

CSM-TLC STAR CHART (B)
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10 Places to Search for Life Beyond Earth

Simon Steel

Senior Director of Education
and STEM Programs
SETI Institute

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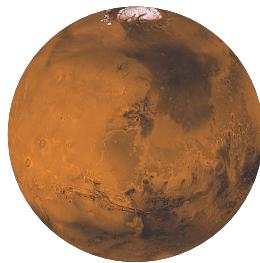
Design/Layout

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01

MARS

THE RUSTY DESERT



Life on Mars has been part of the human imagination for centuries, but the planet's bone-dry surface and ghostly thin atmosphere means that it's a hostile and dangerous world. On the other hand, evidence from many orbiters and landers gives strong evidence that ancient Mars was covered in water and blanketed in a thick protective atmosphere. Could an early Mars have been the cradle of life just like young Earth, and does fossilized evidence still exist on, or beneath, the surface awaiting discovery? Could something still survive?



Acidalia Planitia Mars

A location on Mars associated with the best-selling novel and Hollywood movie, "The Martian". This area is in the Acidalia Planitia region and in the novel and the movie, it is the landing site of a crewed mission named Ares 3.

Credit: REUTERS/NASA/JPL-Caltech/Univ. of Arizona

02

ENCELADUS

THE ARCTIC TIGER



This diminutive moon of Saturn is also its most pristine – it is a gleaming white ice-covered world whose lack of craters suggests a newly minted crust. Close passes by the Cassini spacecraft discovered plumes of water shooting out from “tiger stripe” cracks in the icy surface. These cryovolcanos indicate a liquid ocean below the ice, and chemical analysis suggests that organic molecules in this subsurface sea have all the raw materials and conditions for life in the cold, outer realms of our solar system.

A dramatic illustration of the Cassini spacecraft diving through the geysers of Enceladus' plume. The scene is set against the dark void of space. On the right, the bright, turbulent plume of Enceladus dominates the frame, its white and light blue hues contrasting sharply with the deep black of the void. A thin, curved line of light marks the edge of the plume's source, the moon Enceladus. In the lower-left quadrant, the Cassini spacecraft is shown from a side-on perspective, appearing as a small, dark silhouette against the bright background. It has two long, thin solar panels extending from its sides. The overall mood is one of a daring and intimate scientific encounter.

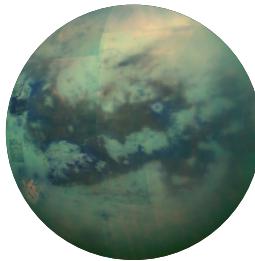
This illustration shows NASA's Cassini spacecraft diving through the plume of Saturn's moon Enceladus, in 2015.

