the majority of the 500-plus exoplanets confirmed to exist are large, Jupiter- class planets, Kepler's initial findings suggest that smaller planets the size of Neptune or a few times the size of Earth may be more common.

"Unlike Kepler, the observation techniques we have used so far have been biased towards finding Hot Jupiter-class planets ... but Kepler has so far found a lot more Neptune-size planets and quite a few Super-Earths (planets just a few times larger than our own). Who knows? We might find that these, and not Hot Jupiters, are the most common kinds of planets in our galaxy."

Edberg points out that, even if some of the candidate planets are later not confirmed to be real planets, Kepler's results will very likely redefine the way astronomers think about exoplanets. "Numbers of discoveries aren't as important as finding out how many Earth-size planets may exist out there," he says. "Kepler gives us an opportunity to have less-biased statistics to build a more complete picture of our Milky Way galaxy and, by extension, the universe."

Still, Edberg warns that one shouldn't count cosmic eggs before they hatch. "It will be comforting if Kepler finds a fair number of Earth-size planets in the habitable zone, but we can't let our imaginations run away from us - finding a potentially habitable planet is a long way from actually confirming that it is habitable. But this latest data set bodes well for some exciting discoveries in the future, and I think we're all anxious for its final results."

All of Kepler's candidate planets await verification from ground-based observatories. In some cases, astronomers may decide there is not enough evidence to prove a planet's existence (this is called a "false positive").

Kepler is NASA's 10th Discovery Mission and is funded by NASA's Science Mission Directorate at the agency's headquarters. The Kepler mission is a part of NASA's Exoplanet Exploration Program.

The spacecraft bus that will deliver NASA's Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory's other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Cosmic neighborhoods to avoid

3 min read

NASA Science Editorial Team

(PLANETQUEST) -- With new evidence suggesting that the galaxy could be full of habitable planets like ours, the universe may be a more friendly place than anyone might have imagined.

However, not every planet is lucky enough to have the right conditions for life. Here are some examples of how things can go very wrong.

Treat:Habitable planets are far enough away from their host stars that they have just the right temperature for liquid water to exist.

Trick:A planet that's too far away from its star becomes a dead, frozen iceball incapable of sustaining any life besides a hockey game. And a planet that's too close will have its water boiled away as its surface is bombarded by radiation and furnace-like heat.

Treat:Habitable planets exist in solar systems relatively free of orbital chaos, where orbits are stable and planets keep to themselves.

Trick:Chaotic, young solar systems with unstable or intersecting orbits can be a cosmic demolition derby, with planets and moons smashing into each other mercilessly. Massive gas planets that migrate inwards toward their star can consume smaller, Earth-size worlds that lie in their path. Planets in some hectic systems can even be ejected entirely, doomed to roam the cosmos alone.

Treat:Habitable planets have nice, predictable orbits that keep their surface temperatures relatively stable throughout the year.

Trick:Planets with extremely eccentric, or oval-shaped orbits yo-yo around their host stars. As the planet dive-bombs inward towards the star, temperatures can spike hundreds of degrees in just hours, giving new meaning to the term "heat wave."

Treat:Habitable planets are big enough to hold on to a life-sustaining atmosphere, but not so big that they become buried under thick layers of gas.

Trick:Being a small planet can be no fun - just ask Mars. Too small to hold onto a thick enough atmosphere, the liquid water that Mars may have once had likely evaporated as it lost its atmosphere, turning it into a hostile planetary desert.

Really big planets are no better - though worlds like Neptune and Saturn may have rocky cores at their center, the incredible pressure of their thick atmospheres would crush anything that tried to land long before it reached the core.

Treat:Habitable exoplanets are old enough to have become settled and stable, but not so old that their cores have cooled or that they're at risk of being consumed by their host stars.

Trick:Between their molten surfaces and the constant bombardment of debris, young planets are no place for life as we know it to be maintained.

The perils of old planetary age are just as scary. As a planet's core cools, life-giving liquid water sinks inward through the crust and disappears from the planet's surface.

An aging star can also pose a significant danger to a planet. All stars balloon into red giants as they age, consuming planets that are too close to escape. Some of them are later blown to pieces by stellar explosions.

Written by Joshua Rodriguez/PlanetQuest

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Details of ‘Earthlike’ world will have to wait

2 min read

NASA Science Editorial Team

(PLANETQUEST) -- Just how similar to Earth is the newly discovered planet orbiting the star Gliese 581? Until astronomers can take a closer look with a space-based exoplanet mission, that answer is likely to remain a mystery, NASA experts said.

"This finding is encouraging news for those who believe habitable planets are very common," said Michael Devirian, manager of NASA's Exoplanet Exploration Program. "The next step is for follow-up space missions to take a closer look."

The discovery was announced last week by a team of planet hunters from the University of California Santa Cruz and the Carnegie Institution of Washington. The new planet orbits within the so-called "habitable zone" of its star, where liquid water and life as we know it could exist, and may be small enough to have a rocky surface like Earth's. Although astronomers have detected nearly 500 planets beyond our solar system since the late 1990s, this is the first potentially Earthlike world.

Victoria Meadows, an astrobiologist with the University of Washington, called the announcement "enormously exciting." "We're all a bit shell-shocked," she said. "We need direct observations of the planet to really study it, as opposed to guessing what it might be like ... we're dying for more info. But this is a hopeful sign that there will be plenty of planets like this to study in the future."

The announcement also raised hopes that the Kepler mission, which is currently searching a field of 100,000 distant stars for habitable planets, will turn in a bumper crop of Earthlike worlds.

The discovery was the result of more than a decade of observations using the W. M. Keck Observatory in Hawaii, one of the world's largest optical telescopes. The research was sponsored by NASA and the National Science Foundation.

The paper reports the discovery of two new planets around Gliese 581, bringing the total number of known planets around this star to six, the most yet discovered in a planetary system outside of our own. Like our solar system, the planets around Gliese 581 have nearly-circular orbits. The system is located 20 light-years from Earth in the constellation Libra.

