Module 1 Reference Material

This information is provided as a reference.

Reference Materials are provided for each Module. The expectation is not for you to read all of the information or to watch all of the videos provided, but use sections of the information as needed to help with your labs and APA papers.

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1. History of the Universe

Reference Materials are provided for each Module. The expectation is not for you to read all of the information or to watch all of the videos provided, but use sections of the information as needed to help with your labs and APA papers.

"*It all started with the big bang!*" ~Theme song from *The Big Bang Theory (*Barenaked Ladies, 2011)

Module Video - The Cosmic Calendar (National Geographic, 2014)

Origins of the Universe

Most, but not all, scientists accept a theory (or paradigm) postulating that the universe as we now know it developed from the expansion of a microscopic, incredibly dense region. Also known as the "**Big Bang**" or "**Inflationary Universe**" **theory**, this model posits that an infinitely small space contained unstable energy, which began converting to matter at the moment of a rapid, exponential expansion (i.e., explosion or "Big Bang") (Harvard-Smithsonian Center for Astrophysics, 2009) (see Figure 1). However, current instrumentation, data, and observation cannot tell scientists what happened right at the moment of the "Big Bang" or before it so no one knows how space and time originally were created.

Timeline of the Universe

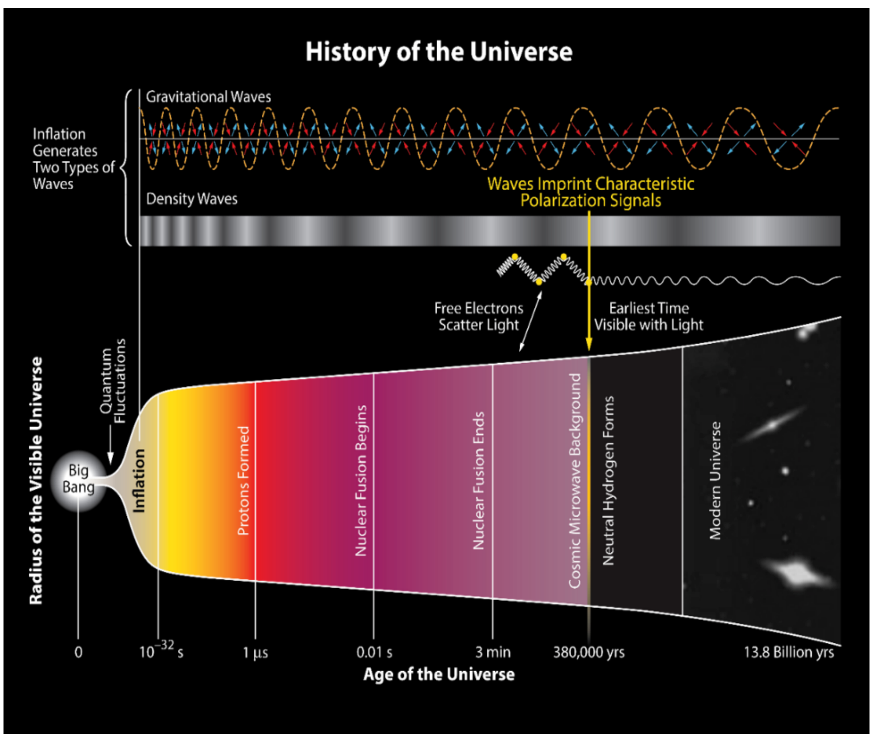


Figure 1. **History of the Universe (BICEP2 and Keck Array CMB Experiments, 2014)**

Key Events (adapted from The 14-billion year history by the Universe Forum, Harvard-Smithsonian Center for Astrophysics)

T minus zero: Moment of the "Big Bang" when particles began to form, giving rise to all matter found in the universe. Science, as yet, cannot explain how this occurs. Matter and energy were so dense that 1 teaspoon (tsp) of this space holds 100 million trillion trillion trillion pounds of "stuff."

T plus 3 minutes: All hydrogen (H_2) has now formed. Had the universe remained exceptionally hot and dense, this hydrogen would have been converted to other chemical elements. Eventually, some of this hydrogen will bond to oxygen (O_2) to form water (H_2O), which is essential for life as we know it.

T plus 300,000 years: Although still very hot, the universe continued to expand and cool. It now also contained helium (He) and other simple chemical elements. Astronomical objects began to take shape as gravity attracted matter into constantly growing clumps. With current instrumentation, this is also the earliest point in time at which scientists can detect light.

T plus 100 million years: The universe has cooled even further, but the visible light was no longer present as the first stars have yet to be born.

T plus 1 billion years: The first stars began to light up, and formed **galaxies** (giant star collections held together by mutual gravity) and galaxy clusters.

T plus 14 billion years (present day): Across the universe, many, many galaxies exist, each containing billions of stars and their planetary systems. In the Milky Way galaxy resides our Sun and solar system, including our home planet, Earth.

Additional Resources

1. Carl Sagan *Cosmos* - *Cosmic Calendar* (CarlSaganPortal, 2009) https://www.youtube.com/watch?v=Ln8UwPd1z20
2. *A Brief History of Time* (Hawking, 1988)
3. *The Structure of Scientific Revolutions* (Kuhn, 2012)

Conclusion

In summary, the most commonly accepted explanation of the universe's origin is the "Big Bang" or "Inflationary Universe" theory. Starting as an infinitely small, dense point of energy exploding, the universe has been expanding and cooling over the past 14 billion years. All celestial objects are hypothesized to have come from energy that converted to matter following that infinitesimal beginning, despite the fact scientists cannot explain what caused the "Big Bang" or what occurred before it. As more sophisticated instrumentation is invented and our understanding deepens, perhaps one day the "Big Bang" theory will be revised or replaced with another theory that more fully explains the universe's origins.

2. How Do We Study Space?

Astronomical Observatories

In order to study the universe and objects in it, scientists use telescopes that are sensitive to different regions of the electromagnetic spectrum (EMS; for review, please refer back to Section #5 of VESSS Module #1) (NASA GSFC The Imagine Team, 2013) (see Figure 1). In addition, telescopes may have to be placed into space aboard satellites because some kinds of electromagnetic radiation (ER) (e.g., visible light) may not be capable of completely penetrating the Earth's atmosphere. Depending on the particular ER astronomers wish to study, detectors sensitive only to those wavelengths will be used. As a side note, the very act of collecting ER data can affect what astronomers observe, a phenomenon is known in quantum theory as the "observer effect" (Weizmann Institute of Science, 1998; Buks *et al*., 1998).

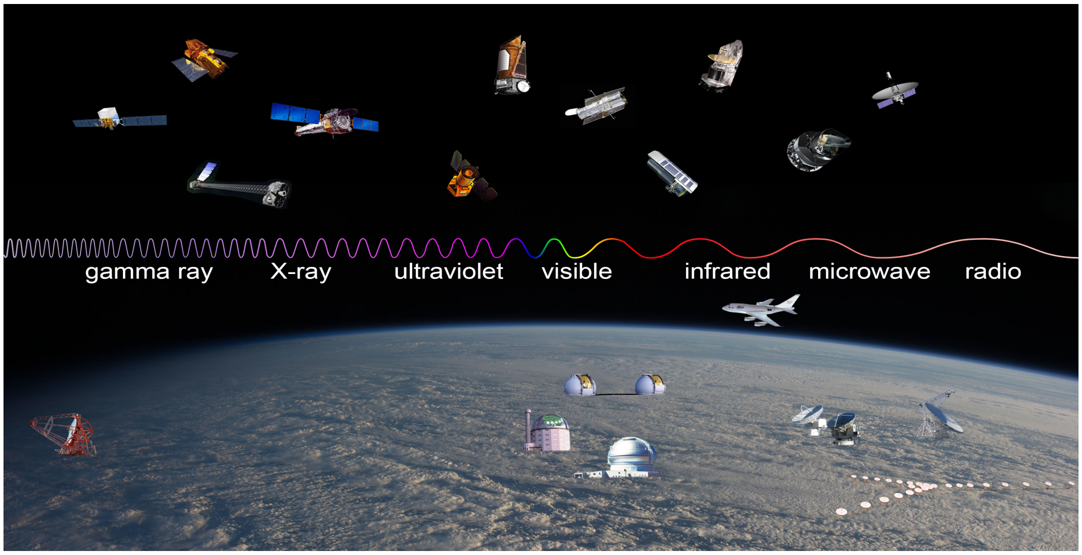


Figure 1. **Representative telescopes (operating as of February 2013) for different regions of the electromagnetic spectrum (EMS) (NASA GSFC The Imagine Team, 2013)**

What follows below are brief descriptions of the types of observatories associated with each region of the EM spectrum, as shown in Figure 1 above.

Radio Observatories (Examples include Spektr-R, Green Bank, and the Very Large Array [VLA])

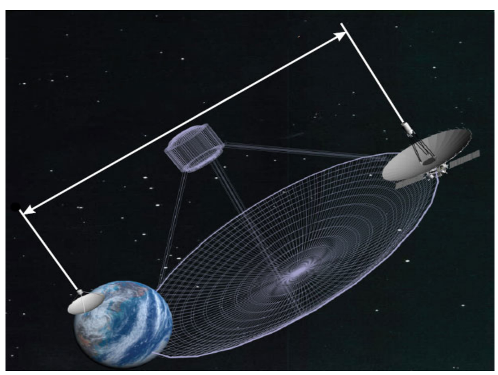


Figure 2. **Artist's conception of the Spektr-R spacecraft creating an imagined radio telescope through interferometry (*Credit*: Lavochkin Association; NASA GSFC The Imagine Team, 2013)**

Radio wavelengths penetrate Earth's atmosphere, including cloud cover, with little to no difficulty. While it is not necessary to place radio telescopes in orbit, doing so complements Earth-based instruments through a technique known as **interferometry** (NASA GSFC The Imagine Team, 2013). This procedure allows radio astronomers to combine data from two point sources in order to create images with the same resolution and fine detail as if they had used a single instrument the same size as the distance between the two input telescopes. For example, the Very Large Baseline Array (VLBA) comprises 10 observatories located between Hawaii and Puerto Rico, one-third the distance around the Earth. By using a radio telescope in space (as illustrated in Figure 2 above), astronomers are capable of producing data as if they had a telescope the size of Earth. Two missions have had space interferometry as their objective: HALCA (Japan, 1997-2005) and Spektr-R (Russia, 2011).

Microwave Observatories (Examples include Planck and CARMA)

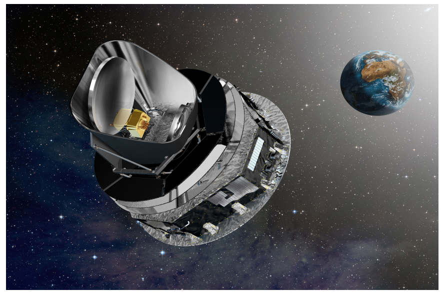


Figure 3. **Artist's conception of the Planck spacecraft (*Credit*: European Space Agency [ESA]/D. Ducros; NASA GSFC The Imagine Team, 2013)**

When studying microwave radiation, astronomers must address two issues. First, Earth's atmosphere forms an effective barrier to any microwave radiation reaching the ground, which means scientists must use satellite-based telescopes. Second, microwaves are a remnant of the Big Bang (for review, please refer back to Section #1 of VESSS Module #2), making the entire sky a source of what is termed cosmic microwave background (CMB). In the approximate 13.8 billion years since the Big Bang, the universe has cooled to just three degrees above absolute zero, which is measured as CMB (NASA GSFC The Imagine Team, 2013). The Cosmic Background Explorer (COBE) satellite, operational between 1989 and 1993, provided the first reliable data for the CMB's temperature. These measurements were further refined by the Wilkinson Microwave Anisotropy Probe (WMAP), functional between 2001 and 2010. Most recently, the Planck spacecraft (as shown in Figure 3 above), which launched in 2009, has as its objective to improve our understanding of CMB.

Infrared Observatories (Examples include Spitzer, Herschel, and SOFIA)

Figure 4. **Artist's conception of SOFIA (left), and photograph of the Keck I and II telescopes (right) (NASA GSFC The Imagine Team, 2013)**

Infrared (IR) observatories also face several challenges in their operations. One problem is that not all IR wavelengths, especially the longer ones, can penetrate Earth's atmosphere (NASA GSFC The Imagine Team, 2013). Another issue is that IR (essentially heat) is emitted by most objects, including the atmosphere, telescopes, and even IR detectors.

Module Video - Launchpad: Infrared Astronomy on Mauna Kea (NASA eClips, 2009)

Scientists use a number of strategies to get around these challenges. Earth-based IR observatories, such as the IRTF in Hawaii (see video) are built high atop mountains in dry climates so that there is as little interference from atmospheric water vapor, which absorbs infrared radiation, as possible. To further calibrate out what interference may be present, astronomers observe a cosmic object of interest with both ground- and space-based telescopes at the same time so that any differences can be noted and subtracted out (NASA GSFC The Imagine Team, 2013) (Figure 4). Finally, to limit the spurious IR/heat generated by instrumentation from adversely affecting measurements, these detectors are continuously cooled.

NASA operates a number of IR observatories using different launch platforms. In partnership with the German Aerospace Center (DLR), NASA manages the Stratospheric Observatory for Infrared Astronomy (SOFIA), which is an IR telescope mounted aboard a modified Boeing 747 aircraft so that the instrument can be flown high above most of Earth's atmosphere. The Spitzer Space Telescope (SST), launched in 2003, is strategically placed in an Earth-trailing, heliocentric orbit, which reduces exposure to IR/heat in near-Earth space (NASA GSFC The Imagine Team, 2013). Finally, the James Webb Space Telescope (JWST), slated for a 2018 launch, will also be placed in a heliocentric orbit at the second Lagrange point (LS) (NASA GSFC The Imagine Team, 2013). JWST's mission objective will be to detect infrared radiation from the earliest known galaxies and the dust clouds that give rise to stars and their planetary systems.

Visible Light (Optical) Observatories (Examples include Kepler, Hubble, Keck [I and II], SALT, and Gemini [South])

Figure 5. The Hubble Space Telescope during a 2009 servicing mission (*Credit*: NASA; NASA GSFC The Imagine Team, 2013).

Since the dawn of our species, humans have been able to see stars and other celestial objects in the night sky because visible light easily passes through Earth's atmosphere. Telescopes sensitive to these wavelengths may be either ground- or space-based. However, ground-based visible (or optical) astronomy is constrained by air turbulence that distorts light traveling through the atmosphere (NASA GSFC The Imagine Team, 2013). While optical astronomy facilities can be built high atop mountains, light still has to pass through a portion of the atmosphere, resulting in some distortion especially for light from extremely distant objects. Space-based optical telescopes escape this limitation, plus they can expand their observation capabilities to include the ultraviolet light typically absorbed by the atmosphere (NASA GSFC The Imagine Team, 2013). The Hubble Space Telescope (HST) is the most well-known space-based optical telescope, but there are others (see Figure 5). Kepler collects visible light data from the Milky Way galaxy, which is analyzed for evidence of extrasolar systems that might contain Earth-like planets. Although the Swift satellite studies gamma-ray bursts, its instrumentation also includes an Ultraviolet and Optical Telescope (UVOT).

Ultraviolet Observatories (Examples include GALEX)

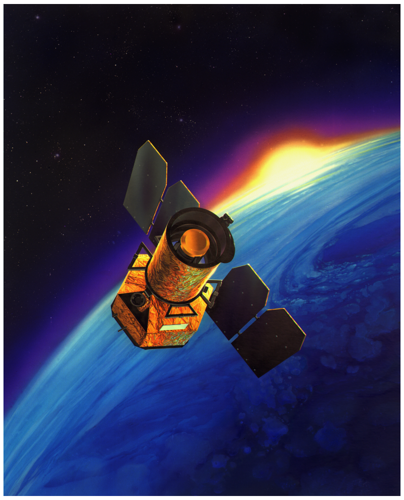


Figure 6. Artist's conception of the GALEX satellite (*Credit*: NASA/JPL-Caltech; NASA GSFC The Imagine Team, 2013)

Unlike some types of observatories previously discussed, ultraviolet (UV) ones must be in orbit because the Earth's atmosphere absorbs most of this radiation. Otherwise, UV and optical telescopes function very similarly, with their main difference being in filters/detectors used (NASA GSFC The Imagine Team, 2013). The most recent UV space observatory was GALEX, operating between 2003 and 2013 (see Figure 6). GALEX's science objective was to understand star formation by studying galaxies that formed when the universe was approximately three billion years old. Other NASA missions that include a UV instrument are the Hubble Space Telescope (HST) and Swift.