Credit: NASA/JPL-Caltech

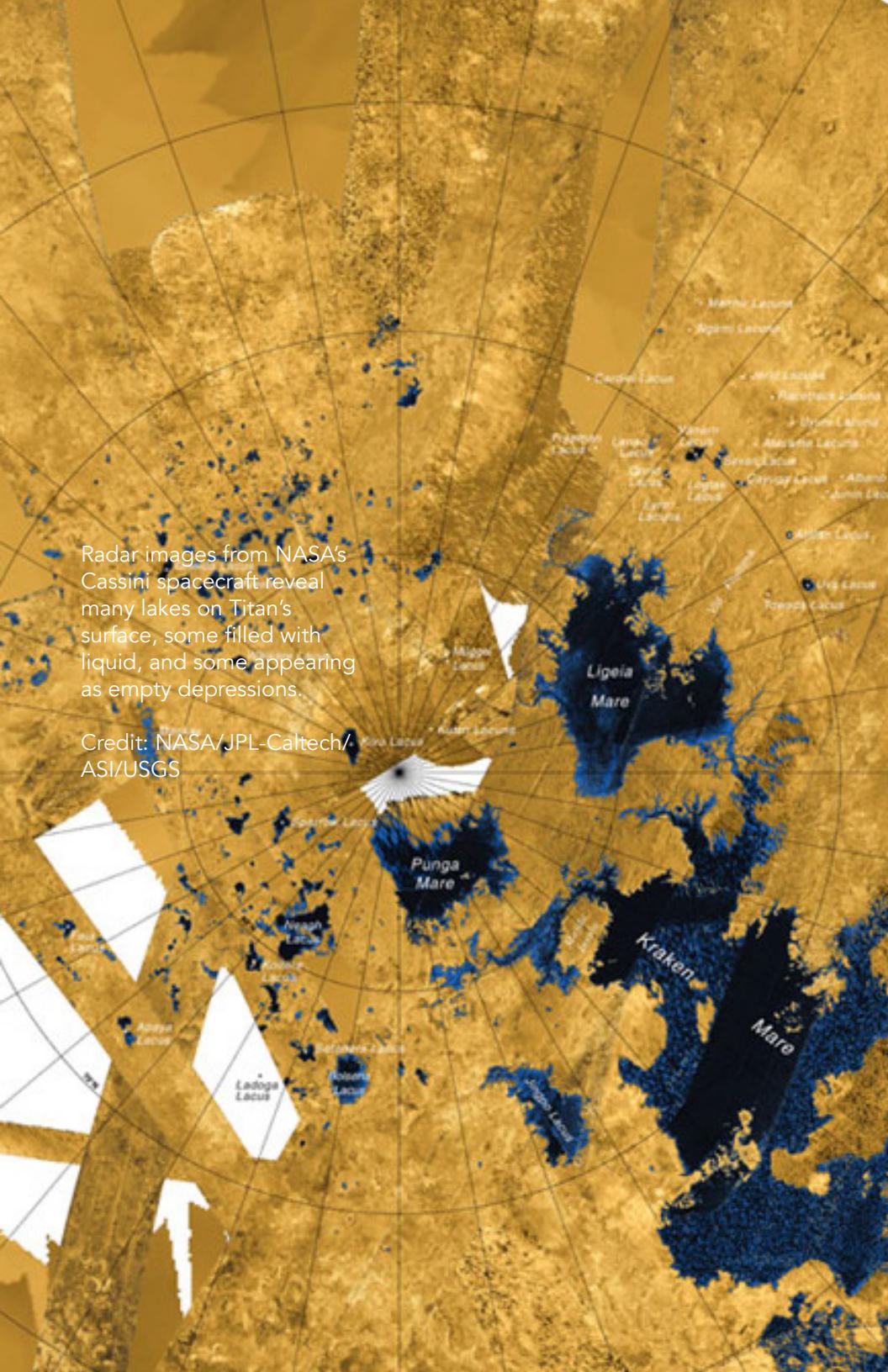
03

TITAN

PRIMORDIAL EARTH



This is the second-largest moon in the Solar System and is bigger than the planet Mercury. It is the only world other than Earth known to have stable liquids on its surface. But with an average surface temperature -180°C, these are lakes of liquid methane, not water. So this cold, distant satellite, choked with organic smog and pelted with ethane rainstorms, may not seem like an environment conducive to life. Yet a lot of the organic ingredients are there in abundance, and lakes and pools allow those molecules to meet and mix. Titan is a perfect kitchen pantry that may be cooking up something exciting!



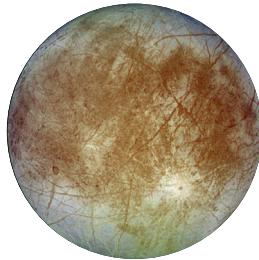
Radar images from NASA's Cassini spacecraft reveal many lakes on Titan's surface, some filled with liquid, and some appearing as empty depressions.