Written by Joshua Rodriguez/PlanetQuest

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Using Planet Colors to Search for Alien Earths

5 min read

Earth is invitingly blue. Mars is angry red. Venus is brilliant white. Astronomers have learned that a planet’s “true colors” can reveal important details. For example, Mars is red because its soil contains rusty red stuff called iron oxide. And the famous tint of our planet, the “blue marble”? It’s because the atmosphere scatters blue light rays more strongly than red ones. Therefore the atmosphere looks blue from above and below.

Planets around other stars probably exhibit a rainbow of colors every bit as diverse as those in our solar system. And astronomers would like to eventually harness color to learn more about exoplanets. Are they rocky or gaseous – or earthlike?

In a study recently accepted for publication in The Astrophysical Journal, a team led by NASA astronomer Lucy McFadden and UCLA graduate student Carolyn Crow describe a simple way to distinguish between the planets of our solar system based on color information. Earth, in particular, stands out clearly among the planets, like a blue jay in a flock of seagulls.

“The method we developed separates the planets out,” Crow says. “It makes Earth look unique.”

This suggests that someday, when we have the technology to gather light from individual exoplanets, astronomers could use color information to identify earthlike worlds. “Eventually, as telescopes get bigger, there will be the light-gathering power to look at the colors of planets around other stars,” McFadden says. “Their colors will tell us which ones to study in more detail.”

Earth the Exoplanet

The project began in 2008, when Crow teamed up with McFadden, her faculty mentor at the University of Maryland in College Park. McFadden currently heads university and post-doctoral programs at NASA’s Goddard Space Flight Center in Greenbelt, Maryland.

New color information about Earth, the moon, and Mars became available, thanks to NASA’s Deep Impact spacecraft. En route to a planned encounter this November with Comet 103P/Hartley 2, Deep Impact observed Earth. The idea was to determine what our home looks like to alien astronomers and eventually use that insight to figure out how to spot earthlike worlds around other stars.

As Deep Impact cruised through space, its High Resolution Instrument (HRI) measured the intensity of Earth’s light. HRI is an 11.8-inch (30 cm) telescope that feeds light through seven different color filters mounted on a revolving wheel. Each filter samples the incoming light at a different portion of the visible-light spectrum, from ultraviolet and blue to red and near-infrared. On May 28, 2008, Deep Impact even caught a glimpse of the moon’s light as it crossed in front of Earth. Later, in 2009, HRI scoped Mars.

McFadden wondered what combination of color information from the filters would best distinguish Earth from the other planets and moons of the solar system. She recruited Crow to work on the project. Eight other researchers from NASA, the University of Maryland, the University of Washington (Seattle), and the Johns Hopkins University Applied Physics Lab also joined the team.

The Magic Mix

The Deep Impact color data covered Earth, the moon, and Mars. The relative amounts of light passing through the filters vary for each planet or moon, providing a kind of color fingerprint. To this the team added existing color information about Mercury, Venus, Jupiter, Saturn, Uranus, Neptune, and Saturn’s moon Titan.

A simple side-by-side comparison of color data on all the major planets was a confusing mess. The team finally found a combination of three different filters – one in the blue, one in the green, and one in the red – that highlights the differences between the planets.

On a special “color-color” diagram the team created, the planets cluster into groups based on similarities in the wavelengths of sunlight that their surfaces and atmospheres reflect. The gas giants Jupiter and Saturn huddle in one corner, Uranus and Neptune in a different one. The rocky inner planets Mars, Venus, and Mercury cluster off in their own corner of “color space.”

But Earth is the true loner in color space. Its uniqueness traces to two factors. One is the scattering of blue light by the atmosphere. This is called Rayleigh scattering, after the English scientist who discovered it.

The other reason Earth stands out in color space is because it does not absorb a lot of infrared light. That’s because our atmosphere is low in infrared-absorbing gases like methane and ammonia, compared to the gas giant planets Jupiter and Saturn.

“It is Earth’s atmosphere that dominates the colors of Earth,” Crow says. “It’s the scattering of light in the ultraviolet and the absence of absorption in the infrared.”

Colorful Future

Someday, the three-filter approach may provide a rough “first cut” look at exoplanet surfaces and atmospheres. “There are some things we can tell from the colors but there are some things that we can’t quite tell without additional information,” Crow says.

For example, if an exoplanet shows a similar color fingerprint to Earth’s, it would not necessarily mean that the planet has the blue skies and vast oceans of our home. But it would tell us to look at that planet more closely.

And that would be an important first step toward making sense of the colorful complexity of the 490 (and counting) alien planets already discovered, and the scores more on the way.

By Daniel PendickNASA’s Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Hubble Finds Hidden Exoplanet in Archival Data

1 min read

NASA Hubble Mission Team

Goddard Space Flight Center

In 19 years of observations, the Hubble Space Telescope has amassed a huge archive of data-an archive that may contain the telltale glow of undiscovered extrasolar planets. Such is the case with HR 8799b, shown in this artist's concept. The planet is one of three extrasolar planets orbiting the young star HR 8799, which lies 130 light-years away. The planetary trio was originally discovered in images taken with the Keck and Gemini North telescopes in 2007 and 2008. But using a new image processing technique that suppresses the glare of the parent star, scientists found the telltale glow of the outermost planet in the system while studying Hubble archival data taken in 1998. The giant planet is young and hot, but still only 1/100,000th the brightness of its parent star. By comparison, Jupiter is one-billionth the brightness of our sun.

Image Credit: NASA, ESA, and G. Bacon (STScI)

Keck Telescopes Gaze into Young Star’s ‘Life Zone’

4 min read

The inner regions of young planet-forming disks offer information about how worlds like Earth form, but not a single telescope in the world can see them. Yet, for the first time, astronomers using the W. M. Keck Observatory in Hawaii have measured the properties of a young solar system at distances closer to the star than Venus is from our sun.

“When it comes to building rocky planets like our own, the innermost part of the disk is where the action is,” said team member William Danchi at NASA’s Goddard Space Flight Center in Greenbelt, Md. Planets forming in a star’s inner disk may orbit within its “habitable zone,” where conditions could potentially support the development of life.