X-ray Observatories (Examples include NuSTAR and Chandra)

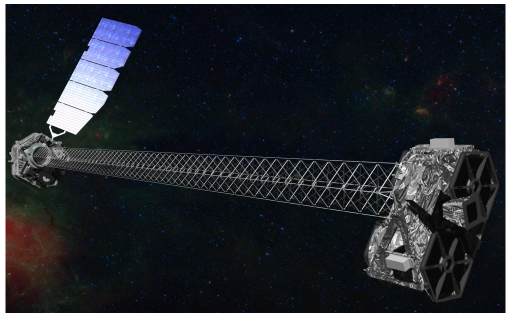


Figure 7. **Artist's conception of the NuSTAR observatory (*Credit*: NASA/JPL-Caltech; NASA GSFC The Imagine Team, 2013)**

Like UV radiation, X-rays are effectively blocked by our atmosphere, which means X-ray observatories must be launched into orbit. Additionally, X-ray wavelengths, being small and very energetic, are difficult to focus because they pass right through mirrors. To solve this problem, there must be at least several meters between where radiation enters a satellite and the X-ray detectors (NASA GSFC The Imagine Team, 2013). Up until recently, this posed significant cost and weight constraints, with only the most powerful rockets capable of placing such large payloads in space (e.g., the Chandra Observatory via the Space Shuttle). In 2012, the Nuclear Spectroscopic Telescope Array (NuSTAR) (Figure 7) was launched aboard a low-cost rocket with a deployable mast (or boom), which separated its mirror and X-ray detector modules to an appropriate distance once in orbit (read more about how X-rays are focused on the X-ray Telescope Introduction page).

Gamma-ray Observatories (Examples include HESS, Fermi, and Swift)

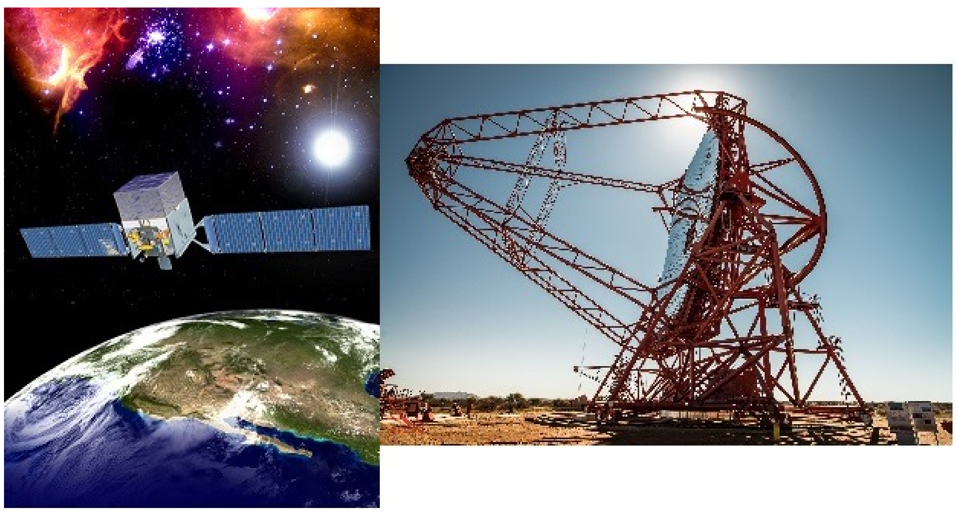


Figure 8. **Artist's conception of the Fermi satellite (left), and photograph of a HESS telescope (right) (*Credit*: NASA [left] and HESS Collaboration [right]; NASA GSFC The Imagine Team, 2013)**

Gamma-rays are the most energetic form of electromagnetic radiation (ER) in the universe. With current technology, it is impossible to focus gamma-rays so astronomers must indirectly detect their origin and presence by other means. In general, special "masks" can cast gamma-rays onto a detector (Gamma-ray Telescopes and Detectors), although sometimes astronomers use Earth's atmosphere as the "detector" (Detecting gamma-rays using the atmosphere) (NASA GSFC The Imagine Team, 2013). The HESS array is just such an example, with several ground-based telescopes arranged in a square configuration examining our atmosphere for clues to the presence of gamma-rays (see Figure 8).

The Swift satellite and Fermi Space Telescope are two space-based gamma-ray observatories. Swift, launched in 2004, has a detector for mysterious of gamma-ray bursts (GRBs), which triggers the spacecraft to rapidly re-orient its X-ray and optical telescopes towards bursts as they happen. Meanwhile, Fermi has been studying high-energy phenomena from pulsars, black holes, active galaxies, diffuse gamma-ray emissions, and GRBs since 2008.

Major Space-based Observatory Missions

These entries are described below according to the following key sequence (Thompson, 2009):

Telescope Name / Agency / Year Launched / Wavelength(s) / Primary Target(s)

Hubble Space Telescope (HST) / NASA, ESA / 1990 / Visible, UV, Near-IR / Deep Space Objects

The first of NASA's Great Observatories, HST has enabled astronomers to expand human understanding of the scale of the universe, stellar life cycles, black holes, and formation of the first galaxies. HST has also captured the general public's imagination with its stunning images. To learn more, please visit https://www.nasa.gov/mission_pages/hubble/main/index.html.

Solar and Heliospheric Observatory (SOHO) / NASA and ESA / 1995 / Visible (Optical), UV, Magnetic / Sun and Solar Wind

SOHO is studying the Sun's internal structure and dynamics, including the convection zone, sunspot structure, and solar tornadoes. In addition, SOHO collects data on the solar wind (a steady stream of charged particles ejected from the Sun's upper atmosphere), which improves scientists' ability to predict solar flares and other space weather phenomena that affect Earth-based electrical grids and communication networks. To learn more, please visit http://sohowww.nascom.nasa.gov/.

Chandra X-ray Observatory / NASA/ 1999 / X-ray / Various

Named for Indian-American physicist Subrahmanyan Chandrasekhar, Chandra is the third of NASA's four Great Observatories and the world's most powerful X-ray telescope. This telescope has been used to study quasars, immense gas clouds, Mars, and black holes including the discovery of Sagittarius A* (supermassive black hole at the center of our Milky Way galaxy). To learn more, please visit http://chandra.harvard.edu/.

XMM-Newton / ESA / 1999 / X-ray / Various

Named in honor of Sir Isaac Newton, the X-ray Multi-Mirror Mission-Newton (XMM-Newton) is capable of much longer, uninterrupted observations of cosmic X-rays than any of its predecessors. This allows the satellite to detect objects billions of light years away, including galaxies, magnetars (a type of neutron star), star-forming regions, and black holes. To learn more, please visit http://www.cosmos.esa.int/web/xmm-newton.

INTEGRAL / ESA / 2002 / Gamma-ray, X-ray, Visible (Optical) / Various

The International Gamma-Ray Astrophysics Laboratory (INTEGRAL) was the first space observatory capable of detecting multiple forms of electromagnetic radiation. INTEGRAL is used to study gamma-ray bursts, supernova explosions, black holes (including Sagittarius A* at the center of the Milky Way Galaxy), and how elements form when a star dies. To learn more, please visit http://sci.esa.int/integral/.

GALEX / NASA / 2003 / UV / Galaxies

NASA's Galaxy Evolution Explorer (GALEX) helped astronomers better understand galaxy formation by providing ultraviolet (UV) data on the shape, brightness, size and distance of more than a half-billion celestial objects. To learn more, please visit http://www.galex.caltech.edu/.

Spitzer Space Telescope (SST) / NASA / 2003 / IR / Distant and Nearby Objects

SST, the last of the Great Observatories, detects infrared radiation (heat). In addition to comets, black holes, and distant galaxies, the SST detected radiation emanating from an exoplanet and also helped astronomers determine that some "hot Jupiters" weren't really all that hot. To learn more, please visit http://www.spitzer.caltech.edu/.

Swift Gamma-ray Burst Explorer / NASA / 2004 / Gamma-ray, X-ray, UV, Visible (Optical) / Various

Swift primarily searches for gamma-ray bursts (GRBs). The universe's most powerful explosions, GRBs produce gamma-rays before quickly shifting to an X-ray, ultraviolet, and visible (optical) afterglow. To capture the entire range of GRB data, the Swift satellite is designed to detect and re-orient itself to the GRB source in less than a minute. Among Swift's accomplishments are detection of a GRB afterglow lasting 125+ days and a GRB from a star dying 13 billion years ago, the most distant explosion observed to date. To learn more, please visit http://swift.gsfc.nasa.gov/.

COROT / CNES and ESA / 2006 / Visible (Optical) / Extrasolar planets

The Convection, Rotation and planetary Transits (COROT) mission used an optical space telescope to search for extrasolar planets and to study stellar seismology. In 2009, the COROT scientific team claimed that they had detected the smallest yet known exoplanet, a world less than twice the size of Earth, but there was considerable controversy regarding its size and mass because of its apparent proximity to its star. To learn more, please visit http://sci.esa.int/corot/.

Solar Terrestrial Relations Observatory (STEREO) / NASA / 2006 / Visible (Optical), UV, Radio / Sun and Coronal Mass Ejections (CMEs)

STEREO comprises two separate observatories that separated after launch so that one is ahead of the Earth in its orbit and the other follows behind. As a result, the two observatories are able to create stereoscopic and 3-D imaging of the Sun and CMEs (violent solar eruptions that disrupt Earth's magnetic field and impair satellite operations, communications, and power systems). To learn more, please visit http://stereo.gsfc.nasa.gov/.

Fermi Gamma-ray Space Telescope / NASA / 2008 / Gamma-ray / Various

Formerly known as GLAST, Fermi has provided some of the best images ever of celestial objects that emit the most energetic form of electromagnetic radiation (ER): gamma-rays. These objects include dark matter, black holes, pulsars, and even our own Sun. To learn more, please visit http://fermi.gsfc.nasa.gov/.

Herschel Space Observatory / ESA and NASA / 2009 / Far-IR / Various

Launched simultaneously with the Planck telescope, the Herschel Space Observatory is the largest, most powerful IR telescope, capable of detecting sub-millimeter (mm) wavelengths emitted by the coldest objects in the universe. This observatory was designed to search for water in comets and distant dust clouds as well as to study exoplanets and nascent star formation. To learn more, please visit http://www.herschel.caltech.edu/.

Planck Observatory / ESA / 2009 / Microwave / Cosmic Microwave Background (CMB)

The successor to NASA's Cosmic Background Explorer (COBE) and Wilkinson Microwave Anisotropy Probe (WMAP), the Planck Observatory measures in finer detail temperature fluctuations in the CMB. In addition, Planck probes dark matter, dark energy, and the Milky Way galaxy's magnetic field in 3-D. To learn more, please visit http://sci.esa.int/planck/.

Kepler Mission / NASA / 2009 / Visible (Optical) / Extrasolar planets

Kepler, NASA's planet-hunting telescope, is designed to search for other Earth-like planets orbiting other stars in the Milky Way galaxy. By examining tell-tale drops in light (when a planet passes in front of a candidate star) captured by Kepler's detectors, astronomers are looking for planets in stars' "habitable zones," where liquid water (a pre-requisite for life as we know it) can exist on the planet's surface. To learn more, please visit http://kepler.nasa.gov/.

Additional Resources

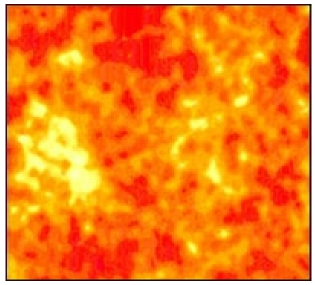
1. *NASA Launchpad: Neon Lights - Spectroscopy in Action* (NASA eClips, 2010)
   This video explains how astronomers analyze electromagnetic radiation detected by telescopes.
   https://youtu.be/SPgYrsONgwU

2. *NASA 360 Talks - Repairing Hubble* (NASA eClips, 2015)
   This video features the final Hubble Space Telescope repair mission in 2009.
   https://www.youtube.com/watch?v=SoqD-6Z8iKQ

Conclusion

In summary, humans' understanding of the universe and our place in it has been significantly expanded through design, construction, and operation of observatories that are sensitive to various regions of the electromagnetic spectrum, whether those instruments are Earth-, aircraft- or space-based. Although this section has introduced some of the observatories currently in operation, there are others as well as new projects in development. One of the most highly anticipated missions will be the James Webb Space Telescope (JWST), successor to the Hubble Space Telescope (HST). JWST, scheduled for a 2018 launch, will be used to study light from stars and galaxies that formed in the immediate aftermath of the Big Bang so that astronomers can better understand stellar formation and evolution (to learn more, please visit http://www.jwst.nasa.gov/). It is an exciting time for astronomy; as NASA's Astrophysics Division director Jon Morse said, "...I look forward to an exciting portfolio well into the coming decades" (Thompson, 2009).

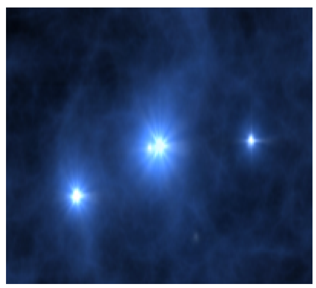
3. The Big Bang



Watch a video or read the story of the history of the Universe.

The night sky presents the viewer with a picture of a calm and unchanging Universe. So the 1929 discovery by Edwin Hubble that the Universe is, in fact, expanding at enormous speed was revolutionary. Hubble noted that galaxies outside our own Milky Way were all moving away from us, each at a speed proportional to its distance from us. He quickly realized what this meant that there must have been an instant in time (now known to be about 14 billion years ago) when the entire Universe was contained in a single point in space. The Universe must have been born in this single violent event which came to be known as the "Big Bang."

Astronomers combine mathematical models with observations to develop workable theories of how the Universe came to be. The mathematical underpinnings of the Big Bang theory include Albert Einstein's general theory of relativity along with standard theories of fundamental particles. Today, NASA spacecraft such as the Hubble Space Telescope and the Spitzer Space Telescope continue Edwin Hubble's work of measuring the expansion of the Universe. One of the goals has long been to decide whether the Universe will expand forever, or whether it will someday stop, turn around, and collapse in a "Big Crunch?"



The structure of the universe evolved from the Big Bang, as represented by WMAP's "baby picture", through the clumping and ignition of matter (which caused reionization) up to the present. Watch the video.

Background Radiation

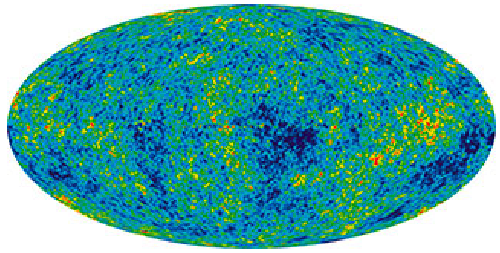
According to the theories of physics, if we were to look at the Universe one second after the Big Bang, what we would see is a 10 billion degrees sea of neutrons, protons, electrons, anti-electrons (positrons), photons, and neutrinos. Then, as time went on, we would see the Universe cool, the neutrons either decaying into protons and electrons or combining with protons to make deuterium (an isotope of hydrogen). As it continued to cool, it would eventually reach the temperature where electrons combined with nuclei to form neutral atoms. Before this "recombination" occurred, the Universe would have been opaque because the free electrons would have caused light (photons) to scatter the way sunlight scatters from the water droplets in clouds. But when the free electrons were absorbed to form neutral atoms, the Universe suddenly became transparent. Those same photons the afterglow of the Big Bang known as cosmic background radiation can be observed today.

Missions Study Cosmic Background Radiation

NASA has launched two missions to study the cosmic background radiation, taking "baby pictures" of the Universe only 400,000 years after it was born. The first of these was the Cosmic Background Explorer (COBE). In 1992, the COBE team announced that they had mapped the primordial hot and cold spots in cosmic background radiation. These spots are related to the gravitational field in the early Universe and formed the seeds of the giant clusters of galaxies that stretch hundreds of millions of light years across the Universe. This work earned NASA's Dr. John C. Mather and George F. Smoot of the University of California the 2006 Nobel Prize in Physics.

The second mission to examine the cosmic background radiation was the Wilkinson Microwave Anisotropy Probe (WMAP). With greatly improved resolution compared to COBE, WMAP surveyed the entire sky, measuring temperature differences of the microwave radiation that is nearly uniformly distributed across the Universe. The picture shows a map of the sky, with hot regions in red and cooler regions in blue. By combining this evidence with theoretical models of the Universe, scientists have concluded that the Universe is "flat," meaning that, on cosmological scales, the geometry of space satisfies the rules of Euclidean geometry (e.g., parallel lines never meet, the ratio of a circle circumference to diameter is pi, etc.).

A third mission, Planck, led by the European Space Agency with significant participation from NASA, was launched in 2009. Planck is making the most accurate maps of the microwave background radiation yet. With instruments sensitive to temperature variations of a few millionths of a degree, and mapping the full sky over nine wavelength bands, it measures the fluctuations of the temperature of the CMB with an accuracy set by fundamental astrophysical limits.