Credit: NASA/JPL-Caltech/
ASI/USGS

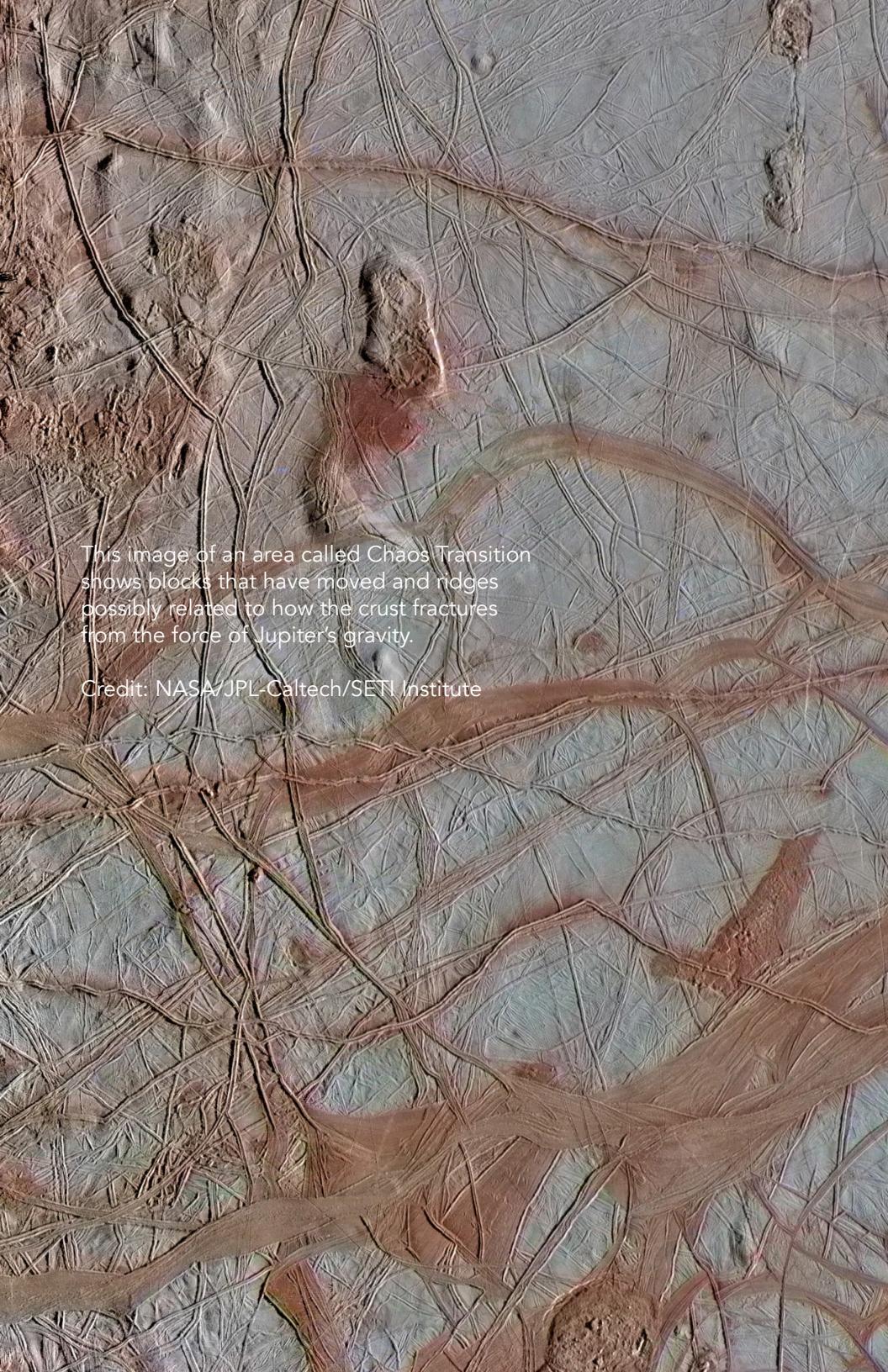
04

EUROPA

OCEAN MOON



The smallest of the four Galilean moons orbiting Jupiter, Europa, is by far the most interesting (if not as pretty as Io!). The gravitational tidal forces that stretch and squeeze this icy world have created a liquid ocean below the frozen surface, and the heat that has melted the interior may also provide the warmth and energy needed by native Europan life forms. We will get a closer look in the late 2020s when NASA's Europa Clipper mission arrives in the Jovian system.

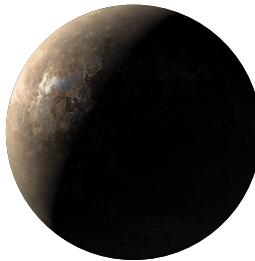


This image of an area called Chaos Transition shows blocks that have moved and ridges possibly related to how the crust fractures from the force of Jupiter's gravity.

Credit: NASA/JPL-Caltech/SETI Institute

05

PROXIMA CENTAURI b THE EXOPLANET NEXT DOOR



The triple star system Alpha and Proxima Centauri has at least one planet (a second, larger one is still tentative), but it isn't orbiting one of the two sun-like stars. Instead, it is tucked close to the tiny cool, red dwarf star Proxima Centauri. An Earth-sized world, buffeted by fierce winds from its stellar host, orbits every 11 days, and endures conditions that would be harsh for any nascent life trying to take hold. But its closeness to us, at around four light years, means that it is possible in the coming century or two, for a visit by robotic explorers from Earth, thereby beginning humanity's interstellar age.