To achieve the feat, the team used the Keck Interferometer to combine infrared light gathered by both of the observatory’s twin 10-meter telescopes, which are separated by 85 meters. The double-barreled approach gives astronomers the effective resolution of a single 85-meter telescope – several times larger than any now planned.

“Nothing else in the world provides us with the types of measurements the Keck Interferometer does,” said Wesley Traub at Caltech’s Jet Propulsion Laboratory in Pasadena, Calif. “In effect, it’s a zoom lens for the Keck telescopes.”

In August 2008, the team – led by Sam Ragland of Keck Observatory and including astronomers from the California Institute of Technology and the National Optical Astronomical Observatory – observed a Young Stellar Object (YSO) known as MWC 419. The blue, B-type star has several times the sun’s mass and lies about 2,100 light-years away in the constellation Cassiopeia. With an age less than ten million years, MWC 419 ranks as a stellar kindergartener.

The team also employed a new near-infrared camera designed to image wavelengths in the so-called L band from 3.5 to 4.1 micrometers. “This unique infrared capability adds a new dimension to the Keck Interferometer in probing the density and temperature of planet-forming regions around YSO disks. This wavelength region is relatively unexplored,” Ragland explained. “Basically, anything we see through this camera is brand new information.”

The increased ability to observe fine detail, coupled with the new camera, let the team measure temperatures in the planet-forming disk to within about 50 million miles of the star. “That’s about half of Earth’s distance from the sun, and well within the orbit of Venus,” Danchi said.

For comparison, the planets directly detected around the stars HR 8799, Fomalhaut and GJ 758 orbit between 40 and 100 times farther away.

The team reported temperature measurements of dust at various regions throughout MWC 419’s inner disk in the Sept. 20 issue of The Astrophysical Journal. Temperature differences help shed light on the inner disk’s detailed structure and may indicate that its dust has different chemical compositions and physical properties, factors that may play a role in the types of planets that form. For example, conditions in our solar system favored the formation of rocky worlds from Mars sunward, whereas gas giants and icy moons assembled farther out.

In turn, the astronomers note, the size of the young star might affect the composition and physical characteristics of its dust disk. The team is continuing to use the Keck Interferometer in a larger program to observe planet-forming disks around sun-like stars.

The Keck Interferometer was developed by the Jet Propulsion Laboratory and the W.M. Keck Observatory. It is managed by the W.M. Keck Observatory, which operates two 10-meter optical/infrared telescopes on the summit of Mauna Kea on the island of Hawaii and is a scientific partnership of the California Institute of Technology, the University of California and NASA. NASA's Exoplanet Science Institute manages time allocation on the telescope for NASA.

By Francis ReddyNASA's Goddard Space Flight Center, Greenbelt, Md.

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Shao Honored for Interferometry Contributions

1 min read

NASA Science Editorial Team

Michael Shao, an expert in the field of optical systems engineering and manager of JPL’s Interferometry Center of Excellence, has received the 2010 Michelson Prize from the International Astronomical Union and the Mount Wilson Institute.

At a recent meeting of the International Society for Optical Engineering, Shao was honored for his many years of fundamental contributions to the field of optical interferometry and for his pioneering work on ground-based and space-based interferometers, including the Keck Interferometer, for which he served as project scientist.

Shao, who joined JPL in 1989, is currently the project scientist for the Space Interferometry Mission.

The Michelson Prize is awarded to provide recognition within the interferometry community, as well as in the broader science community, of scientific research programs and results from the rapidly growing field of optical interferometry. Shao was acknowledged under the prize’s Lifetime Achievements category, which recognizes a substantial history of contributions and international leadership as evidenced by publications, advancement of knowledge, reputation, procurement and management of resources, or accomplishments of former students.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

Spitzer Watches Wild Weather on a Star-Skimming Planet

4 min read

What would happen if, for a single day, the sun's light and heat were amplified a thousand times? While this sounds like the setup for a classic tale of science fiction, astronomers know of one planet that experiences just such a climate extreme. Now, thanks to NASA's Spitzer Space Telescope, scientists have measured how this planet's atmosphere responds to a super-summer day.

The planet in question orbits a sun-like star catalogued as HD 80606. Part of a binary system, the star is joined in space by a near-twin called HD 80607. These siblings aren't particularly close — they're separated by about 125 times the distance between Saturn and our sun. The stellar couple lies 190 light-years away in the constellation Ursa Major where, tucked between the Greater Bear's front legs, they can be seen through binoculars.

HD 80606b was discovered in 2001 by a Swiss planet-hunting team led by Dominique Naef of the Geneva Observatory, Switzerland. It's a gas giant planet — much like Jupiter in our own solar system but about four times more massive. What makes HD 80606b unique is its orbit — the most elongated yet found, almost as lopsided as the orbit of Comet Halley in our own solar system. Like Halley, HD 80606b spends most of its time far from its star and then, at closest approach, dramatically whips around it.

"There are several other planets with very high eccentricities, but HD 80606b has the highest known," says Greg Laughlin of Lick Observatory, University of California at Santa Cruz. He's the lead author of the study, which appears today in the science journal Nature.

Every 111 days, HD 80606b shuttles between 79 million miles from its star — equivalent to midway between Venus and Earth in our solar system — to just 2.8 million miles away. That's nearly 13 times closer then Mercury's average distance to the sun — and less than four times the diameter of HD 80606.

At the farthest part of its orbit, HD 80606b receives a little less than the intensity of solar energy Earth receives from the sun. But in the 30 hours bracketing the planet's wild swing through closest approach, the energy HD 80606b receives from its star spikes by nearly 830 times.

Laughlin and his colleagues observed HD 80606b before, during and just after its closest passage to the star on Nov. 20, 2007. The Spitzer team didn't know whether the planet would disappear completely behind the star. Measurements made with the planet constantly in view could provide the temperature change, but not the actual temperatures. In fact, HD 80606b did pass behind its star. The Spitzer measurements show that, over the course of six hours, the planet's temperature rose from 980 to 2,240 degrees Fahrenheit.