Credit: NASA/WMAP Science Team

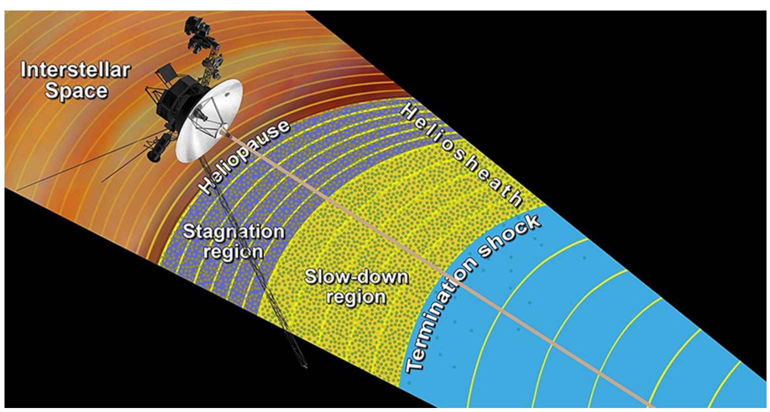
The Universe's "baby picture": WMAP's (http://map.gsfc.nasa.gov/news/index.html#microwavesk) map of the temperature of the microwave background radiation shows tiny variations (of few micro degrees) in the 3K background. Hot spots show as red, cold spots as dark blue.

Inflation

One problem that arose from the original COBE results, and that persists with the higher-resolution WMAP data, was that the Universe was *too* homogeneous. How could pieces of the Universe that had never been in contact with each other have come to equilibrium at the very same temperature? This and other cosmological problems could be solved, however, if there had been a very short period immediately after the Big Bang where the Universe experienced an incredible burst of expansion called "inflation." For this inflation to have taken place, the Universe at the time of the Big Bang must have been filled with an unstable form of energy whose nature is not yet known. Whatever its nature, the inflationary model predicts that this primordial energy would have been unevenly distributed in space due to a kind of quantum noise that arose when the Universe was extremely small. This pattern would have been transferred to the matter of the Universe and would show up in the photons that began streaming away freely at the moment of recombination. As a result, we would expect to see, and do see, this kind of pattern in the COBE and WMAP pictures of the Universe.

But all this leaves unanswered the question of what powered inflation. One difficulty in answering this question is that inflation was over well before recombination, and so the opacity of the Universe before recombination is, in effect, a curtain drawn over those interesting very early events. Fortunately, there is a way to observe the Universe that does not involve photons at all. Gravitational waves, the only known form of information that can reach us undistorted from the instant of the Big Bang, can carry information that we can get no other way. Two missions that are being considered by NASA, LISA and the Big Bang Observer, will look for the gravitational waves from the epoch of inflation

Our star and its planets are a tiny part of the Milky Way galaxy. The Milky Way is a huge city of stars, so big that even at the speed of light, it would take 100,000 years to cross it. All the stars in the night sky, including our sun, are just some of the residents of this galaxy. Beyond our own galaxy lies a vast expanse of galaxies.



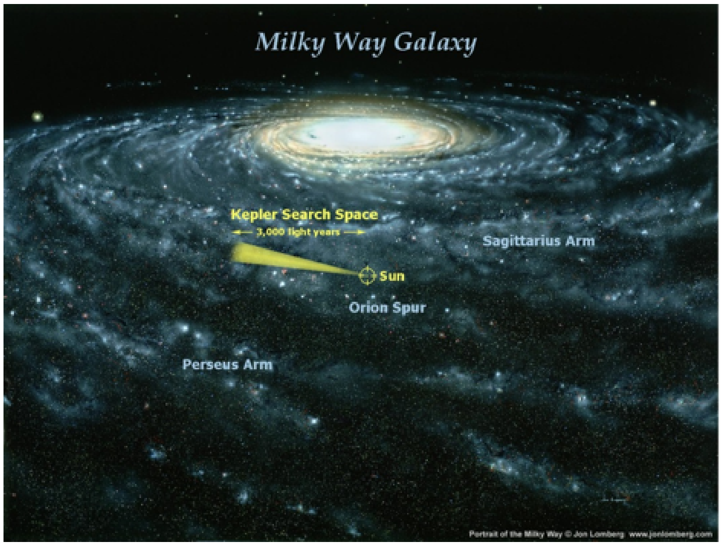
Voyager 1: First to Interstellar Space

10 Need-to-Know Things About the Universe:

1. Our universe is expanding. Scientists believe about 14 billion years ago the universe was compressed into a single point in space.
2. There are at least 100,000,000,000 galaxies in the universe. A galaxy is of stars: Our sun is just one of at least 100,000,000,000 stars in our own Milky Way galaxy, and each of those stars could have their own planetary system.
3. About 68 percent of the universe is made of dark energy. Dark matter makes up about 27 percent. The rest – everything on Earth, everything ever observed with all of our instruments, all normal matter adds up to less than five percent of the universe.
4. We now know that our universe has a *foamy* structure. The galaxies that comprise the observable universe are concentrated in vast sheets and filaments surrounding enormous cosmic voids.
5. The Milky Way galaxy is in the Local Group, a neighborhood of about 30 galaxies. Our nearest major neighboring galaxy is called Andromeda.
6. More than 1,700 extrasolar planets (or exoplanets) planets have been confirmed. Thousands of potential exoplanets await discovery confirmation.
7. Other planetary systems could have the potential for life, but no signs have yet been found beyond Earth.

8. Two-thirds of the galaxies within the Universe are spiral-shaped like our Milky Way galaxy. The have elliptical shapes and a few have unusual shapes like toothpicks or rings.
9. The Hubble Space Telescope observed a tiny patch of sky (one-tenth the diameter of the moon) for 11.6 days and found approximately 10,000 galaxies of all sizes, shapes, and colors.
10. Black holes are not empty spaces in the Universe. A black hole is a great amount of matter packed into a very small area, which results in a gravitational field so strong that nothing -- not even light -- can escape.

4. Galaxies

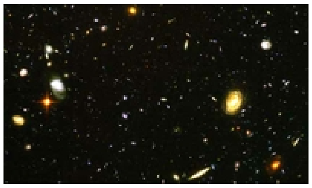


Artist's Conception - The Milky Way

Where are we?

We live in a somewhat remote arm of the Milky Way. This video shows you the way from our home to a vantage point outside the Local Group.

Animation (QuickTime, 3MB)



Hubble Ultra Deep Field galaxies: Credit: NASA, ESA, S. Beckwith (STScI) and the HUDF Team

Our galaxy, the Milky Way, is typical: it has hundreds of billions of stars, enough gas and dust to make billions more stars, and at least ten times as much dark matter as all the stars and gas put together. And it’s all held together by gravity.

Like more than two-thirds of the known galaxies, the Milky Way has a spiral shape. At the center of the spiral, a lot of energy and, occasionally, vivid flares are being generated. Based on the immense gravity that would be required to explain the movement of stars and the energy expelled, the astronomers conclude that the center of the Milky Way is a supermassive black hole.

Other galaxies have elliptical shapes, and a few have unusual shapes like toothpicks or rings. The Hubble Ultra Deep Field (HUDF) shows this diversity. Hubble observed a tiny patch of sky (one-tenth the diameter of the moon) for one million seconds (11.6 days) and found approximately 10,000 galaxies, of all sizes, shapes, and colors. From the ground, we see very little in this spot, which is in the constellation Fornax.

Formation

After the Big Bang, the Universe was composed of radiation and subatomic particles. What happened next is up for debate: did small particles slowly team up and gradually form stars, star clusters, and eventually galaxies? Or did the Universe first organize as immense clumps of matter that later subdivided into galaxies?

Collisions

The shapes of galaxies are influenced by their neighbors, and, often, galaxies collide. The Milky Way is itself on a collision course with our nearest neighbor, the Andromeda galaxy. Even though it is the same age as the Milky Way, Hubble observations reveal that the stars in Andromeda's halo are much younger than those in the Milky Way. From this and other evidence, astronomers infer that Andromeda has already smashed into at least one and maybe several other galaxies.

5. Stars

Stars are the most widely recognized astronomical objects and represent the most fundamental building blocks of galaxies. The age, distribution, and composition of the stars in a galaxy trace the history, dynamics, and evolution of that galaxy. Moreover, stars are responsible for the manufacture and distribution of heavy elements such as carbon, nitrogen, and oxygen, and their characteristics are intimately tied to the characteristics of the planetary systems that may coalesce about them. Consequently, the study of the birth, life, and death of stars is central to the field of astronomy.

Powerful Stellar Eruption - The observations of Eta Carinae's light echo are providing new insight into the behavior of powerful massive stars on the brink of detonation. Credit: NOAO, AURA, NSF, and N. Smith (University of Arizona)

Star Formation

Stars are born within the clouds of dust and scattered throughout most galaxies. A familiar example of such a dust cloud is the Orion Nebula, revealed in vivid detail in the adjacent image, which combines images at visible and infrared wavelengths measured by NASA's Hubble Space Telescope and Spitzer Space Telescope. Turbulence deep within these clouds gives rise to knots with sufficient mass that the gas and dust can begin to collapse under their own gravitational attraction. As the cloud collapses, the material at the center begins to heat up. Known as a protostar, it is this hot core at the heart of the collapsing cloud that will one day become a star. Three-dimensional computer models of star formation predict that the spinning clouds of collapsing gas and dust may break up into two or three blobs; this would explain why the majority of the stars in the Milky Way are paired or in groups of multiple stars.

As the cloud collapses, a dense, hot core forms and begins gathering dust and gas. Not all of this material ends up as part of a star the remaining dust can become planets, asteroids, or comets or may remain as dust.

In some cases, the cloud may not collapse at a steady pace. In January 2004, an amateur astronomer, James McNeil, discovered a small nebula that appeared unexpectedly near the nebula Messier 78, in the constellation of Orion. When observers around the world pointed their instruments at McNeil's Nebula, they found something interesting — its brightness appears to vary. Observations with NASA's Chandra X-ray Observatory provided a likely explanation: the interaction between the young star's magnetic field and the surrounding gas causes episodic increases in brightness.

Main Sequence Stars

A star the size of our Sun requires about 50 million years to mature from the beginning of the collapse to adulthood. Our Sun will stay in this mature phase (on the main sequence as shown in the Hertzsprung - Russell diagram) for approximately 10 billion years. Stars are fueled by the nuclear fusion of hydrogen to form helium deep in their interiors. The outflow of energy from the central regions of the star provides the pressure necessary to keep the star from collapsing under its own weight, and the energy by which it shines.

As shown in the Hertzsprung - Russell diagram, Main Sequence stars span a wide range of luminosities and colors, and can be classified according to those characteristics. The smallest stars, known as red dwarfs, may contain as little as 10% the mass of the Sun and emit only 0.01% as much energy, glowing feebly at temperatures between 3000-4000K. Despite their diminutive nature, red dwarfs are by far the most numerous stars in the Universe and have lifespans of tens of billions of years.

On the other hand, the most massive stars, known as hypergiants, may be 100 or more times more massive than the Sun, and have surface temperatures of more than 30,000 K. Hypergiants emit hundreds of thousands of times more energy than the Sun, but have lifetimes of only a few million years. Although extreme stars such as these are believed to have been common in the early Universe, today they are extremely rare as the entire Milky Way galaxy contains only a handful of hypergiants.

Stars and Their Fates

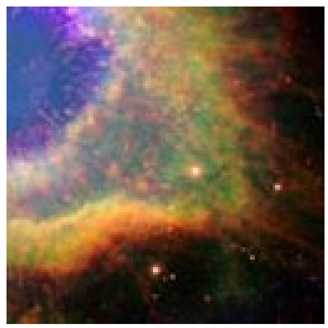
In general, the larger a star, the shorter its life, although all but the most massive stars live for billions of years. When a star has fused all the hydrogen in its core, nuclear reactions cease. Deprived of the energy production needed to support it, the core begins to collapse into itself and becomes much hotter. Hydrogen is still available outside the core, so hydrogen fusion continues in a shell surrounding the core. The increasingly hot core also pushes the outer layers of the star outward, causing them to expand and cool, transforming the star into a red giant.

If the star is sufficiently massive, the collapsing core may become hot enough to support more exotic nuclear reactions that consume helium and produce a variety of heavier elements up to iron. However, such reactions offer only a temporary reprieve. Gradually, the star's internal nuclear fires become increasingly unstable sometimes burning furiously, other times dying down. These variations cause the star to pulsate and throw off its outer layers, enshrouding itself in a cocoon of gas and dust. What happens next depends on the size of the core.

Average Stars Become White Dwarfs

For average stars like the Sun, the process of ejecting its outer layers continues until the stellar core is exposed. This dead, but still ferociously hot stellar cinder is called a White Dwarf. White dwarfs, which are roughly the size of our Earth despite containing the mass of a star once puzzled astronomers: why didn't they collapse further? What force supported the mass of the core? Quantum mechanics provided the explanation. Pressure from fast moving electrons keeps these stars from collapsing. The more massive the core, the denser the white dwarf that is formed. Thus, the smaller a white dwarf is in diameter, the larger it is in mass. These paradoxical stars are very common; our own Sun will be white dwarf billions of years from now. White dwarfs are intrinsically very faint because they are so small and, lacking a source of energy production, they fade into oblivion as they gradually cool down.

This fate awaits only those stars with a mass up to about 1.4 times the mass of our Sun. Above that mass, electron pressure cannot support the core against further collapse. Such stars suffer a different fate as described below.



White Dwarfs May Become Novae

If white dwarf forms in a binary or multiple star system, it may experience a more eventful demise as a nova. Nova is Latin for "new" and they were named as such because novae were once thought to be new stars. Today, we understand that they are in fact, very old stars, white dwarfs. If a white dwarf is close enough to a companion star, its gravity may drag matter mostly hydrogen from the outer layers of that star onto itself, building up its surface layer. When enough hydrogen has accumulated on the surface, a burst of nuclear fusion occurs, causing the white dwarf to brighten substantially and expel the remaining material. Within a few days, the glow subsides and the cycle starts again. Sometimes, particularly massive white dwarfs (those near the 1.4 solar mass limit mentioned above) may accrete so much mass in the manner that they collapse and explode completely, becoming what is known as a supernova.

Supernovae Leave Behind Neutron Stars or Black Holes

Main sequence stars over eight solar masses are destined to die in a titanic explosion called a supernova. A supernova is not merely a bigger nova. In a nova, only the star's surface explodes. In a supernova, the star's core collapses and then explodes. In massive stars, a complex series of nuclear reactions leads to the production of iron in the core. Having achieve iron, the star has wrung all the energy it can out of nuclear fusion fusion reactions that form elements heavier than iron actually consume energy rather than produce it. The star no longer has any way to support its own mass, and the iron core collapses. In just a matter of seconds, the core shrinks from roughly 5000 miles across to just a dozen, and the temperature spikes 100 billion degrees or more. The outer layers of the star initially begin to collapse along with the core, but rebound with the enormous release of energy and are thrown violently outward. Supernovae release an almost unimaginable amount of energy. For a period of days to weeks, a supernova may outshine an entire galaxy. Likewise, all the naturally occurring elements and a rich array of subatomic particles are produced in these explosions. On average, a supernova explosion occurs about once every hundred years in the typical galaxy. About 25 to 50 supernovae are discovered each year in other galaxies, but most are too far away to be seen without a telescope.

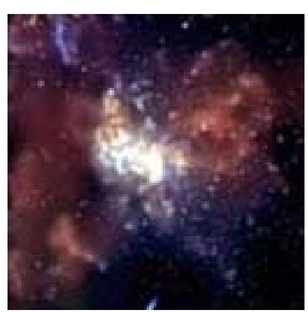
Neutron Stars

If the collapsing stellar core at the center of a supernova contains between about 1.4 and 3 solar masses, the collapse continues until electrons and protons combine to form neutrons, producing a neutron star. Neutron stars are incredibly dense - similar to the density of an atomic nucleus. Because it contains so much mass packed into such a small volume, the gravitation at the surface of a neutron star is immense. Like the White Dwarf stars above, if a neutron star forms in a multiple star system it can accrete gas by stripping it off any nearby companions. The Rossi X-Ray Timing Explorer has captured telltale X-Ray emissions of gas swirling just a few miles from the surface of a neutron star.

Neutron stars also have powerful magnetic fields which can accelerate atomic particles around its magnetic poles producing powerful beams of radiation. Those beams sweep around like massive searchlight beams as the star rotates. If such a beam is oriented so that it periodically points toward the Earth, we observe it as regular pulses of radiation that occur whenever the magnetic pole sweeps past the line of sight. In this case, the neutron star is known as a pulsar.

Black Holes

If the collapsed stellar core is larger than three solar masses, it collapses completely to form a black hole: an infinitely dense object whose gravity is so strong that nothing can escape its immediate proximity, not even light. Since photons are what our instruments are designed to see, black holes can only be detected indirectly. Indirect observations are possible because the gravitational field of a black hole is so powerful that any nearby material often the outer layers of a companion star is caught up and dragged in. As matter spirals into a black hole, it forms a disk that is heated to enormous temperatures, emitting copious quantities of X-rays and Gamma rays that indicate the presence of the underlying hidden companion.