An artist's impression of the exoplanet Proxima b, shown in the foreground on the right side of the image. The planet has a reddish-brown hue, suggesting a rocky composition with some surface water or ice. In the background, the small, dim red dwarf star Proxima Centauri is visible as a bright orange-yellow dot. A few other stars of varying sizes are scattered across the dark, star-filled background of space.

This artist's impression shows the planet Proxima b orbiting the red dwarf star Proxima Centauri, the closest star to the Solar System.

Credit: ESO/M. Kornmesser

06

TRAPPIST 1e

GOLDILOCKS WORLD (DISCOVERED 2017)



Our solar system has two Earth-size planets - the Trappist 1 system greedily has seven, three of which fall within the habitable zone of their small, red dwarf star. Being in the habitable zone means that the conditions are right for surface liquid water, should there be water, to exist and act as a fertile soup for the organic building blocks of life. Trappist 1e is the Goldilocks world of the seven, similar in mass, radius, density, surface gravity and temperature to Earth. It is one of the most potentially habitable exoplanets discovered so far.

The background of the image is a dark blue space filled with numerous small white stars. In the upper right quadrant, there is a large, semi-transparent red circle, which appears to be a planet or moon. Below it, another smaller red crescent shape is visible. The lower half of the image is dominated by a large, dark red sphere, likely representing Earth, with a bright red ring around its horizon. At the very bottom, there is a stylized illustration of a futuristic city at night, with glowing blue and white lights from buildings and roads.

Some 40 light-years from Earth, a planet called TRAPPIST-1e offers a heart-stopping view: brilliant objects in a red sky, looming like larger and smaller versions of our own moon. But these are no moons. They are other Earth-sized planets in a spectacular planetary system outside our own.

Credit: NASA-JPL-Caltech

07

BOYAJIAN'S STAR

ALIEN MEGASTRUCTURE (DISCOVERED 2015)



Slightly hotter than our Sun, the star studied by astronomer Tabetha Boyajian had wild and unpredictable variations in brightness. These variations triggered speculation of an extraordinary cause: alien megastructures bigger than planets and constructed to harness the energy output of the star were intermittently blocking the light from reaching our telescopes. Such structures, postulated by physicist Freeman Dyson, fell from favor as an explanation for the star's brightness variations when dust rings fitted the observations more accurately. Still, the idea of observing megastructures is now a mainstream way of searching for intelligent alien life, and Boyajian's Star paved the way.



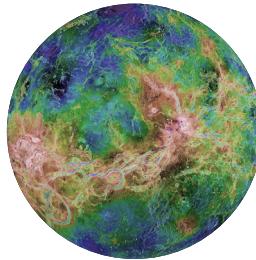
This illustration depicts a hypothetical uneven ring of dust orbiting KIC 8462852, also known as Boyajian's Star or Tabby's Star.

Credit: NASA-JPL-Caltech

08

VENUS

EARTH'S TWIN



The nearest of the planets is sometimes called Earth's twin. But even with a similar mass, surface gravity, composition, and an orbit only slightly closer to the Sun than ours, Venus has an atmosphere of almost pure carbon dioxide, a surface temperature that would melt lead and pressure that would crush you, and your spacecraft, to pulp. Now rise to the top layers of the Venusian atmosphere, around 50 km above the stark surface, where temperatures and pressures are bearable and sulfuric acid clouds drift along, and you enter an environment that could provide a habitat for floating and very alien life. Maybe we don't have to look very far away after all.



Magellan radar image of Wheatley crater on Venus.

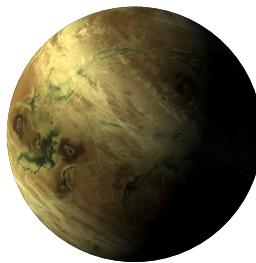
This 72 km diameter crater shows a radar bright ejecta pattern and a generally flat floor with some rough raised areas and faulting.