Tides lock the rotation of most "hot Jupiters" to their orbital period. This means they keep the same side facing the star, which makes it impossible for astronomers to observe the hot spot. But because of its odd orbit, HD 80606b hasn't become tidally locked. It rotates on its axis every 34 hours. "The planet is spinning at a fast enough rate for the planet's hot spot to come into view," says co-author Drake Deming of NASA's Goddard Space Flight Center. "The hot spot can't hide."

"We watched the development of one of the fiercest storms in the galaxy," Laughlin says. "This is the first time that we've detected weather changes in real time on a planet outside our solar system." The team used the data to model how heat flows through the planet's atmosphere — the first time such information has been available for a planet orbiting another star. HD 80606b heats up and cools down fast. This indicates that the stellar energy intercepted by the planet is being absorbed fairly high up in the atmosphere, where the air is relatively thin.

Because the scientists detected the planet’s disappearance behind the star, there’s a 15 percent chance that HD 80606b will pass in front of — or transit — the star from our viewing angle. The next possibility of detecting HD 80606b in transit falls on Feb. 14. The event could last up to 17 hours and would provide much additional information on the nature of this peculiar world.

By Francis ReddyNASA’s Goddard Space Flight Center, Greenbelt, Md.

This image from the NASA/ESA Hubble Space Telescope features the spiral galaxy IC 1954, located…

Missions

Humans in Space

Climate Change

Solar System

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunters: Angling for Extraterrestrials and Earthlike Worlds

5 min read

NASA Science Editorial Team

By Joshua Rodriguez / PlanetQuest

As an avid fly fisherman and geocaching enthusiast, Robert Peters is a natural hunter, which makes him the perfect person to work on technology to help find Earthlike planets. In his role as an engineer with JPL's Terrestrial Planet Finder project, he's responsible for the testing and development of the Adaptive Nuller - an instrument that will one day help scientists analyze the atmospheres of distant planets for signs of life.

PlanetQuest: What is an "adaptive nuller" and how does it help you find and characterize exoplanets?

Robert Peters: A nuller is basically an optical subtraction system that cancels out light coming from a star. One of the problems with nulling across a lot of frequencies of light is that the phase and amplitude of the light we need to cancel out is different at every frequency. An adaptive nuller automatically adjusts itself to cancel out light at each different frequency. Once you've gotten rid of the starlight you can analyze the light from the planet itself.

PQ: What's the difference between a nuller and a coronagraph?

RP: A coronagraph is a lot like putting your thumb in front of the star to block out its light and see the planets that are orbiting it. A nuller actually combines waves of light so that they cancel each other out. The advantage of nulling is that you can use it with an interferometer, which allows you to combine the power smaller telescopes into one huge telescope.

Nulling is also more useful for observing planets in the mid-infrared band of light, whereas a coronagraph is better for visible light. A nuller is also useful for characterizing an Earthlike planet, because the dips in the spectrum that can indicate water or oxygen are more pronounced in the mid-infrared.

PQ: How does the nuller help scientists discover whether or not a planet can support life?

RP: The nuller can cancel out the light of a star at a ratio of 100,000 to 1 - then, we use other processes to go through the data that's left and find the light from the planets. Then, you can analyze that data to find markers of life in the atmosphere of the planet, like water and oxygen. The nuller is the first step in isolating enough of the planet's light to look for signs of life.

PQ: Does your job involve more software programming or testing out prototypes in the lab?

RP: It's a lot of both. The nuller is controlled by software that I have to program, but I have to set up the parts and test the system on a big breadboard that floats on air legs. Because the system is so sensitive to vibration, I have to test at night, after everyone's left the building - usually about once a week or so.

PQ: Is what you're working on now an actual instrument that will fly in an exoplanet-finding mission someday?

RP: The actual testbed won't be going to space, but we've demonstrated that the technology works and could be actually used successfully in the Terrestrial Planet Finder mission. In fact, when I first started this, it was a just a side project that I was asked to explore - now, it's a critical part of making the mission work.

PQ: How did you end up working on such an interesting project?

RP: I was hired at JPL as I was finishing up grad school at Montana State University, studying physics and playing with lasers in the electric lab. When I eventually was transferred to the Terrestrial Planet Finder project, I worked with Oliver Lay, brainstorming on his idea for an adaptive nuller, so I started on the ground floor of this project. I didn't originally plan on getting involved with NASA, but I watched a lot of "Star Trek" when I was growing up and got a lot of variety while I was studying physics, so it makes sense that I ended up here.

PQ: When you aren't at work, what do you like to do with your spare time?

RP: Well, I like fly fishing - I have a fly rod under my desk that I take out to the creek near the lab sometimes when I want to relax. I've also gotten into tying my own flies and making my own rods out of bamboo. I like fly fishing because it's like hunting for fish - you have to convince them that this ball of thread you're tossing around is food. My wife Shannon and I also like to go geocaching.

PQ: Geocaching?

RP: It's a sport where people hide things in the woods - everything from toys to logbooks you sign when you find them. You're given GPS coordinates and clues and have to go find the prize. It's a lot of fun and a really good way to find new places to go hiking.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Evaporating Planet

1 min read

NASA Hubble Mission Team

Goddard Space Flight Center

Planet HD 209458b is evaporating. It is so close to its parent star that its heated atmosphere is simply expanding away into space. Some astronomers studying this distant planetary system now believe they have detected water vapor among the gases being liberated.

This controversial claim, if true, would mark the first instance of planetary water beyond our solar system, and indicate anew that life might be sustainable elsewhere in the universe. Although spectroscopic observations from the Hubble Space Telescope are the basis for the water detection claim, the planetary system is too small and faint to image. The image is an artist's concept of the HD 209458b system.