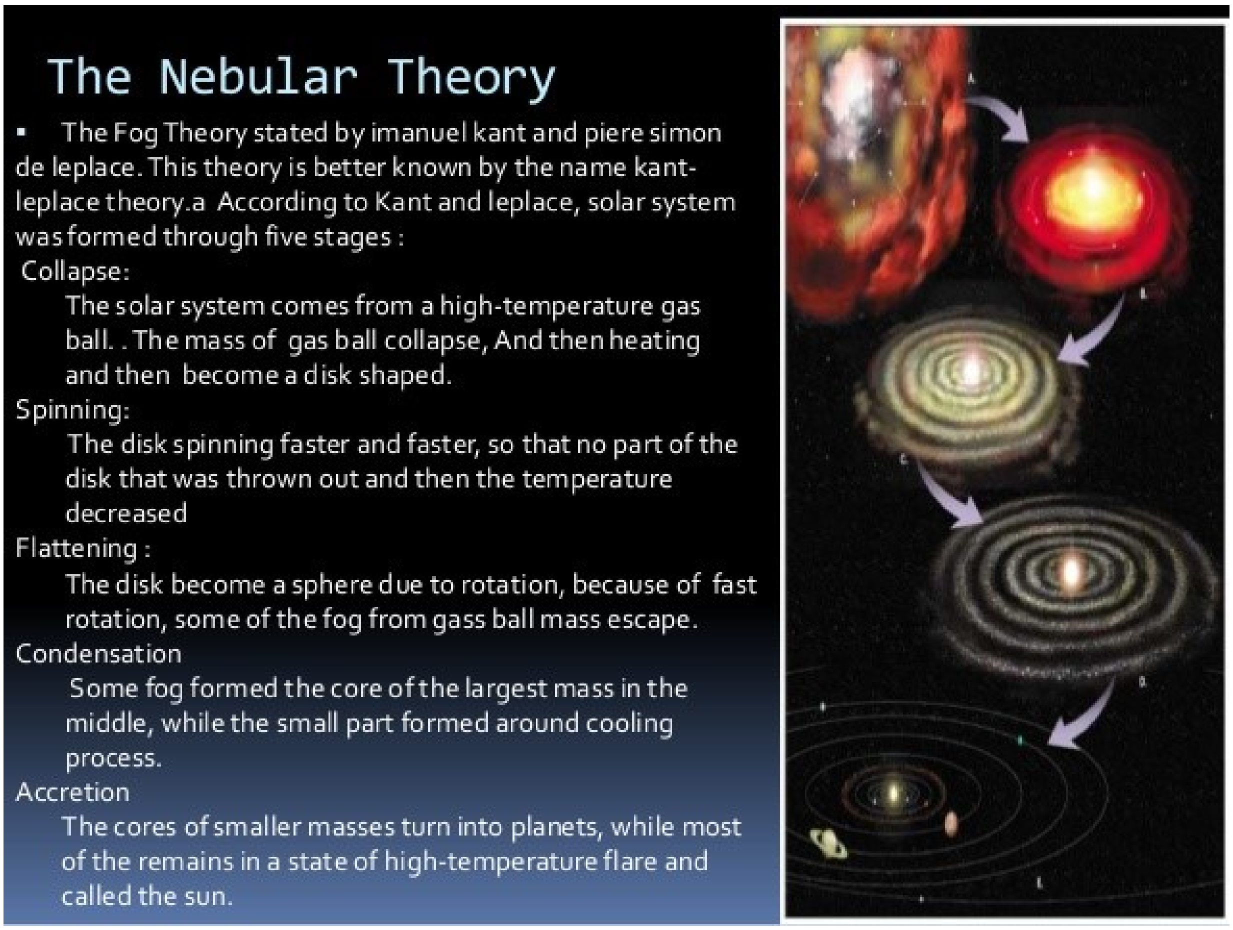
From the Remains, New Stars Arise

The dust and debris left behind by novae and supernovae eventually blend with the surrounding interstellar gas and dust, enriching it with the heavy elements and chemical compound produced during stellar death. Eventually, those materials are recycled, providing the building blocks for a new generation of stars and accompanying planetary systems.

6. Solar System Formation-The Solar Nebula or Nebula Theory

A few billion years ago, after generations of more ancient suns had been born and died, a swirling cloud of dust and gas collapsed upon itself to give birth to an infant star. The words *solar system* refer to the sun and all of the objects that travel around it -- planets, natural satellites such as the moon, asteroid belt, comets, and meteoroids. Our solar system is part of a spiral galaxy known as the Milky Way. The Sun, the center of our solar system, holds eight planets and countless smaller objects in its orbit.

As the ball-shaped cloud fell inward, it began to flatten and rotate, eventually resembling a spinning pancake. Mostly the stuff of the cloud was simple atoms of hydrogen and helium, but it was peppered here and there by more complicated elements forged in the internal furnaces and death explosions of older stars. Ninety-nine percent of the nebula became our Sun, the remaining 1 percent was everything else found in the Solar System. Even as a new sun took shape at the center of the cloud, disturbances formed farther out. In a remarkably short time by astronomical standards -- "just" tens of millions of years, or less -- these whirlpools of matter condensed into planets.



Today, that star system is home to an amazing diversity of environments -- from immense mountains and enormous, jagged canyons on rocky inner planets to sulfur volcanoes and ice geysers on moons circling huge gas planets farther out from the star, their orbits crisscrossed by legions of comets and asteroids.

This is the story, astronomers tell us, of how the Sun, our Earth and the solar system that both of them occupy came to be. There is plenty of evidence from observations over many decades to establish the broad outlines of the story. But exactly how the placental cloud of dust and gas, called the "solar nebula," turned into the solar system that we see around us today still poses many mysteries for scientists.

One of the main ways that scientists approach the question of how the solar system formed is by comparing the elements and isotopes that made up the original cloud of dust and gas to the compositions of the planets, moons, asteroids and comets in the solar system today. (An isotope is a variation of an element that is heavier or lighter than the standard form of the element because each atom has more or fewer neutrons in its nucleus.) But what were the ingredients in the original solar nebula?

Fortunately, nature provides a fossil record of the solar nebula. Like other stars its size, the Sun has an outer atmosphere that is slowly but steadily flowing off into space. This material, consisting mostly of electrically charged atoms called ions, flows outward past the planets in a constant stream called the "solar wind." This wind is a snapshot of the materials in the surface layers of the Sun, which in turn reflects the makeup of the original solar nebula.

Astronomers have long studied the Sun's composition by breaking down the Sun's color spectrum using instruments on telescopes and satellites. But these observations are not precise enough for today's planetary science. By analyzing the solar wind in terrestrial laboratories, Genesis scientists can find precise ratios of isotopes and elements in the solar nebula. The basic data gained from the Genesis mission are needed to advance theories about the solar nebula and evolution of the planets.

Understanding the origins of the variations of the oxygen isotopes is a key to understanding the origin of the solar system. Does any part of today's solar system contain the same ratios of these oxygen isotopes as those that Genesis finds existed in the original solar nebula? Finding out how these isotope ratio differences survived will narrow the possibilities of how the different materials or regions of the nebula mixed or didn't mix.

Like all families, the members of our solar system family share a common origins story. Their story started even before our solar system formed 4.56 billion years ago. Their story started when the story started for every single thing in our universe. Our universe was born from the Big Bang about 13.5 billion years ago. The first stars lived out their lives and eventually exploded, sending "star stuff" out into the cosmos. That original stellar material was recycled as another generation of stars, and many of these, too, exploded at the end of their lives. Our Sun is thought to be a third-generation star and our entire solar system is made of the recycled star stuff of previous star generations.

Our solar system began forming about 4.6 billion years ago within a concentration of interstellar dust and hydrogen gas called a molecular cloud. The cloud contracted under its own gravity and our proto-Sun formed in the hot dense center. The remainder of the cloud formed a swirling disk called the solar nebula.

http://www.spitzer.caltech.edu/images/1925-ssc2008-10b-A-Roadmap-to-the-Milky-Way-Annotated-

Within the solar nebula, scientists believe that dust and ice particles embedded in the gas moved, occasionally colliding and clumping together. Through this process, called "accretion," these microscopic particles formed larger bodies that eventually became planetesimals with sizes up to a few kilometers across. In the inner, hotter part of the solar nebula, planetesimals were composed mostly of silicates and metals. In the outer, cooler portion of the nebula, water ice was the dominant component.

The Sun's light warmed the objects in our solar system, especially those in the inner solar system. There, it was too warm for lightweight volatiles, such as water and ammonia, to condense. In addition, particles from the Sun (the solar wind) pushed volatiles out of the inner solar system. When the volatiles reached the cold temperatures of the outer solar system -- out beyond an invisible boundary called the "frost line" -- they condensed onto the nascent giant planets. Thus, the outer planets had rocks, metals, and volatiles available to accumulate, while the relatively warm, "windy" inner region was stripped of all but the densest materials, like rock and metal.

When the nascent planets grew from a few kilometers to a few hundred kilometers across, they became massive enough that their gravity influenced each other's motions. This increased the frequency of collisions, through which the largest bodies grew most rapidly. During this "childhood" stage of growth, the bodies are referred to as planetesimals. Eventually, regions of the nebula were dominated by large protoplanets. The interiors of these more mature bodies were becoming ordered -- differentiated -- into protoplanets. The process of collision and accretion continued until only four large bodies remained in the inner solar system -- Mercury, Venus, Earth, and Mars, the terrestrial planets. In the cold outer solar nebula, much larger protoplanets formed. The largest ones swept up other protoplanets, planetesimals, and nebular gas, leading to the formation of Jupiter, Saturn, Uranus, and Neptune.

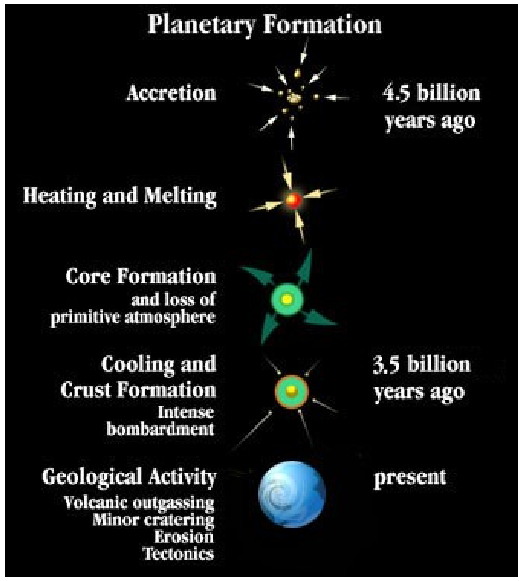
Shortly after Earth formed, the Moon did. A large object (about half as wide as Earth) collided with our world. The off-center cosmic smash-up increased Earth's spin, and its energy disintegrated the impacting object, melted Earth's outer layers, and flung debris into orbit around Earth. This material formed a ring of gas, dust and molten rock around Earth. In less than a hundred years -- an incredibly short time for the formation of an entire world -- this debris clumped (accreted), growing larger and larger to form our Moon!

http://www.nasa.gov/multimedia/imagegallery/image_feature_1454.html

The solar system's birth story is an unfolding tale. The processes of solar nebula collapse and accretion explain why there is so much space in space, where we find the various types of planets and other small bodies, and why the planets all lie in about the same plane and orbit the Sun in the same direction. Despite their diversity, all the planets, dwarf planets, comets, and asteroids in the solar system formed together, along with the Sun, as a system. Scientists still have many questions about our solar system's story. How did the planets form quickly enough to escape the blast of the early Sun's intense solar wind, which would have swept gas and dust out of the growing planets' reach?

Fortunately, vital clues are scattered throughout the solar system -- from the oldest rocks on the Earth, Earth's Moon, Mars and the asteroids to the frozen outer reaches of the Kuiper Belt. NASA robotic missions are examining these distant worlds, making new discoveries that will help to fill in the pages of this story. Ongoing research is examining the early solar nebula's composition and conditions such as radiation, by studying grains from comets, from the Sun, and the composition of Jupiter. Comets are made of the ices and dust from the original nebula that formed our solar system, and can tell us more about how our planets formed.

Scientists have examined meteorites to learn more about the primitive material that made up the solar nebula. Recent research on the radioactive isotopes within meteorites suggests a nearby supernova explosion may have influenced the environment and materials in the early solar system, seeding it with materials and perhaps triggering it to collapse into a swirling accretion disk.



Our understanding of the solar system's formation is also being guided by the new worlds discovered around distant stars. The unusual orbits of many of these distant planets have sparked a hot topic of research: that planets' orbits may shift -- migrate -- early after their formation. This "planetary migration" is the best explanation for these newly discovered "hot Jupiters"-- massive gas giants orbiting extremely close to their stars.

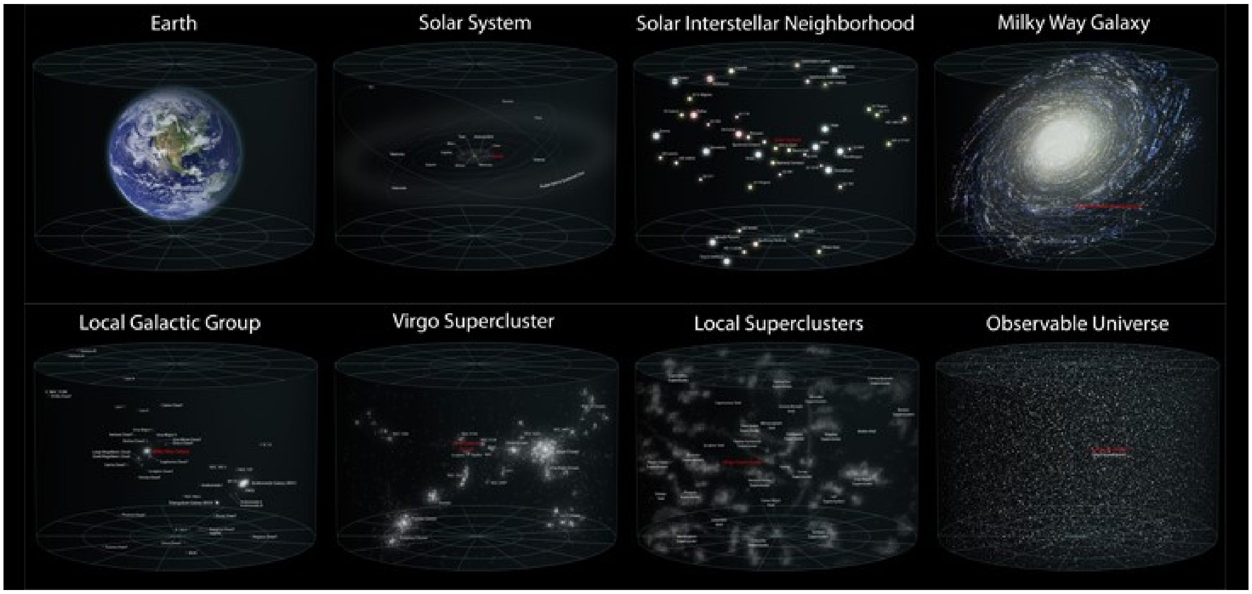
The Deep Impact-EPOXI mission is one of several NASA spacecraft studying comets to find clues about the origin of our solar system.

Planetary migration is caused by gravitational interactions between the gas in the solar nebula and the young planets, and also by gravitational interactions between the planets and the remaining planetesimals. These interactions transfer angular momentum between the objects, causing the planet to either give up energy, and move closer toward the star, or gain energy, and migrate outward.

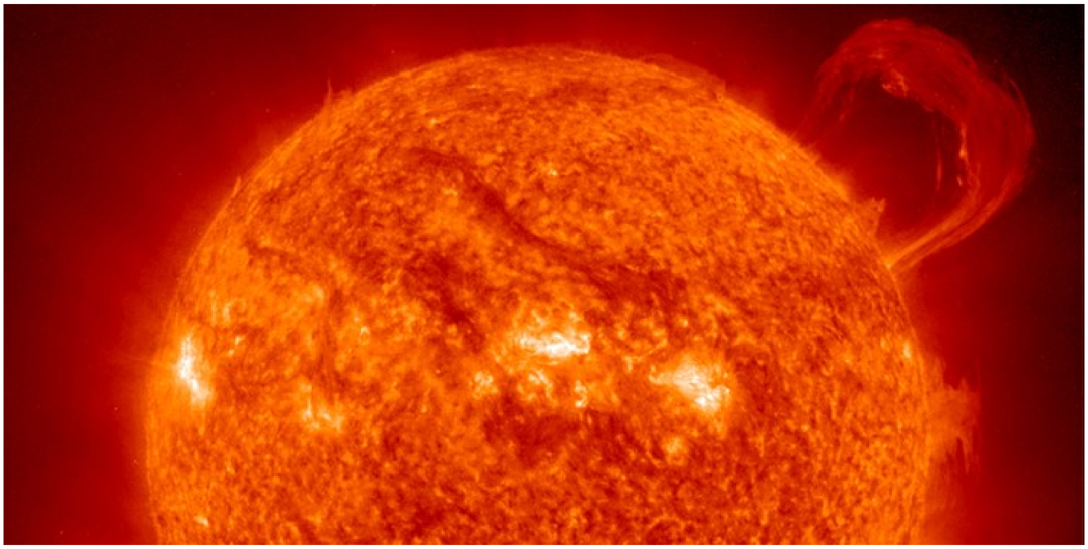
One model for our own solar system suggests that our giant planets' orbits shifted dramatically early in the solar system's history, with Jupiter's orbit migrating slightly inward toward the Sun, and those of Saturn, Neptune, and Uranus expanding farther from the Sun. These dramatic movements gave us the order of the planets and smaller bodies that we are familiar with today and caused many smaller bodies (such as comets) to scatter out into the Kuiper belt and Oort cloud.