Credit: NASA/JPL/USGS

09

KEPLER-452b

EARTH 2.0 (DISCOVERED 2015)

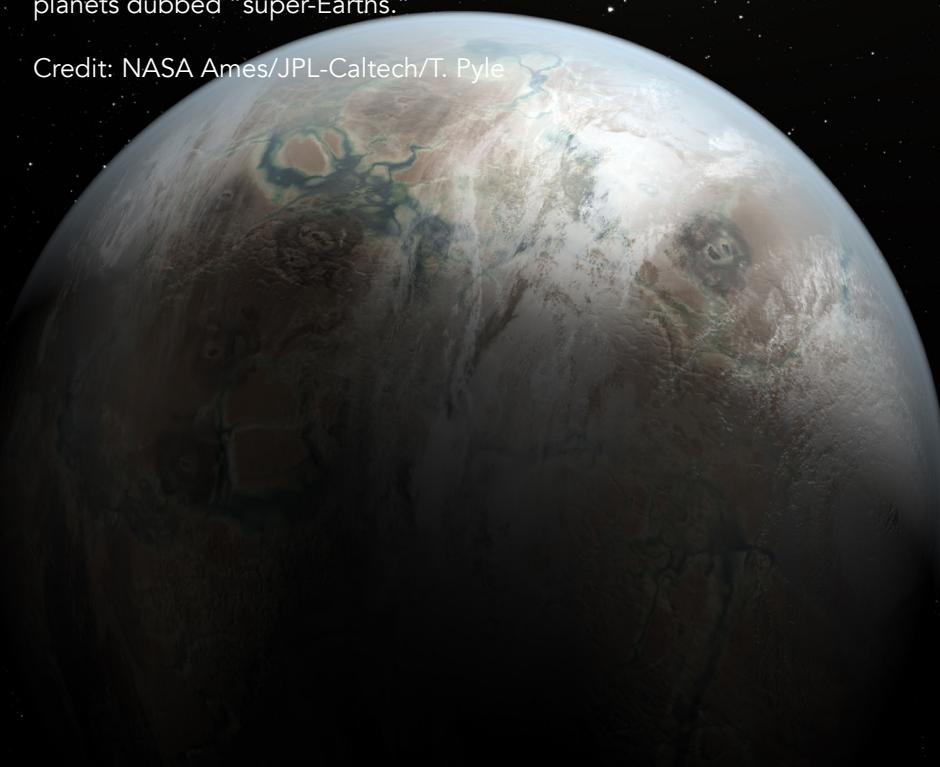


Over 1,400 light years away is a Sun-like star, Kepler-452. Observations have sensed (but not proven) the existence of an earth-sized planet orbiting at a very similar distance from its star as ours is from the Sun. Estimates put its mass at five times that of the Earth, so it has twice the surface gravity of our world. Its star, Kepler-452, would look almost like our Sun in its sky, but Kepler-452 is over a billion years older than our Sun. If intelligent life has emerged there, it could be much more advanced and developed, or it could already have blossomed and died. Exoplanets can provide us with insights into Earth's past, or sometimes a glimpse into our distant future.



Scientists do not know if Kepler-452b can support life or not. What is known about the planet is that it is about 60 percent larger than Earth, placing it in a class of planets dubbed "super-Earths."

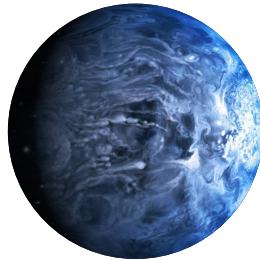
Credit: NASA Ames/JPL-Caltech/T. Pyle



10

GLIESE 1214b

WATERWORLD (DISCOVERED 2009)



Almost hugging its diminutive red dwarf star, a year on Gliese 1214b lasts barely 36 hours. Although it is much larger than Earth - probably more like Neptune - its low density means that a large part of its volume is made up of water rather than rock. As close as the planet is to its star, a much of this water will turn to steam. While such temperatures are not conducive to the usual forms of life, discoveries of terrestrial extremophiles in water above 100 °C means that where there's water on Earth, there's life. Perhaps we shouldn't rush to discount the superheated oceans of Gliese 1214b.



The planet, GJ1214b, has a mass about six times that of Earth and its interior is likely mostly made of water ice. It appears to be rather hot and surrounded by a thick atmosphere, which makes it inhospitable for life as we know it on Earth.

Credit: ESO/L. Calçada



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