Image Credit: NASA, European Space Agency, Alfred Vidal-Madjar (Institut d'Astrophysique de Paris, CNRS)

Oldest Known Planet Identified

1 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA's Hubble Space Telescope precisely measured the mass of the oldest known planet in our Milky Way galaxy. At an estimated age of 13 billion years, the planet is more than twice as old as Earth's 4.5 billion years. It's about as old as a planet can be. It formed around a young, sun-like star barely 1 billion years after our universe's birth in the Big Bang. The ancient planet has had a remarkable history because it resides in an unlikely, rough neighborhood. It orbits a peculiar pair of burned-out stars in the crowded core of a cluster of more than 100,000 stars. The new Hubble findings close a decade of speculation and debate about the identity of this ancient world. Until Hubble's measurement, astronomers had debated the identity of this object. Was it a planet or a brown dwarf? Hubble's analysis shows that the object is 2.5 times the mass of Jupiter, confirming that it is a planet. Its very existence provides tantalizing evidence that the first planets formed rapidly, within a billion years of the Big Bang, leading astronomers to conclude that planets may be very abundant in our galaxy.

Illustration Credit: NASA and G. Bacon (STScI)

Ring Around a Star

1 min read

NASA Hubble Mission Team

Goddard Space Flight Center

NASA Hubble Space Telescope's most detailed visible-light image ever taken of a narrow, dusty ring around the nearby star Fomalhaut offers the strongest evidence yet that an unruly and unseen planet may be gravitationally tugging on the ring.

Hubble unequivocally shows that the center of the ring is a whopping 1.4 billion miles away from the star. The most plausible explanation is that an unseen planet moving in an elliptical orbit is reshaping the ring with its gravitational pull.

The observations offer insights into our solar system's formative years, when the planets played a game of demolition derby with the debris left over from the formation of our planets, gravitationally scattering many objects across space. Some icy material may have collided with the inner solar system planets, irrigating them with water formed in the colder outer solar system.

Image Credit: NASA, ESA, P. Kalas and J. Graham (University of California, Berkeley) and M. Clampin (NASA/GSFC)

James Webb Space Telescope

Perseverance Rover

Parker Solar Probe

Juno

Orbiting a Red Dwarf Star

1 min read

NASA Hubble Mission Team

Goddard Space Flight Center

This artist's concept of a gas giant planet orbiting a red dwarf K star shows a planet has not been directly imaged, but its presence was detected in 2003 microlensing observations of a field star in our galaxy. Gravitational microlensing happens when a foreground star amplifies the light of a background star that momentarily aligns with it. Follow-up observations by Hubble Space Telescope in 2005 separated the light of the slightly offset foreground star from the background star. This allowed the host star to be identified as a red dwarf star located 19,000 light-years away. The Hubble observations allow for the planet's mass to be estimated at 2.6 Jupiter masses. The characteristics of the lensing event show that the planet is in a Jupiter-sized orbit around its parent red star. The rings and moon around the gas giant are hypothetical, but plausible, given the nature of the family of gas giant planets in our solar system.

Image credit: NASA,ESA and G. Bacon (STScI)

Planet Hunters: A Conversation with Navigator Chief Scientist Wes Traub

5 min read

NASA Science Editorial Team

Where are the other Earths?

Answering that question is just the first step in NASA's long-range quest to look for life around stars beyond our solar system, according to Dr. Wes Traub. And to answer it, he says, we have to go into space.

Traub was recently named chief scientist for the Navigator Program, a series of interrelated missions that will discover and characterize nearby planetary systems. The program will kick into high gear with SIM PlanetQuest, scheduled to launch within the next decade. SIM PlanetQuest will identify Earthlike targets for the follow-on Terrestrial Planet Finder observatories, which will use remote sensing capabilities to characterize the planets and determine which are habitable, or even inhabited.

Previously a senior physicist at the Harvard-Smithsonian Center for Astrophysics, Traub received his Ph.D. in physics from University of Wisconsin-Madison in 1968. He was the project scientist for Infrared-Optical Telescope Array (IOTA) and the principal investigator for Far-Infrared Spectrometer (FIRS-2). His research fields include extrasolar planets, high angular resolution astrophysics and stratospheric physics and chemistry.

Q: Briefly, what are NASA's planet-finding goals over the next decade?

Traub: Well, NASA has been in the planet-finding business for a long time. This is not something new. So the plan for NASA in the coming decade is basically to follow up on the recent discoveries of about 200 planets we know about today. The main thing we'd like to know is, are there any other planets out there that look like Earth?

Q: How will a mission like SIM PlanetQuest be unique in terms of trying to locate some of these planets?

Traub: SIM will tell us whether there are Earthlike planets around nearby stars, and that will be a big step. It will tell us two crucial things: the mass of the planet, and where it's located with respect to the star. SIM will tell us whether or not the planet is in the right range from the star -- in the habitable zone - to have liquid water on the surface.

Q: How does SIM PlanetQuest set the stage for more advanced planet-finders in the future?

Traub: The purpose of SIM PlanetQuest is to look for all sizes of planets around nearby stars, and the range goes all the way out to these heavy Jupiters, all the way down to single-Earth mass. Nearby stars are of interest because we can follow up with later missions that will focus on these stars, and isolate the really bright light of the star from the faint light of the planet so we can characterize these planets and see if there's life.

Q: So SIM PlanetQuest is going to act as a precursor and look for planets where we could then narrow in and find something that could be truly Earthlike.

Traub: Absolutely. We'll know exactly where and when to look with two succeeding missions planned after SIM - the Terrestrial Planet Finder Coronagraph, and the Terrestrial Planet Finder

Interferometer. These two missions will check whether SIM gave the right info, find planets SIM couldn't find, and will characterize the planets. They will tell us whether or not the light that comes from a planet is similar to the light from Earth.

Q: What is the most important question that you hope will be answered by these missions?

Traub: I think the most important thing would be to answer the question of whether there's life on other planets. I know this sounds like it's beginning to edge into the territory of material you see in the supermarket checkout line.

Actually, just 10 years ago, when I went to my first meeting that was going to discuss searching for planets I was a little embarrassed about it. I didn't tell my colleagues I was going, and then I realized there were other people there that I respected, and I thought, well, maybe this isn't so bad. So it edges on asking questions that are outside the realm of traditional astronomy, but I think this is the kind of thing that we are able to do and that people are really interested in. And I think, technically, we can do it today.

Q: Speaking as an individual, and not as a scientist, do you think there is a planet out there with intelligent life?