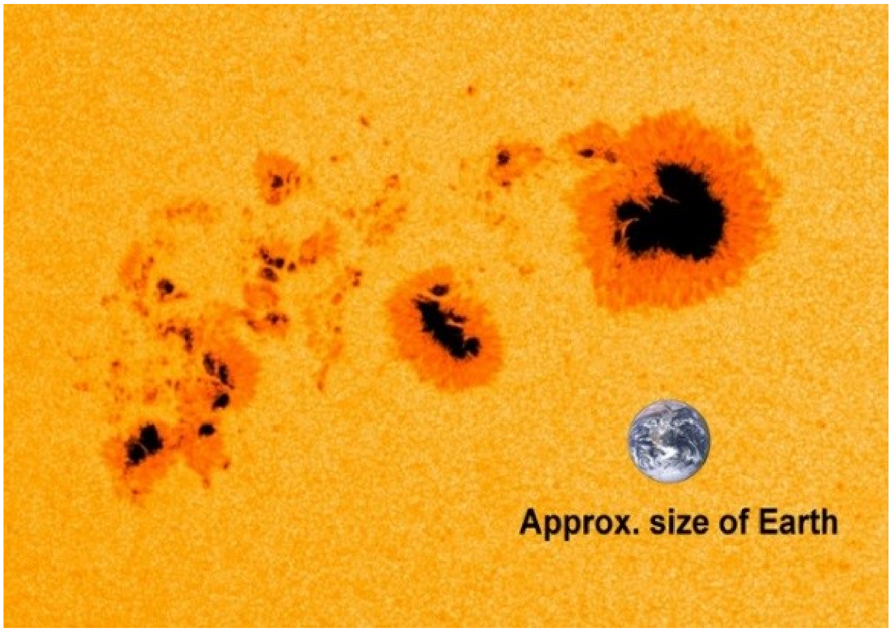
Planetary migration may also account for an intense period of bombardment throughout the inner solar system, around 3.9 billion years ago. Some computer models suggest that interactions of Jupiter and Saturn's orbits destabilized the orbits of asteroids and comets in the outer solar system, causing them to pelt the inner solar system. Scientists are continuing to investigate how the gravitational influences of the giant planets interacted to dramatically reshape our solar system.

Did the planets form in their present locations, or did the giant planets form closer to the Sun and, through complex gravitational interactions, migrate to their orbits of today? More detailed understanding of the dates of impacts and the materials in the early solar system may provide us with final answers.


Earth
Solar System
Solar Interstellar Neighborhood
Milky Way Galaxy
Local Galactic Group
Virgo Supercluster
Local Superclusters
Observable Universe

7. The Sun





January 2014- One of the largest sunspots seen in the last decade

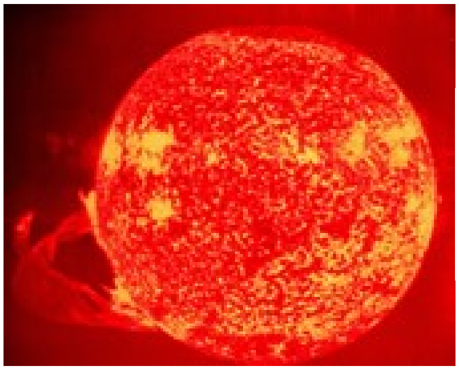
The Sun is a star, a hot ball of glowing gasses at the heart of our solar system. Its influence extends far beyond the orbits of distant Neptune and Pluto. Without the Sun's intense energy and heat, there would be no life on Earth. And though it is special to us, there are billions of stars like our Sun scattered across the Milky Way Galaxy.

Did you know that outer space has weather too? Not rain or snow but winds and magnetic waves that move through space!

When you watch the video- A space weather forecast model, which forecasted the arrival of three successive coronal mass ejections from the Sun. The Sun is yellow at left, the Earth is green at right, and the banana-shaped regions of contrasting colors are the coronal mass ejections headed toward Earth in early August 2011. (Source: NOAA)

When storms in outer space occur near Earth or in the Earth's upper atmosphere, we call it space weather. Unlike weather within our atmosphere (rain, snow, heat, wind, etc.), space weather comes in the form of radio blackouts, solar radiation storms, and geomagnetic storms caused by solar disturbances from the Sun.

NOAA's **Space Weather Prediction Center** (SWPC) is the official source for space weather forecasts for our Nation. They forecast solar storms, much like our National Weather Service offices forecast weather here on Earth. SWPC forecasters use ground-based instruments and satellites to monitor the active regions of the Sun for any changes and issue watches, warnings, and alerts for **hazardous space weather events**. Just like there are categories used to classify hurricanes, there are also **Space Weather Scales** for communicating the severity of solar storms. To predict these storms, forecasters watch the Sun for solar flares and coronal mass ejections. Solar storms are massive explosions on the Sun's surface. They often arise near sunspots and release a wide spectrum of photons such as X-Rays, visible light, and ultraviolet light, as well as highly energized protons outward into space. The biggest solar storms arise from **coronal mass ejections** (CME). A CME is an enormous bubble of plasma expelled by the Sun; it contains billions of tons of fast-moving solar particles as well as the magnetic field that binds them. The velocity of a CME can exceed 5 million miles per hour!



The Sun reached its solar maximum in May 2013. What did that mean for the Earth?

Earth's magnetic field helps to protect us from the effects of some solar storms, but how can space weather impact the Earth? Strong solar storms can cause fluctuations of electrical currents in space and energize electrons and protons trapped in Earth's varying magnetic field. These disturbances can cause problems with radio communications, Global Positioning Systems (GPS), power grids, and satellites. Imagine all the ways in which we are dependent upon satellites: cell phones, weather prediction, TV, search and rescue, navigation, space travel, military surveillance, credit card and ATM transactions, etc. What if those satellites were damaged? As we become more dependent on technology, the need for space weather monitoring and forecasting becomes more important.

Every storm cloud has a silver lining; in the case of space weather, that lining is **auroras**, commonly known as the Northern or Southern Lights. When electrons and protons around Earth are energized by solar disturbances, they can follow Earth's magnetic field toward the North and South magnetic poles where they collide with atmospheric molecules, energizing them and causing them to glow. The colors that result depend on the types of nearby atmospheric gasses and are most commonly a brilliant yellow-green color.

Understanding the Connection

Concepts of the electromagnetic spectrum, Earth-Sun relationships, the Earth's atmosphere and energy all tie into the concept of space weather. During space weather events, scientist track auroras, space weather alerts, solar wind, and satellite imagery of the Sun using the data resources.

Need-to-Know Things About the Sun:

1) The Sun is a yellow star. A star does not have a solid surface but is a ball of gas (92.1 percent hydrogen (H_2) and 7.8 percent helium (He) held together by its own gravity.

2) The Sun (just like every other star) provides energy by converting H nuclei into He through the process of Nuclear Fusion. In the solar interior, at temperature of 15 million K, a nuclear reaction called the proton-proton chain, converts four hydrogen nuclei (protons) into the nucleus of a helium atom. During the reaction, some of the matter is converted to the energy of the Sun. A star the size of the Sun can exist in its present stable state for 10 billion years.

3) The Sun is the center of our solar systems and makes up 99.8 percent of the mass of the entire solar system.

4) The sun produces a solar wind which contains charged particles such as electrons and protons.

5) A solar eclipse occurs when the new moon passes in between the Sun and Earth. Because the moon's orbit is at a 5^0 above or below the orbital plane of the Earth around the sun.

6) The next solar eclipse in the United States will occur on August 21, 2017.

7) The Sun is an average size star, average temperature, and average age (4.6- 5 billion years old).

8) It takes 8 minutes for sunlight to reach the Earth from the Sun.

9) To provide perspective, it would take about one million Earths to fit into the Sun.

10) If the Sun were as tall as a typical front door, Earth would be about the size of a nickel.

11) Since the Sun is not a solid body, different parts of the Sun rotate at different rates. At the equator, the Sun spins once about every 25 Earth days, but at its poles, the Sun rotates once on its axis every 36 days.

12) The solar atmosphere is where we see features such as sunspots and solar flares on the Sun. The Sun's outer atmosphere, the corona, extends beyond the orbit of dwarf-planet Pluto.

13) The Sun is orbited by eight planets, at least five dwarf planets, tens of thousands of asteroids, and hundreds of thousands to three trillion comets and icy bodies.

14) The Sun does not have any rings.

15) Spacecraft are constantly increasing our understanding of the Sun.

16) Without the Sun's intense energy there would be no life on Earth.

17) The temperature at the Sun's core is about 15 million degrees Celsius (27 million degrees Fahrenheit).

18) The Sun has four main layers: The solar interior; the photosphere (visible surface) radiates most of the light that is seen; chromosphere (thin layer) incandescent gasses a few thousand km thick; corona (uppermost part of the Sun’s atmosphere) ionized gases escape the gravitational pull of the Sun and stream towards the Earth producing the solar winds.

-

8. Formation of the Earth/Moon System

The light areas of the moon are known as the highlands. The dark features, called Maria (Latin for “seas”), are impact basins that were filled with lava between 4.2 and 1.2 billion years ago. These light and dark areas represent rocks of different composition and ages, which provide evidence for how the early crust may have crystallized from a lunar magma ocean. The craters themselves, which have been preserved for billions of years, provide an impact history for the moon and other bodies in the inner solar system.

The leading theory of the moon's origin is that a Mars-sized body (often called Theia) collided with Earth approximately 4.5 billion years ago, and the resulting debris from both Earth and the impactor accumulated to form our natural satellite. The newly formed moon was in a molten state. Within about 100 million years, most of the global "magma ocean" had crystallized, with less dense rocks floating upward and eventually forming the lunar crust. The early moon may have developed an internal dynamo, the mechanism for global magnetic fields for terrestrial planets.

Since the ancient time of volcanism, the arid, lifeless moon has remained nearly unchanged. With too sparse an atmosphere to impede impacts, a steady rain of asteroids, meteoroids, and comets strikes the surface. Over billions of years, the surface has been ground up into fragments ranging from huge boulders to powder. Nearly the entire moon is covered by a rubble pile of charcoal-gray, powdery dust and rocky debris called the lunar regolith. Beneath is a region of fractured bedrock referred to as the megaregolith.

The moon was first visited by the U.S.S.R.'s Luna 1 and Luna 2 in 1959, and a number of U.S. and U.S.S.R. robotic spacecraft followed. The U.S. sent three classes of robotic missions to prepare the way for human exploration: the Rangers (1961-1965) were impact probes, the Lunar Orbiters (1966-1967) mapped the surface to find landing sites, and the Surveyors (1966-1968) were soft landers. The first human landing on the moon was on 20 July 1969. During the Apollo missions of 1969-1972, 12 American astronauts walked on the moon and used a Lunar Roving Vehicle to travel on the surface and extend their studies of soil mechanics, meteoroids, lunar ranging, magnetic fields, and solar wind. The Apollo astronauts brought back 382 kilograms (842 pounds) of rock and soil to Earth for study.

How the Moon Got its Name

Earth's only natural satellite is simply called the moon because people didn't know other moons existed until Galileo Galilei discovered four moons orbiting Jupiter in 1610. Other moons in our solar system are given names so they won't be confused with each other. We call them moons because, like our own, they are natural satellites orbiting a solar system body (which in turn is orbiting a star).

Tides

Tides are wave motion in the ocean. Tides are a change in the ocean water level, typically reaching a high and low level twice a day usually occurring about 6 hours apart. The term for the change from low to high tide is called the ("flood tide"). The change from high tide to low tide is called the ("ebb tide").

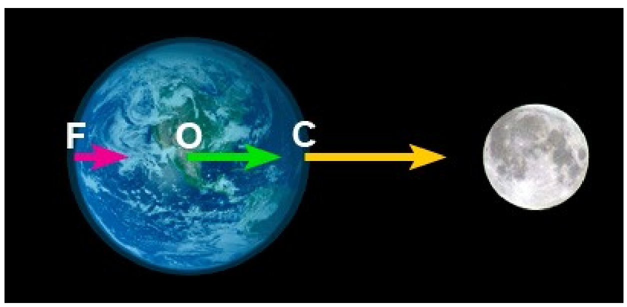
Tides result from the pull of gravity: on the Earth alone, between the Earth and moon, and between the Earth and the Sun. The gravitational pull of the Sun on the Earth is about 178 times *stronger* than the gravitational pull on the Earth from the moon. However, because of the close proximity of the moon, when compared to the Sun, the tidal pull by the moon is over twice that of the Sun.

The result of this tidal pull is a bulge in the ocean water almost in line with the position of the moon; one bulge toward the moon and one on the opposite side of the Earth, away from the moon. When we observe the tides what we are actually seeing is the result of the Earth rotating under this bulge.

The TWO High Tides

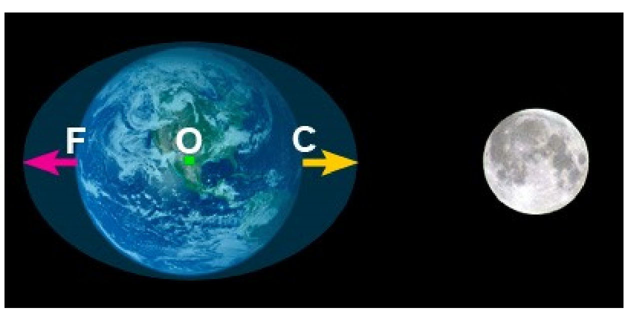
It appears easy to understand why there should be a bulge of water, producing a high tide, on the side of the earth facing of the moon. But why is there a bulge on the opposite side as well?

It is obviously not gravity that is doing it but rather, it is the *difference* in gravitational force across the Earth that causes the bulge. This difference in gradational force comes from the moon's pull at various points on the Earth.



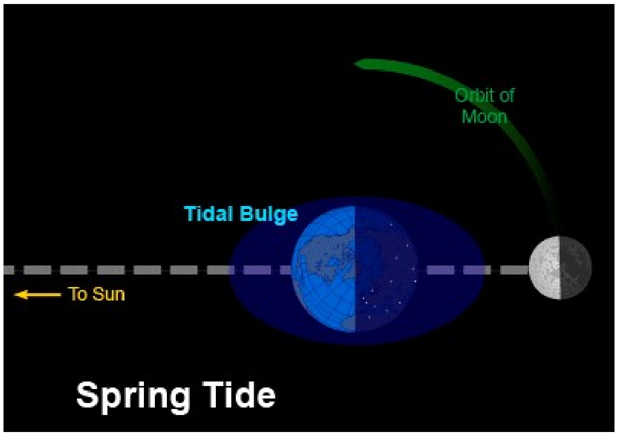
Because the pull of gravity becomes stronger as the distance decreases, the moon pulls a little harder at point "C" (closest point to the moon) than it does at point "O" (in the center of the earth), and the pull is weaker still at point "F" (farthest point from the moon). If it were not for the Earth's gravity, the planet would be pulled apart (above image).

Yet also because of the Earth's gravity which pulls us toward the center of the planet we can, mathematically subtract the moon's pull at the center of the earth from the moon's pull at both point "C" and "F". When this vector-based subtraction occurs we are left with two smaller forces; one toward the moon and one on the opposite side point away from the moon (image below) producing two bulges.



As the Earth makes one rotation in 24 hours, we pass under these areas where the tidal force pulls water away from the Earth's surface, and experience high tides. Also, since the difference in gravitational force is constant across the Earth, the bulge on both side of the Earth is essentially the same. This explains why consecutive high tides are nearly the same height each time regardless whether the moon is overhead or on the opposite side of the Earth.

Spring Tides



The change in the water level with the daily tides from location to location results from many factors. The oceans and shorelines have complex shapes and the depth, and configuration of the sea floor varies considerably.

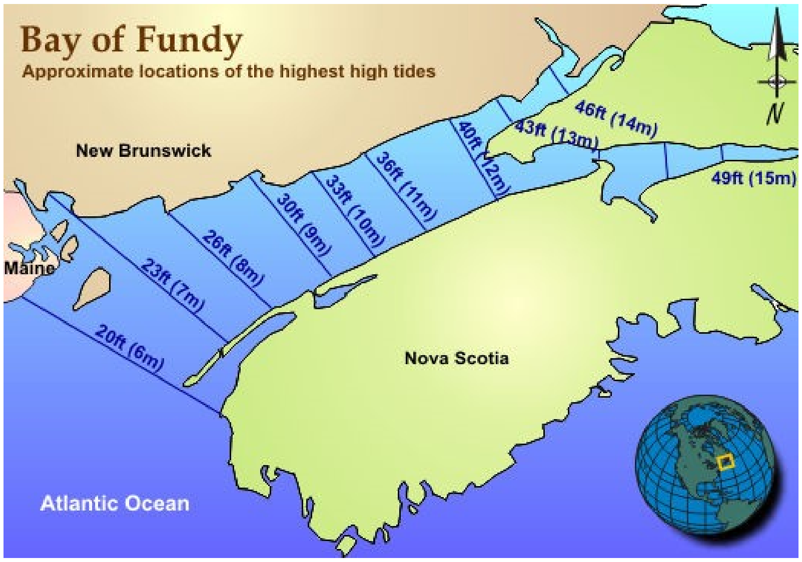
As a result, some locations experience only one high and low tide each day, called a **diurnal tide**. Other locations experience two high and low tides daily, called a **semi-diurnal tide**. Still, other sites have **mixed tides**, where the difference in successive high-water and low-water marks differ appreciably.

Another factor in the variation of tides is based on the orbit of the moon around the Earth and the Earth around the Sun. Both orbits are not circles but ellipses. The distance between the Earth and moon can vary by up to 13,000 miles (31,000 km). Since the tidal force increases with decreasing distance then tides will be higher than normal when the moon is at its closest point (called perigee) to the Earth, approximately every 28 days.

Likewise, the Earth's elliptical orbit also causes variations in the Sun's pull on the tides as we move from the closest point to the farthest point (called apogee) over the course of a year. And just to complicate things even more, the moon's orbit is inclined 5° to the Earth's rotation. So the north/south orientations of the bulge also varies between the northern and southern hemisphere over this same 28-day orbital period.

Highest Tides in the World

Bay of Fundy



Explaination of the Bay of Fundy

The world's highest tides occur in the Bay of Fundy in Atlantic Canada. This time lapse movie speeds up by 720 times the fall and rise of the tide in Hall's Harbour, Nova Scotia.

Located in Canada, between the provinces of Nova Scotia and New Brunswick, sits the Bay of Fundy, home to the world largest tidal variations. While the Earth's average height variation in sea level from tides is three feet, the water level near Wolfville, in Nova Scotia's Minas Basin can be as much as 53 feet (16 meters) higher than at low tide.

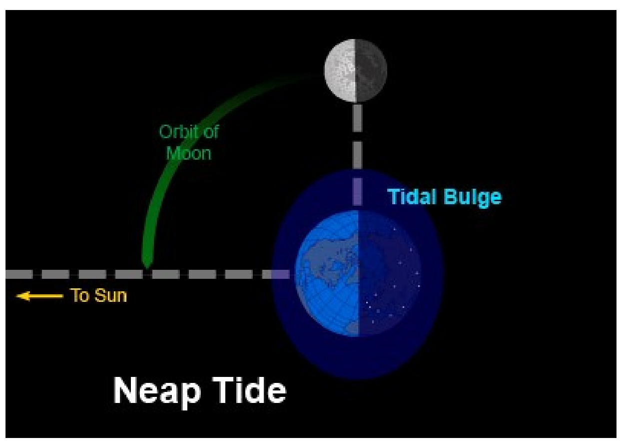
Tides along the Atlantic coast are basically semi-diurnal, meaning there are two significant high tides every 24 hours. Along the Atlantic coast side of Nova Scotia's Atlantic coast, outside the Bay of Fundy, the tidal range is from 4 to 8 feet (1½-2½meters) and without much variation in the time of the high and low tides.

So, why is there such a large variation in the tide inside of the Bay of Fundy versus outside? It is because of the funnel shape and depth of the bay...and a little physics.

Liquid in a tank, or in this case a basin, will flow back and forth in a characteristic "oscillation" period and, if conditions are right, will rhythmically slosh back and forth. In essence, a standing wave develops. The natural period of oscillation in the Bay of Fundy is approximately 12 hours which is about the same length of time for one tidal oscillation (a high/low tide cycle). This coincidence of the tide cycle and the oscillation period of the bay result in the much larger tidal ranges observed in the bay versus what occurs outside the bay.

The huge volume of tidal water flowing through the bay four times daily has created some unique features such as the "Old Sow" whirlpool (the largest whirlpool in the Western Hemisphere), the "Reversing Falls" (series of rapids on the Saint John River that reverse direction with each flood and ebb tide) and the Hopewell Rocks (rocky islands at high tide and a place where you can walk the beach and explore these formations along with the many caves cut into the cliff walls at low tide).

Neap Tides



As the moon completes one orbit around the earth (about every 28 days), there are two times in each orbit when the Earth, moon and Sun are in line with each other and two times when the Earth, moon and Sun are at right angles.

When all three are inline (around full and new moons), the combined effect of the moon's and Sun's pull on the Earth's water is at its greatest, resulting in the greatest ranges between high and low tide. This called a "spring" tide (from the water *springing* or rising up).

Seven days after either a full or new moon, the Earth, moon and Sun are at right angles to each other. At this time the pull of the moon and the pull of the Sun partially cancel each other out. The resulting tide, called a "neap" tide, has the smallest range between high and low tide.

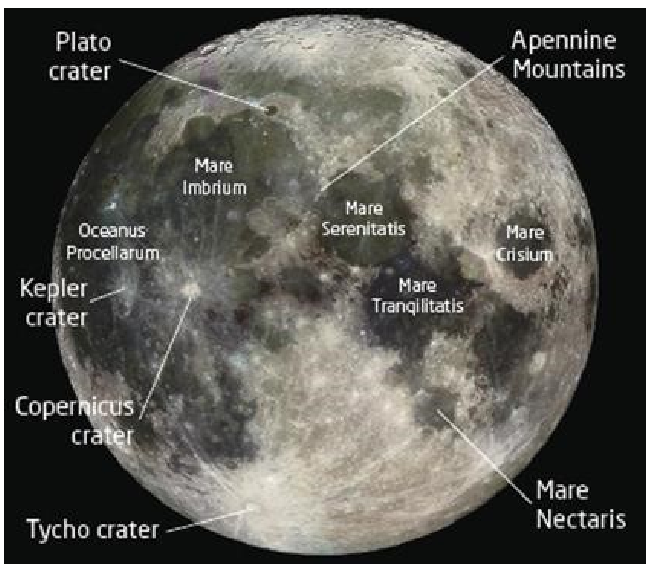
Significant Dates

- **1610:** Galileo Galilei is the first to use a telescope to make scientific observations of the moon.
- **1959-1976:** The U.S.S.R.'s Luna program of 17 robotic missions achieves many "firsts" and three sample returns.
- **1961-1968:** The U.S. Ranger, Lunar Orbiter, and Surveyor robotic missions pave the way for Apollo human lunar landings.
- **1969:** Astronaut Neil Armstrong is the first human to walk on the moon's surface.
- **1994-1999:** Clementine and Lunar Prospector data suggest that water ice may exist at the lunar poles.
- **2003:** The European Space Agency's SMART-1 lunar orbiter inventories key chemical elements.
- **2007-2008:** Japan's second lunar spacecraft, Kaguya, and China's first lunar spacecraft, Chang'e 1, both begin one-year missions orbiting the moon; India's Chandrayaan-1 soon follows in lunar orbit.

- **2008:** The NASA Lunar Science Institute is formed to help lead NASA's research activities related to lunar exploration goals.
- **2009:** NASA's LRO and LCROSS launch together, beginning the U.S. return to lunar exploration. In October, LCROSS was directed to impact a permanently shadowed region near the lunar South Pole, resulting in the discovery of water ice.
- **2011:** Twin GRAIL spacecraft launch to map the interior of the moon from crust to core, and NASA begins the ARTEMIS mission to study the moon's interior and surface composition.

Need-to-Know Things About the Moon:

1. The next lunar eclipse in Virginia will be on March 23, 2016
2. The only time that a lunar eclipse can occur is during a Full moon.
3. Average distance from Earth: 384,400 km
4. The moon takes 27.3 days to orbit the Earth and 29.5 days to rotate on its axis. This is why the same side of the moon is always seen.
5. The moon has the greatest influence on the Earth's tides and causes a spring tide during the new and full moon phases and a neap tide during the first and third quarters.
6. The moon is drifting away from the Earth at approximately 3.8 cm a year.
7. Only 12 people have walked on the surface of the moon.
8. This satellite has no atmosphere, therefore it is not protected from cosmic rays, meteorites, and solar winds. This results in a wide temperature variations: 233 to 123^{0}C.
9. Due to the lack of an atmosphere on the moon, there is no weathering or erosion. The footprints left by the Apollo missions are still in the moon.
10. The moon has moonquakes.
11. The moon has no global magnetic field.
12. Diameter is ¼ diameter of the Earth. Forty-nine moons would fit inside the Earth.
13. The first spacecraft to reach the moon was the USSR's Luna 1 in 1959.
14. During the Cold War in the 1950s, the United States considered a project called Project A119. The project considered detonating a nuclear bomb on the Moon as demonstration of the US power and a means of intimidation directed at the USSR.
15. Features of the Moon:
    1. Craters - caused by impact of meteorites
    2. Domes - remains of lava that flowed on the surface
    3. Maria (means "seas"). Early observers thought the Maria, dark areas on the Moon's surface, were sea basins. They are massive impact basins filled with lava that cooled.
    4. Mountains- can rise up to 5km
    5. Rilles- faults on the lunar surface; sometimes called lava channels
    6. Regolith (from Greek rhegos (blanket) and lithos (rock) - loose material that covers the solid bedrock. Can be 4- 5 meters most places and up to 15 meters in the older highlands.
    7. Highlands- the lighter areas of the moon surface



9. The Earth

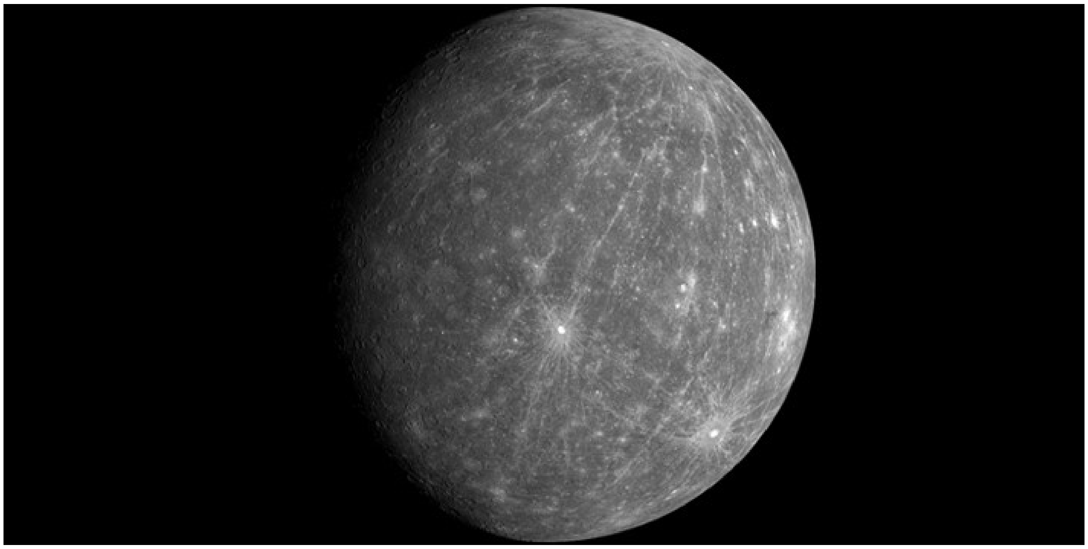
The composite of the NASA image assembled here was made possible by the new satellite's 'day-night band' of the Visible Infrared Imaging Radiometer Suite (VIIRS), which detects light in a range of wavelengths from green to near-infrared and uses filtering techniques to observe dim signals such as city lights, gas flares, auroras, wildfires, and reflected moonlight.

Earth, our home planet, is the only planet in our solar system known to harbor life, a life that is incredibly diverse. All the things we need to survive exist under a thin layer of atmosphere that separates us from the cold, airless void of space.

Need-to-Know Things About Earth:

1. If the Sun were as tall as a typical front door, Earth would be the size of a nickel.
2. Earth is the third planet from the sun at a distance of about 150 million km (93 million miles) or one AU.
3. Earth is the only place in the solar system where waters exist in all three phases: solid, liquid, and gas.
4. The Earth has a tilt of 23.5^{0} which accounts for its seasons.
5. The Earth is tectonically active.
6. Earth is the densest planet in our solar system.
7. One day on Earth takes 24 hours (this is the time it takes the Earth to rotate or spin once). Earth makes a complete orbit around the sun (a year in Earth time) in about 365.25 days.
8. Earth is a rocky planet, also known as a terrestrial planet, with a solid and dynamic surface of mountains, valleys, canyons, plains and so much more. What makes Earth different from the other terrestrial planets is that it is also an ocean planet: 70 percent of the Earth's surface is covered in oceans.
9. The Earth's atmosphere is made up of 78 percent nitrogen (N_2), 21 percent oxygen (O_2) and 1 percent other ingredients -- the perfect balance for us to breathe and live. Many planets have atmospheres, but only Earth's is breathable.
10. Earth has one moon. Another name for a moon is a *satellite.*
11. Earth has no rings.
12. Many orbiting spacecraft study the Earth from above as a whole system and together aid in understanding our home planet.
13. Earth is the perfect place for life.
14. Earth has a magnetic field which is caused by the iron-nickel core’s rapid rotation. This field protects us from the effects of the solar winds.
15. Earth's atmosphere protects us from incoming meteoroids, most of which break up in our atmosphere before they can strike the surface as meteorites.

10. Inner Planet Mercury



MESSENGER spacecraft images have revealed portions of Mercury never seen by human eyes. Image Credit: NASA/Johns Hopkins University Applied Physics Laboratory/Carnegie Institution of Washington

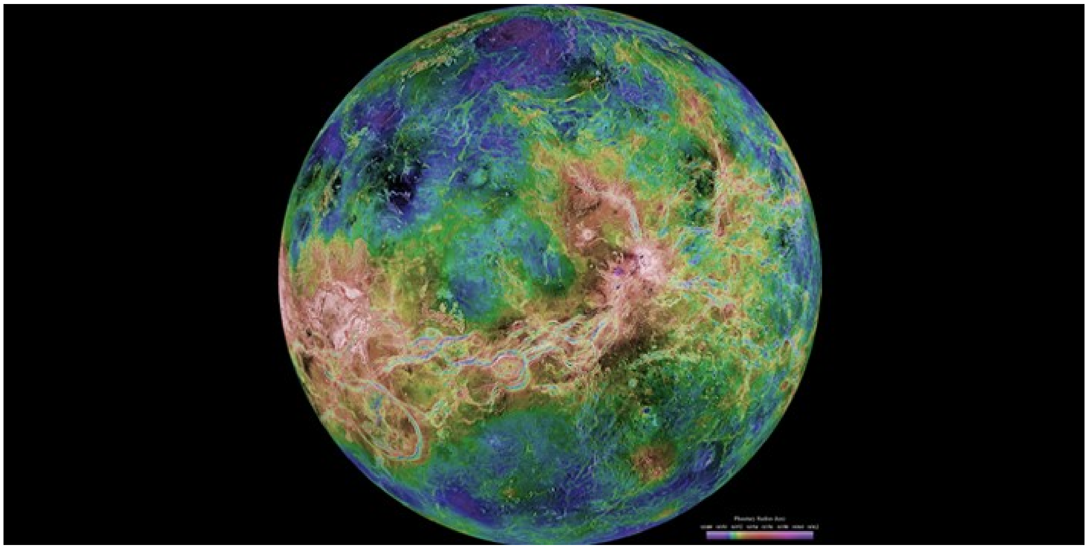
http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=7543

Sun-scorched Mercury is only slightly larger than Earth's moon. Like the moon, Mercury has very little atmosphere to stop impacts and it is covered with craters. Mercury's dayside is super-heated by the sun, but at night temperatures drop hundreds of degrees below freezing. Ice may even exist in craters. Mercury's egg-shaped orbit takes it around the sun every 88 Earth days.