Traub: I guess at heart I believe there are planets with life on them. I don't know about intelligent life. The usual argument is that there are billions of stars out there, and today we think the chances of planets being around each one of them are pretty high, which we didn't used to think. And we think that life formed very quickly, as soon as it was possible on Earth. But out of the billions of stars in our galaxy, we only have a chance of looking at about 200 stars that are nearby. The chances of intelligent life being there on one of those, right now, are pretty small.

Q: It must strike you once and a while that you have a really interesting job - looking for life on other planets and coming up with missions to find those planets. Is there anything boring about it?

Traub: Oh, there's nothing boring about it. When I came here to JPL from Boston about a year ago, people said, why are you moving? I explained, you know, this is the most exciting thing I could think of to do with my life. Even in three lifetimes. There is going to be no other point in history where we can discover the first Earthlike planet and tell if there's life on it - this will never happen again. I just hope it happens when I'm working on it.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunters: Putting Together The Big Picture in Planet-Finding

5 min read

NASA Science Editorial Team

By Joshua Rodriguez / PlanetQuest

"I just do it for the pictures," laughs Dr. David Imel as he points to the myriad posters of stars and galaxies hanging from the walls in his office at Caltech. But the picture Imel wants to see most doesn't exist yet - a pale blue dot orbiting a distant star. Another Earth.

As the manager of the Michelson Science Center at Caltech, Imel coordinates a team of scientists and engineers whose goal is to find the elusive Earthlike planet. He and his team schedule and organize telescope time, process raw data from missions, and organize information about exoplanets, or planets orbiting stars beyond our solar system, so that it's efficient to use, and provide planning and analysis tools to the science community.

Imel didn't actually plan on getting into this kind of science at all. He graduated from the University of Washington in Seattle with a degree in physics and got his doctorate at Caltech while looking for something as elusive as Earthlike planets: neutrino mass. But when he decided to take a job in the radar section at JPL to do something more practical, Imel found himself on a career path that would eventually lead him into exoplanet research.

We caught up with him in his office at Caltech to talk about his work and some of his hobbies.

PlanetQuest: What's the Michelson Science Center about?

David Imel: It's the science center for NASA's planet-finding science program.

PQ: What exactly does the Science Center do?

Imel: We implement science operations for projects such as the Keck Interferometer (a pair of combined 10-meter telescopes atop Mauna Kea) and SIM PlanetQuest, a spaceborne interferometer which will be capable of measuring infinitesimal wobbles of stars due to the planets orbiting them. We accept proposals for observing time on these instruments, put together efficient observing strategies, and collect and process the data.

Keck observatory at twilight.

The Michelson Science Center also has fellowships for grads and postdocs to try to train the next generation of planet-finders.

PQ: How did you get your current job at the Science Center?

Imel: In 2003 I got an e-mail looking for someone to manage an astrophysics science center with an emphasis in interferometry. I've always had a romantic interest in astronomy: I'm a stargazer at heart and have taken groups to the mountains to introduce them to a dark night sky and tell them the stories of the constellations. So although I'm not an astronomer, I was very excited about the opportunity to work with astronomers to answer one of the most fundamental questions we have: "Are there other Earths?"

PQ: Do you think that astronomers will find an Earthlike planet within your lifetime?

Imel: Absolutely. I like to think of a saying from the physics world, "If it's possible, then it does exist." We just can't see it yet---it's an engineering issue. We've found planets in places we've never expected. It's just a matter of building instruments with the right sensitivity. It wouldn't surprise me if we found a planet with organic material - with more than a hundred billion stars in our galaxy alone, the odds seem pretty good that another one exists.

PQ: What do you think the impact of finding an Earthlike planet will have on society?

Imel: Well, the Earth-like planet is the Holy Grail - scientists talk about finding the "blue dot." You have to find out if the composition of the atmosphere and the chemistry of the planet could support life. I think that stepping out and expanding our reach is a major goal for space exploration - it's the next step for society. I think it will really change how we think about the universe and our future.

PQ: Besides science, what else do you like to do with your time?

Imel: I have a ridiculously long list of hobbies which includes things like fencing, backpacking, sailing, and even knitting.

PQ: Knitting?

Imel: Yes. I find it both intriguing and soothing. I once used a spreadsheet to create a recursive matrix equation for a really complicated pattern - that way I didn't have to remember every stitch. Kind of a funny way to do it, I guess.

PQ: How did you get into backpacking?

Imel: I was invited by a couple of guys at JPL who were a lot more experienced than I. I was amazed at the freedom you feel waking up every morning to go down the trail to the next place; the scenery was gorgeous, and then of course, there was the night sky! My favorite places to backpack include the Eastern Sierras and the Yosemite high backcountry.

PQ: What keeps you excited about your job?

Imel: I think that these are the most interesting questions in astronomy right now - whether there are other habitable planets, whether there is life elsewhere in the universe. We may eventually come to a point where we become a multi-planet species, and I think this is the first step down that road.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

NASA’s Dawn Spacecraft Begins Interplanetary Cruise Phase

1 min read

NASA Science Editorial Team

NASA's Dawn spacecraft has successfully completed the initial checkout phase of the mission and begun its interplanetary cruise phase, which is highlighted by nearly continuous thrusting of its ion propulsion system. Dawn is on a 8-year, 3-billion mile journey to asteroid Vesta and dwarf planet Ceres.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Sun

Facts About Earth

Asteroids, Comets & Meteors

Kuiper Belt

Planet Hunters: Former Athlete Flexes New Muscles for Planet Search

4 min read

NASA Science Editorial Team

JPL physicist Ken Brown aims high.

Twice named All-American in track and field, he placed 12th in the 1992 U.S. Olympic Trials qualifier in high jump. Now, he has his sights set on even loftier goals -- building an instrument to spot hard-to-see planets outside our solar system, inspiring students, improving education, and strengthening the community.

Brown and his team at JPL are developing an experimental version of an instrument that will eventually fly in space. Called a "nulling" interferometer, the instrument will be able to cancel out the blinding light of a distant star to see if a planet shines close by. It will be a key part of NASA's Terrestrial Planet Finder, a future mission to search for planets like Earth elsewhere in our galaxy.