10 Need-to-Know Things About Mercury:

1. Mercury is the smallest planet in our solar system -- only slightly larger than the Earth's moon.
2. It is the closest planet to the sun at a distance of about 58 million km (36 million miles) or 0.39 AU.
3. One day on Mercury (the time it takes for Mercury to rotate or spin once) takes 59 Earth days. Mercury makes a complete orbit around the sun (a year in Mercury time) in just 88 Earth days.
4. Mercury is a rocky planet, also known as a terrestrial planet. Mercury has a solid, cratered surface, much like Earth's moon.
5. Mercury's thin atmosphere, or *exosphere,* is composed mostly of oxygen (O_2), sodium (Na), hydrogen (H_2), helium (He), and potassium (K). Atoms that are blasted off the surface by the solar wind and micrometeoroid impacts create Mercury's exosphere.
6. Mercury has no moons.
7. There are no rings around Mercury.
8. Only two spacecraft have visited this rocky planet: Mariner 10 in 1974-5; and MESSENGER, which flew past Mercury three times before going into orbit around Mercury in 2011.
9. No evidence for life has been found on Mercury. Daytime temperatures can reach 800 degrees Fahrenheit (430 degrees Celsius) and drop to -290 degrees Fahrenheit (-180 degrees Celsius) at night. It is unlikely life (as we know it) could survive on this planet.
10. Standing on Mercury's surface at its closest point to the sun, the sun would appear more than three times larger than it does on Earth.

11. Inner Planet Venus



Magellan spacecraft radar data enabled scientists to penetrate Venus' thick clouds and create simulated views of the surface.

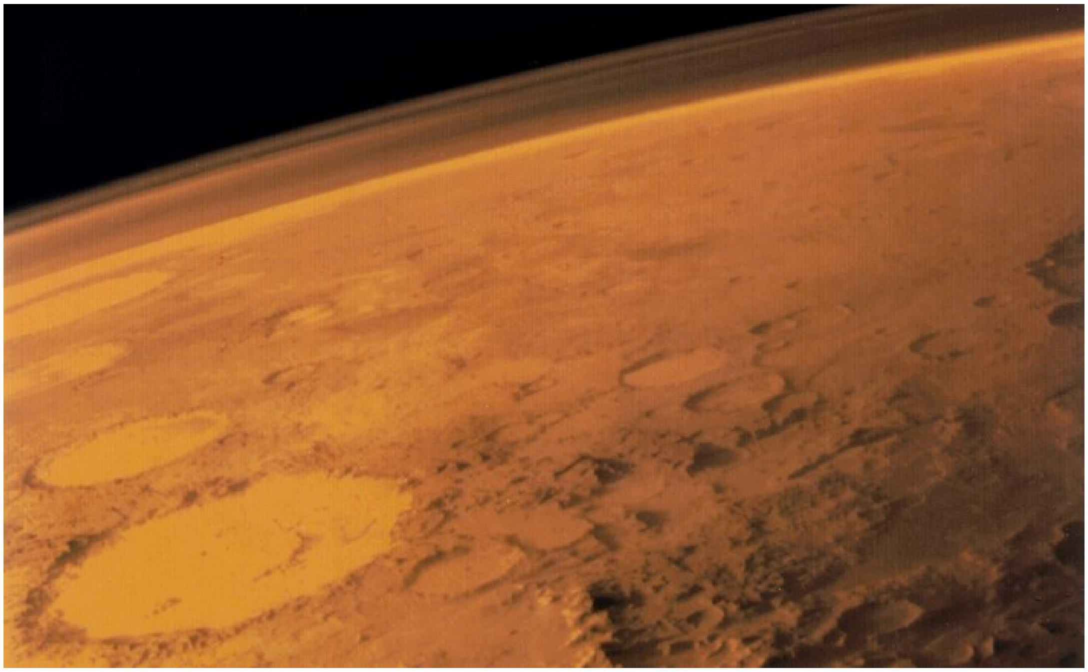
http://solarsystem.nasa.gov//multimedia/display.cfm?IM_ID=9603

Venus is a dim world of intense heat and volcanic activity. Similar in structure and size to Earth, Venus' thick, toxic atmosphere traps heat in a runaway 'greenhouse effect.' The scorched world has temperatures hot enough to melt lead. Glimpses below the clouds reveal volcanoes and deformed mountains. Venus spins slowly in the opposite direction of most planets.

10 Need-to-Know Things About Venus:

1. Venus is only a little smaller than Earth.
2. Venus is the second-closest planet to the sun at a distance of about 108 million km (67 million miles) or 0.72 AU.
3. One day on Venus lasts as long as 243 Earth days (the time it takes for Venus to rotate or spin once). Venus makes a complete orbit around the sun (a year in Venusian time) in 225 Earth days.
4. Venus is a rocky planet, also known as a terrestrial planet. Venus' solid surface is a cratered and volcanic landscape.
5. Venus' thick and toxic atmosphere is made up mostly of carbon dioxide (CO_2) and nitrogen (N_2), with clouds of sulfuric acid (H_2SO_4) droplets.
6. Venus has no moons.
7. There are no rings around Venus.
8. More than 40 spacecraft have explored Venus. The Magellan mission in the early 1990s mapped 98 percent of the planet's surface.
9. No evidence for life has been found on Venus. The planet's extremely high temperatures of almost 480 degrees Celsius (900 degrees Fahrenheit) make it seem an unlikely place for life as we know it.
10. Venus spins backwards (retrograde rotation) when compared to the other planets. This means that the sun rises in the west and sets in the east on Venus.

12. Inner Planet Mars



Mars lost much of its atmosphere over time. Where did the atmosphere--and the water--go? The MAVEN mission's hunt for answers will help us understand when, and for how long, Mars might have had an environment that could have supported microbial life in its ancient past.

http://solarsystem.nasa.gov/maven

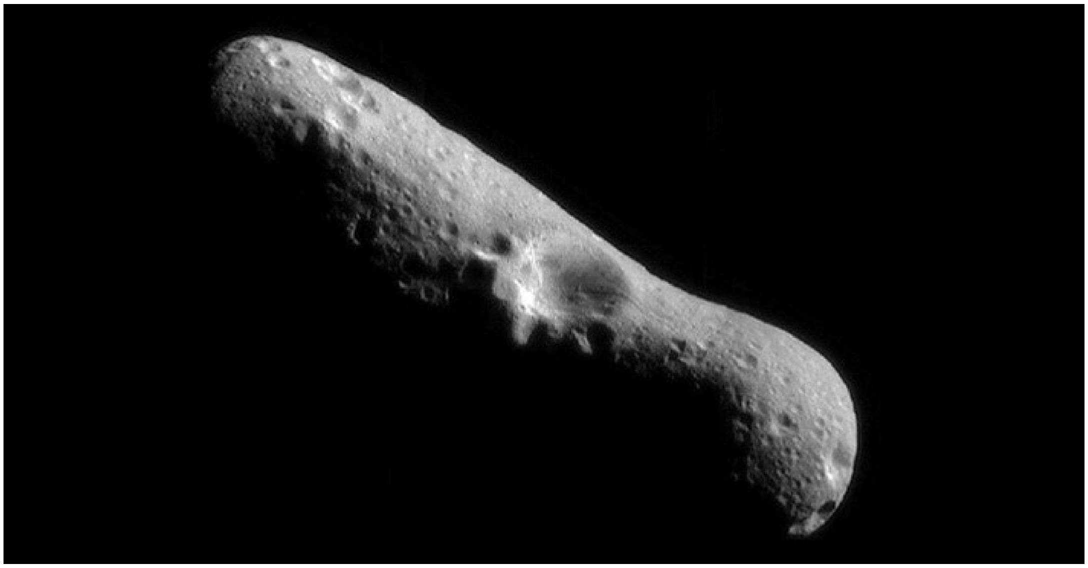
Mars is a cold desert world. It is half the diameter of Earth and has the same amount of dry land. Like Earth, Mars has seasons, polar ice caps, volcanoes, canyons, and weather, but its atmosphere is too thin for liquid water to exist for long on the surface. There are signs of ancient floods on Mars, but evidence for water now exists mainly in icy soil and thin clouds.

10 Need-to-Know Things About Mars

1. If the Sun were as tall as a typical front door, Earth would be the size of a nickel, and Mars would be about as big as an aspirin tablet.
2. Mars orbits our Sun, a star. Mars is the fourth planet from the Sun at a distance of about 228 million km (142 million miles) or 1.52 AU.
3. One day on Mars takes just a little over 24 hours (the time it takes for Mars to rotate or spin once). Mars makes a complete orbit around the sun (a year in Martian time) in 687 Earth days.
4. Mars is a rocky planet, also known as a terrestrial planet. Mars' solid surface has been altered by volcanoes, impacts, crustal movement, and atmospheric effects such as dust storms.
5. Mars has a thin atmosphere made up mostly of carbon dioxide (CO_2), nitrogen (N_2) and argon (Ar).
6. Mars has two moons named Phoebus and Deimos.
7. There are no rings around Mars.
8. More than 40 spacecraft have been launched for Mars, from flybys and orbiters to rovers and landers that touched the surface of the Red Planet. The first true Mars mission success was Mariner 4 in 1965.
9. At this time in the planet's history, Mars' surface cannot support life as we know it. A key science goal is determining Mars' past and future potential for life.
10. Mars is known as the Red Planet because iron minerals in the Martian soil oxidize, or rust, causing the soil -- and the dusty atmosphere – to appear red.

13. Asteroid Belt

This picture of Eros, the first of an asteroid taken from an orbiting spacecraft, is a mosaic of four images obtained by NASA's NEAR mission immediately after the spacecraft's insertion into orbit.



http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=1887

Asteroids are rocky, airless worlds that orbit our sun, but are too small to be called planets. Tens of thousands of these minor planets are gathered in the main asteroid belt, a vast doughnut-shaped ring between the orbits of Mars and Jupiter. Asteroids that pass close to Earth are called near-earth objects.

10 Need-to-Know Things About Asteroids:

1. If all of the asteroids were combined into a ball, they would still be much smaller than Earth's moon. If the sun were as tall as a typical front door, Earth would be the size of a nickel, the moon would be about as big as a green pea and Ceres (the largest object in the main asteroid belt) would be as small as a sesame seed.
2. Most Asteroids orbit our Sun, a star, in a region of space between the orbits of Mars and Jupiter known as the Asteroid Belt.
3. Days and years vary by asteroid. A day on asteroid Ida, for example, takes only 4.6 hours (the time it takes to rotate or spin once). Ida makes a complete orbit around the Sun (a year in this asteroid's time) in 4.8 Earth years.
4. Asteroids are solid, rocky and irregular bodies.
5. Asteroids do not have atmospheres.
6. More than 150 asteroids are known to have a small companion moon (some have two moons). The first discovery of an asteroid-moon system was of asteroid Ida and its moon Dactyl in 1993.
7. One asteroid, named Chariklo, is known to have two dense and narrow rings.
8. More than 10 spacecraft have explored asteroids. NEAR Shoemaker even landed on an asteroid (Eros). The Dawn mission is the first mission to orbit (2011) the main belt asteroid (Vesta).
9. Asteroids cannot support life as we know it.
10. Ceres, the first and largest asteroid to be discovered (1801 by Giuseppe Piazzi) and the closest dwarf planet to the Sun, encompasses over one-third of the estimated total mass of all the asteroids in the asteroid belt.

14. Meteors and Meteorites

NASA's Opportunity rover found this meteorite on Mars. It is about the size of a basketball.

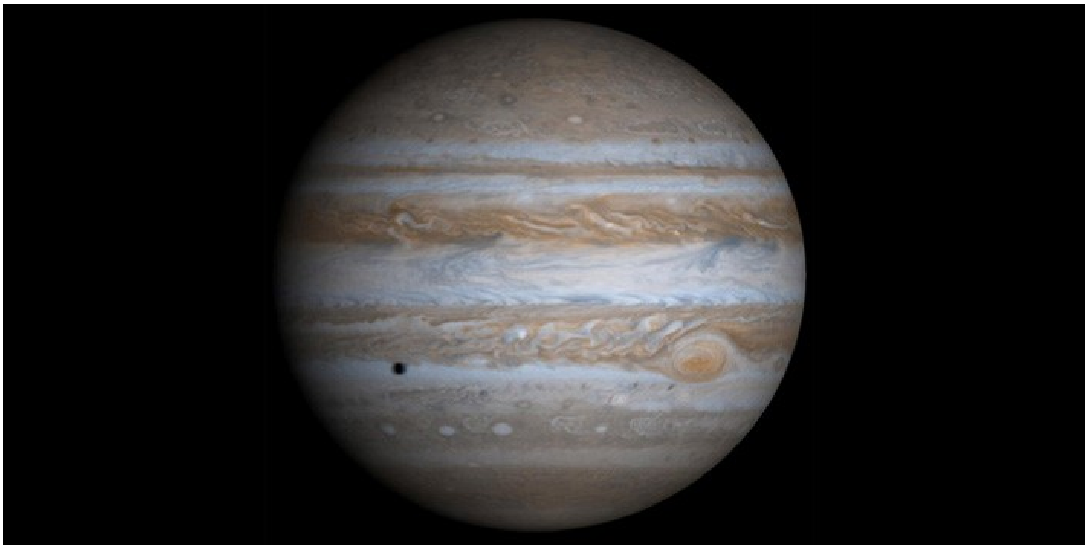
http://solarsystem.nasa.gov//multimedia/display.cfm?IM_ID=10293

Little chunks of rock and debris in space are called meteoroids. They become meteors -- or shooting stars -- when they fall through a planet's atmosphere; leaving a bright trail as they are heated to incandescence by the friction of the atmosphere. Pieces that survive the journey and hit the ground are called meteorites.

10 Need-to-Know Things About Meteors and Meteorites:

1. Meteoroids become meteors -- or shooting stars -- when they interact with a planet's atmosphere and cause a streak of light in the sky. Debris that makes it to the surface of a planet from meteoroids are called meteorites.
2. Meteorites may vary in size from tiny grains to large boulders. One of the largest meteorite found on Earth is the Hoba meteorite from southwest Africa, which weighs roughly 54,000 kg (119,000 pounds).
3. Meteor showers are usually named after a star or constellation which is close to the radiant (the position from which the meteor appears to come).
4. Meteors and meteorites begin as meteoroids, which are little chunks of rock and debris in space.
5. Most meteorites are either iron, stony, or stony-iron.
6. Meteorites may look very much like Earth rocks, or they may have a burned appearance. Some may have depression (thumbprint-like), roughened or smooth exteriors.
7. Many of the meteor showers are associated with comets. The Leonids are associated with comet Tempel-Tuttle; Aquarids and Orionids with comet Halley, and the Taurids with comet Encke.
8. When comets come around the sun, they leave a dusty trail. Every year the Earth passes through the comet trails, which allows the debris to enter our atmosphere where it burns up and creates fiery and colorful streaks (meteors) in the sky.
9. Leonid MAC (an airborne mission that took flight during the years 1998 - 2002) studied the interaction of meteoroids with the Earth's atmosphere.
10. Meteoroids, meteors, and meteorites cannot support life. However, they may have provided the Earth with a source of amino acids: the building blocks of life.
11. 2016 Major Meteor Showers- Northern Hemisphere
    1. Quadrantid- Jan 1 - 10 (released particles from an asteroid)
    2. Lyrids- April 16 - 25 (released particles from Thatcher Comet)
    3. Perseids- July 13 - Aug. 26 (released particles from Swift-Tuttle Comet)
    4. Orionids- Oct. 4 - Nov. 14 (released particles from Halley’s Comet)
    5. Leonids- Nov. 5 - 30 (released particles from Tempel-Tuttle Comet)
    6. Geminids- Dec. 4 - 16 (released particles from an asteroid)
    7. Ursids- Dec. 17- 23 (released particles from Tuttle Comet)

15. Jovian Planet Jupiter



A true-color image of Jupiter taken by the Cassini spacecraft. The Galilean moon Europa casts a shadow on the planet's cloud tops.

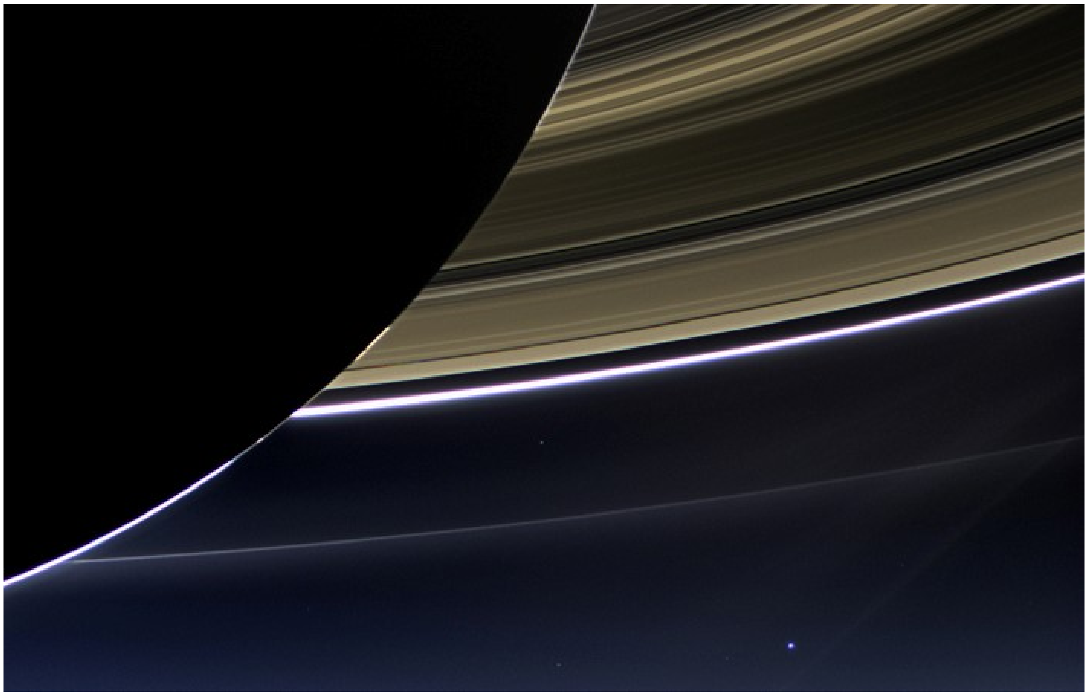
http://solarsystem.nasa.gov//multimedia/display.cfm?IM_ID=9523

The most massive planet in our solar system -- with dozens of moons and an enormous magnetic field -- Jupiter forms a kind of miniature solar system. It resembles a star in composition but did not grow big enough to ignite. The planet's swirling cloud stripes are punctuated by massive storms such as the Great Red Spot, which has raged for hundreds of years.