"Light is a wave," Brown said. "The idea of an interferometer is to split the incoming light and 'null out' the bright light from a star so that the only light we see is from the planets." The team first performed the nulling experiment at room temperature, then inside a vacuum chamber with the temperature lowered to minus 301 degrees Fahrenheit (minus 185 degrees Celsius).

"We need to simulate the spacecraft's environment," Brown said, "to learn as much as we can about how our instrument will perform and test for every possibility before launching."

The next step for Brown and his team of eight colleagues will be to build an even larger experimental interferometer, move it into a specially designed chamber, and lower the temperature even further, to minus 458 degrees Fahrenheit (minus 272 degrees Celsius), the temperature of space. This larger instrument will include mirrors that will move and point to targets just as the flight version will do in space. "It's not a trivial thing," said Brown, who has been working on the Terrestrial Planet Finder Mission for about a year.

If it were trivial, or boring, it probably wouldn't appeal to Brown. He likes to practice what he preaches to students, "Choose something to do because you're interested in it, not because it's easy. If something is hard, that's OK, you just need to understand it better."

Like physics, education is something that interests Brown. He teaches basic physics at Cal State, Dominguez Hills, and often speaks to secondary students. "We're losing our future mathematicians and scientists," he said. "I try to go out and be an example of what's possible." Brown also serves on the California Department of Education's Technology Advisory Group. Chaired by Ask Jeeves founder Garrett Gruener for Jack O'Connell, state superintendent of public instruction, the group's mission is to find better ways to help students learn. "We're looking at the next generation of learners and how technology can help," Brown said.

Education is something of a family business for the Browns. His father, a retired probation officer, is a prominent member of the University of Iowa's Black Alumni Association. His mother is a professor of music at Cal State Long Beach, and his wife is a school psychologist and counselor.

Community involvement is also a family concern. Brown serves as president of the board of JobStarts, Inc., a non-profit organization that helps residents of South Los Angles find work and provides training in financial literacy. His father was one of the founders of the organization, which just celebrated its 15th anniversary.

Brown began his career with JPL as a college intern and has worked on a variety of missions, including the ocean-observing Topex/Poseiden and Cassini, which recently arrived at Saturn. As a youngster, Brown got the "engineering bug" by taking things apart and trying to put them back together. "I wasn't always as successful as my parents would have liked," he said.

Brown received his B.S. in computer science and physics from Morehouse College and a master's in applied physics from Clark Atlanta University. A native of Los Angeles, he moved back to California after college and now lives in South Los Angeles with his wife and two young sons.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Planet Hunters: Burning the Midnight Oil at 13,600 Feet

4 min read

NASA Science Editorial Team

By Joshua Rodriguez, PlanetQuest

Robert Ligon is an engineer, not an astronaut. Nonetheless, his work takes place on an otherworldly landscape miles above sea level, where the air is thin and clear. He is part of a team that is pushing the technology envelope to aid in NASA's search for new worlds.

As optical engineer for the Keck Interferometer project, Ligon travels to Hawaii about nine times a year, where he helps keep a complex, multi-faceted system of optics working smoothly during all-night observing runs at the Keck Observatory. The work is conducted in the rarefied atmosphere atop Mauna Kea, a dormant volcano rising more than 13,600 feet above the Pacific Ocean.

The Keck Interferometer links the world's two largest optical telescopes to create a virtual telescope of unprecedented power, capable of probing regions around nearby stars where Earthlike planets may have formed. The project is managed by the Jet Propulsion Laboratory for NASA's Science Mission Directorate.

Robert was born in Hawaii and received his M.S in optical sciences from the University of Arizona in 1996.

PlanetQuest: Please describe your role in NASA's planet-finding program.

Robert Ligon: I help design and build all the optical subsystems on the Keck Interferometer project. This includes trouble-shooting, getting them to work together, and achieving good image quality.

PQ: How did you get started in this field?

Ligon: I was returning to school at the University of Arizona, and a friend suggested I take an optical engineering class with him and try it out. I found out that physical optics is a lot like electrical engineering, except you can actually see things, like the interference of light. I was hooked, and I ended up getting my degree from there.

PQ: Were you interested in this kind of thing when you were young?

In his spare time, Ligon is an avid skin diver and underwater photographer. He snapped this image of a green turtle off the big island of Hawaii in August 2004.

Ligon: When I was a kid I loved taking things apart. Sadly, I wasn't as good putting them back together again. That was the one thing my parents didn't like. But I was really an outdoors person, and I think that's what linked me to optics. It was a way to exercise my brain while still connecting to nature.

PQ: Is there a particular teacher who influenced you along the way?

Ligon: Yes, Professor James Palmer, my radiometry teacher at the University of Arizona. He was a lab rat, very good at enjoying the lab, but also good at enjoying the rest of his life. He was a singer in a choir that traveled quite a bit, and he did a lot of interesting things outside of the lab. He was really good at teaching me to have balance in my life.

PQ: What do you like to do in you spare time?

Ligon: I like to be outdoors. When I'm not working, I'm usually at the beach or in the mountains, every single weekend.

PQ: What advice would you give to a young person considering a similar career?

Ligon: If someone was going into the engineering field, I would suggest to them to just do something they love, because engineering encompasses a lot. People may think that engineers just twiddle things and tinker, but there are a whole lot of different subsets of engineering that have to do with business, procurement and other aspects. Engineers have to be more well-rounded than a lot of people realize.

PQ: What has been your favorite moment working on the project?

Ligon: When we first started working on the project on the summit, we worked constantly. Every single night we were up on the summit debugging the system. It was a big ordeal for us. So when we were ready for our first night using the giant Keck telescopes, everybody was kind of bunkered down for a very long night. And it ended up that we locked on the stars, and within five minutes we got our first fringes (interference patterns). It was really a great moment.

PQ: What's the coolest part of what you do?

Ligon: The coolest part of optical engineering is the visual-ness of it. You can see the waves, but you don't need an oscilloscope. Just by looking at the interference of optical beams you get an understanding of what the equations are doing. And these are the kind of effects that can be seen everywhere in the world in rainbows, oil slicks on water, or with sun dogs. There are so many optical effects in nature -- it's incredible to learn about the science behind that.

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Search for Life

Stars

Universe

Black Holes

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.

Free-Floating Planets Confirmed

5 min read

NASA Science Editorial Team

Royal Astronomical Society Press Notice

Ref. PN 01/12 (NAM5)Issued by: RAS Press Officers

Peter BondPhone: +44 (0)1483-268672Fax: +44 (0)1483-274047E-mail: 100604.1111@compuserve.comMobile phone: 07711-213486

Dr Jacqueline MittonPhone: +44 (0)1223-564914Fax: +44 (0)1223-572892E-mail: jmitton@dial.pipex.comMobile phone: 07770-386133

NAM PRESS ROOM.The press room phone numbers are:+44 (0)1223-313724+44 (0)1223-313754+44 (0)1223-315553

RAS Web site:http://www.ras.org.uk

UK National Astronomy Meeting Web site:http://www.ast.cam.ac.uk/~nam2001/

Astronomers have known for many years that stars form when the cores of giant clouds of cold molecular material fragment and collapse. However, the details of the star formation process are poorly understood. In particular, the smallest fragments that can collapse to form very low mass stars or sub-stellar objects have not yet been identified.

Dr. Philip Lucas (University of Hertfordshire) and Dr. Patrick Roche (Oxford University) controversially announced last year that they had directly observed 13 faint points of light in Orion (a giant stellar nursery where thousands of stars are being born) which appeared to have masses closer to those of the giant planets -- a few times more massive than Jupiter in our Solar System -- than the stars.

On Tuesday 3 April, the same pair will announce at the UK National Astronomy Meeting in Cambridge that they have confirmed their discovery of 'free floating planets' in the Orion Nebula. Their measurements of the spectrum of the infrared light from 20 objects in the Nebula show the characteristic signature of water vapour. This confirms that these objects are indeed young, low-mass bodies, and that the faintest of them are of planetary mass. These planetary mass objects can only be seen because they are very young and still warm after the process of formation.

Dr Lucas commented, "It's exciting to find these planet-sized objects floating around in space, unlike planets such as our Earth which orbit a star. Our new results provide the first steps in the exploration of their physical properties."

"The identification and study of these objects is extremely interesting in itself," added Dr. Roche, "but it can also aid our understanding of the star formation process, which is one of the major mysteries in astronomy."

This proof is sure to add fuel to the controversy of how such objects were born. Are they actually planets, thrown out of their solar systems and now floating in space, or have they been formed directly from a gas cloud in space, much like a normal star is?

There is also controversy over how to classify these "inbetween" objects. Some astronomers say that as these may have been formed like a star, they should not be called planets. The authors suggest that a new term -- planetars -- may be a good compromise.

FINDING THE EVIDENCE

Lucas and Roche were following up their discovery of these objects last year, when they measured faint points of light in the Orion Nebula -- a vast cloud of gas and dust that can be seen with the naked eye as the middle 'star' in the sword of the constellation of Orion. Their observations were made in infrared light, using the United Kingdom Infrared Telescope at Mauna Kea Observatory, Hawaii.

This sparked a wide controversy among scientists, with some arguing that the result was a mistake because the planets might be normal stars far behind Orion and just happened to look like very young planets.

Now Lucas and Roche have used the same telescope to analyse the light from these giant worlds at different frequencies and shown that they must be inside the Orion Nebula. By studying the spectrum of the light from the planets, they were able to measure the temperature of the objects, and then, with the use of theoretical models, derive their masses.

The spectroscopic analysis shows strong absorption features due to water vapour in the atmospheres of these objects, which shows that they are not hot enough to be distant stars.

The results have been strengthened with the help of theoretical work on the atmospheres by France Allard and Isabelle Baraffe of the Ecole Normale Superieure at Lyon in France and by Peter Hauschildt at the University of Georgia in the United States. Lucas, Roche, Allard and Hauschildt analysed 20 of the brown dwarfs and planet candidates in the Orion Nebula to confirm the result.

The so-called 'planets' float in space by themselves, not orbiting any star. They are thought to be between 5 and 13 times as massive as the planet Jupiter, so they are rather large by the standards of our Solar System and are most unlikely to support life.

However, these worlds are not massive enough to shine by nuclear fusion, the process that powers the Sun and the stars. Nor are they massive enough for even the meagre nuclear reactions that occur in 'brown dwarfs', objects with masses between those of planets and stars.

The scientists admit that there is a slight chance that they are misinterpreting the data. If all the theoretical calculations for these poorly understood objects are wrong, or if they are far older than the stars and brown dwarfs around them, there is an outside chance that they are actually 20 or 30 times the mass of Jupiter -- too big to be called planets. However, all the evidence found so far points to them being free-floating planets, and other astronomers in Japan and Spain are beginning to find signs of more and more planets in other nebulae like Orion.

CONTACT:

Dr Phil LucasDept of Physical SciencesUniversity of HertfordshireCollege LaneHATFIELDAL10 9ABPhone: +44 (0)1707-286070Fax: +44 (0)1707-286142E-mail: pwl@star.herts.ac.uk

Dr Pat RocheDept of AstrophysicsNuclear and Astrophysics Lab.Keble RoadOXFORDOX1 3RHPhone: +44 (0)1865-273338Fax: +44 (0)1865-273418E-mail: pfr@astro.ox.ac.uk

IMAGES ARE AVAILABLE ON THE WEB AT:www-astro.physics.ox.ac.uk/~pwl/trapl.jpgwww-astro.physics.ox.ac.uk/~pwl/trapl.gifwww-astro.physics.ox.ac.uk/~pwl/trapl.tif

The spacecraft bus that will deliver NASA’s Nancy Grace Roman Space Telescope to its orbit and enable it to function once there is now complete after years of construction, installation, and testing. Now that the spacecraft is assembled, engineers will begin working to integrate the observatory’s other major components, including the science instruments and the […]

Sun

Facts About Earth

Asteroids, Comets & Meteors

Kuiper Belt

NASA explores the unknown in air and space, innovates for the benefit of humanity, and inspires the world through discovery.