10 Need-to-Know Things About Jupiter:

1. If the Sun were as tall as a typical front door, the Earth would be the size of a nickel and Jupiter would be about as big as a basketball.
2. Jupiter orbits our sun, a star. Jupiter is the fifth planet from the Sun at a distance of about 778 million km (484 million miles) or 5.2 AU
3. One day on Jupiter takes about 10 hours (the time it takes for Jupiter to rotate or spin once). Jupiter makes a complete orbit around the sun (a year in Jovian time) in about 12 Earth years (4,333 Earth days).
4. Jupiter is a gas giant planet and therefore does not have a solid surface. However, it is predicted that Jupiter has an inner, solid core about the size of the Earth.
5. Jupiter's atmosphere is made up mostly of hydrogen (H_2) and helium (He).
6. Jupiter has 50 known moons, with an additional 17 moons awaiting confirmation of their discovery, for a total of 67 moons.
7. Jupiter has a faint ring system that was discovered in 1979 by the Voyager 1 mission.
8. Many missions have visited Jupiter and its system of moons. The Juno mission will arrive at Jupiter in 2016.
9. Jupiter cannot support life as we know it. However, some of Jupiter's moons have oceans underneath their crusts that might support life.
10. Jupiter's Great Red Spot is a gigantic storm (bigger than Earth) that has been raging for hundreds of years.

16. Jovian Planet Saturn



In this rare image taken on 19 July 2013, the wide-angle camera on NASA's Cassini spacecraft has captured Saturn's rings and our planet Earth and its moon in the same frame.

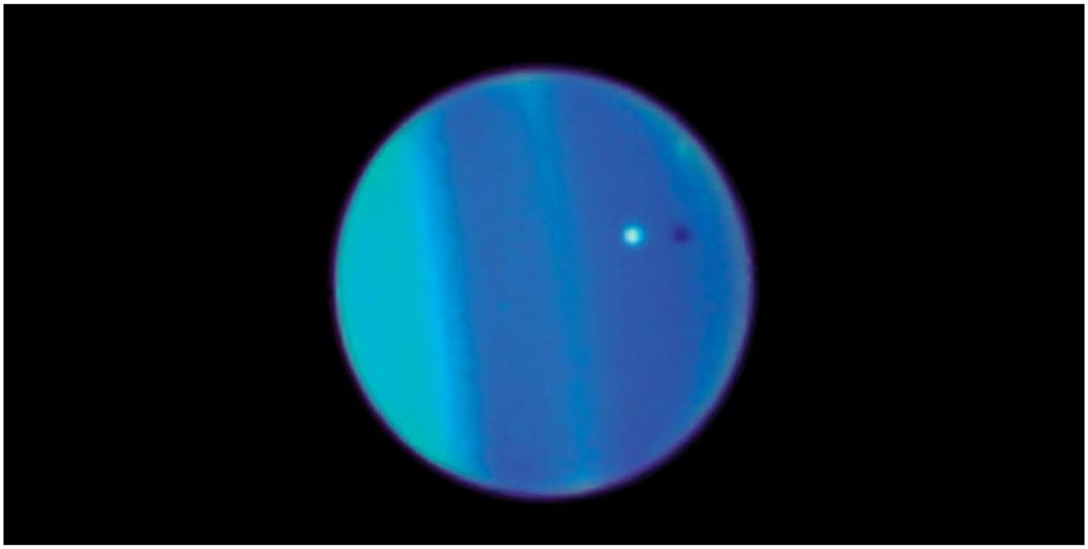
http://solarsystem.nasa.gov/multimedia/display.cfm?Category=Planets&IM_ID=17525

Adorned with thousands of beautiful ringlets, Saturn is unique among the planets. All four gas giant planets have rings -- made of chunks of ice and rock -- but none are as spectacular or as complicated as Saturn's. Like the other gas giants, Saturn is mostly a massive ball of hydrogen and helium.

10 Need-to-Know Things About Saturn:

1. If the Sun were as tall as a typical front door, the Earth would be the size of a nickel and Saturn would be about as big as a basketball.
2. Saturn orbits our Sun, a star. Saturn is the sixth planet from the sun at a distance of about 1.4 billion km (886 million miles) or 9.5 AU.
3. One day on Saturn takes 10.7 hours (the time it takes for Saturn to rotate or spin once). Saturn makes a complete orbit around the Sun (a year in Saturnian time) in 29 Earth years.
4. Saturn is a gas giant planet and does not have a solid surface
5. Saturn's atmosphere is made up mostly of hydrogen (H_2) and helium (He).
6. Saturn has 53 known moons with an additional 9 moons awaiting confirmation of their discovery.
7. Saturn has the most spectacular ring system of all our solar system's planets. It is made up of seven rings with several gaps and divisions between them.
8. Five missions have been sent to Saturn. Since 2004, Cassini has been exploring Saturn, its moons, and rings.
9. Saturn cannot support life as we know it. However, some of Saturn's moons have conditions that might support life.
10. When Galileo Galilei looked at Saturn through a telescope in the 1600s, he noticed strange objects on each side of the planet and drew in his notes a triple-bodied planet system and then later a planet with arms or handles. The *handles* turned out to be the rings of Saturn.

17. Jovian Planet Uranus



Uranus' moon Ariel (white dot) and its shadow (black dot) were caught crossing the face of Uranus in this Hubble Space Telescope image.

http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=10191

Uranus is the only giant planet whose equator is nearly at right angles to its orbit. A collision with an Earth-sized object may explain the unique tilt. Nearly a twin in size to Neptune, Uranus has more methane in its mainly hydrogen and helium atmosphere than Jupiter or Saturn. Methane gives Uranus its blue tint.

10 Need-to-Know Things About Uranus:

1. If the sun were as tall as a typical front door, Earth would be the size of a nickel and Uranus would be about as big as a baseball. Uranus orbits our Sun, a star.

2. Uranus is the seventh planet from the sun at a distance of about 2.9 billion km (1.8 billion miles) or 19.19 AU.

3. One day on Uranus takes about 17 hours (the time it takes for Uranus to rotate or spin once). Uranus makes a complete orbit around the Sun (a year in Uranian time) in about 84 Earth years.

4. Uranus is an ice giant. Most (80 percent or more) of the planet's mass is made up of a hot dense fluid of "icy" materials – water (H_2O), methane (CH_4). And ammonia (NH_3) – above a small rocky core.

5. Uranus has an atmosphere which is mostly made up of hydrogen (H_2) and helium (He), with a small amount of methane (CH_4).

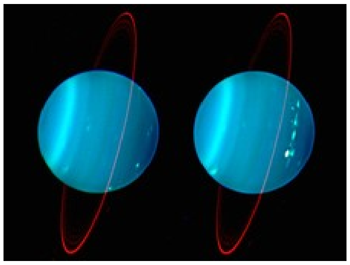
6. Uranus has 27 moons. Uranus' moons are named after characters from the works of William Shakespeare and Alexander Pope.

7. Uranus has faint rings. The inner rings are narrow and dark and the outer rings are brightly colored

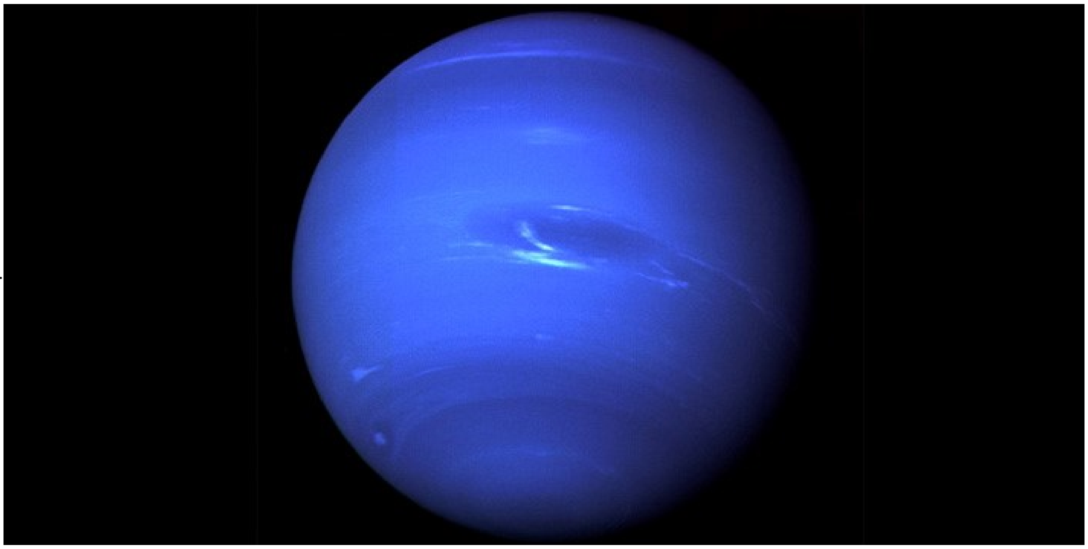
8. Voyager 2 is the only spacecraft to have visited Uranus.

9. Uranus cannot support life as we know it.

10. Like Venus, Uranus has a retrograde rotation (east to west). Unlike any of the other planets, Uranus rotates on its side, which means it spins horizontally.



18. Jovian Planet Neptune



Voyager 2 captured this image of Neptune in 1989.

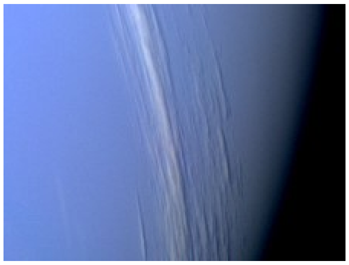
http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=2424

Dark, cold and whipped by supersonic winds, Neptune is the last of the hydrogen and helium gas giants in our solar system. More than 30 times as far from the Sun as Earth, the planet takes almost 165 Earth years to orbit our Sun. In 2011, Neptune completed its first orbit since its discovery in 1846.

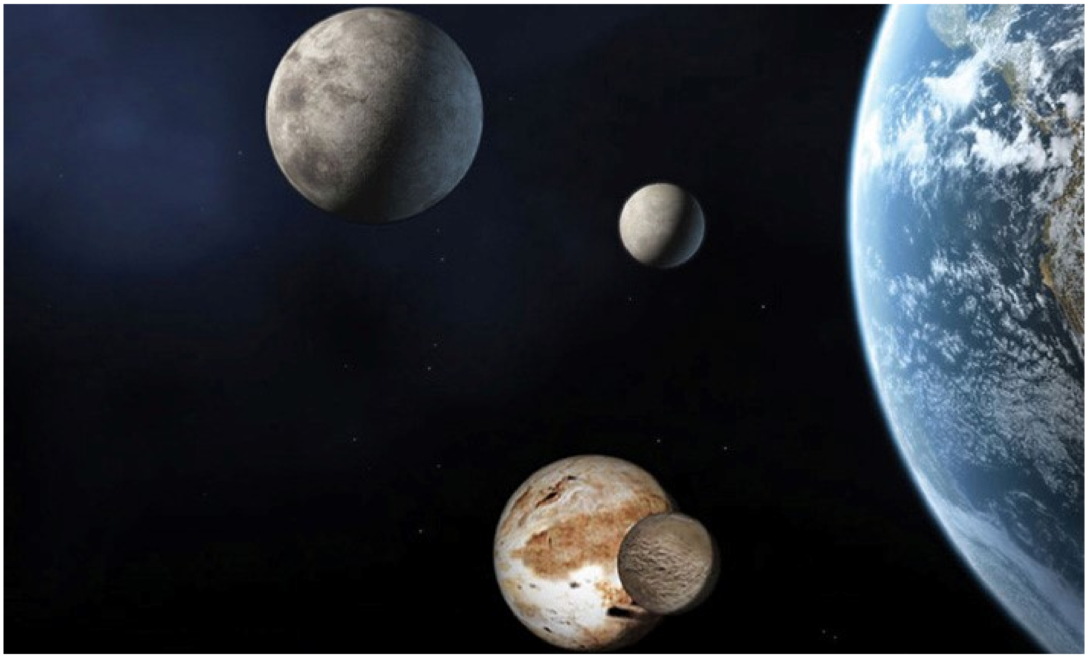
10 Need-to-Know Things About Neptune:

1. If the Sun were as tall as a typical front door, the Earth would be the size of a nickel and Neptune would be about as big as a baseball.
2. Neptune orbits our Sun, a star. Neptune is the eighth planet from the sun at a distance of about 4.5 billion km (2.8 billion miles) or 30.07 AU.
3. One day on Neptune takes about 16 hours (the time it takes for Neptune to rotate or spin once). Neptune makes a complete orbit around the Sun (a year in Neptunian time) in about 165 Earth years (60,190 Earth days).
4. Neptune is a sister ice giant to Uranus. Neptune is mostly made of a very thick, very hot combination of water (H_2O), ammonia (NH_3), and methane (CH_4) over a possible heavier, approximately Earth-sized, solid core.
5. Neptune's atmosphere is made up mostly of hydrogen (H_2), helium (He) and methane (CH_4).
6. Neptune has 13 confirmed moons (and one more awaiting official confirmation of discovery). Neptune's moons are named after various sea gods and nymphs in Greek mythology.
7. Neptune has six rings.
8. Voyager 2 is the only spacecraft to have visited Neptune.
9. Neptune cannot support life as we know it.
10. At times during the course of Neptune's orbit, dwarf planet Pluto is actually closer to the Sun, and us, than Neptune. This is due to the unusual elliptical (egg) shape of Pluto's orbit.

Vertical Relief in Neptune's bright cloud streaks



19. Other Objects in our Solar System- Dwarf Planets



An artist's concept showing the size of the best known dwarf planets compared to Earth and its moon (top). Eris is left center; Ceres is the small body to its right and Pluto and its moon Charon are at the bottom.

Dwarf planets are round and orbit the Sun just like the eight major planets. But unlike planets, dwarf planets are not able to clear their orbital path so there are similar objects at roughly the same distance from the Sun. A dwarf planet is much smaller than a planet (smaller even than Earth's moon), but it is not a moon. Pluto is the best known of the dwarf planets.

10 Need-to-Know Things About Dwarf Planets:

1. If the Sun were as tall as a typical front door, Earth would be the size of a nickel and dwarf planets Pluto and Eris, for example, would each be about the size of the head of a pin.
2. Dwarf planets orbit our Sun, a star. Most are located in the Kuiper Belt, a region of icy objects beyond the orbit of Neptune. Pluto, one of the largest and most famous dwarf planets, is about 5.9 billion km (3.7 billion miles) or 39.48 AU away from the Sun. Dwarf planet Ceres is in the main asteroid belt between Mars and Jupiter.
3. Days and years vary on dwarf planets. One day on Ceres, for example, takes about nine hours (the time it takes for Ceres to rotate or spin once). Ceres makes a complete orbit around the sun (a year in Ceresian time) in about 4.60 Earth years.
4. Dwarf planets are solid rocky and/or icy bodies. The amount of rock vs. ice depends on their location in the solar system.
5. Many, but not all, dwarf planets have moons.
6. There are no known rings around dwarf planets.
7. Dwarf planets Pluto and Eris, for example, have tenuous (thin) atmospheres that expand when they come closer to the Sun and collapse as they move farther away.
8. The first mission to a dwarf planet is Dawn (to Ceres).
9. Dwarf planets cannot support life as we know it.
10. Pluto was considered a planet until 2006. The discovery of similar-sized worlds deeper in the distant Kuiper Belt sparked a debate that resulted in a new official definition of a planet that did not include Pluto.

20. Other Objects in our Solar System- Comets

This image of Comet C/2001 Q4 (NEAT) was taken at Kitt Peak National Observatory near Tucson, Ariz. in 2004

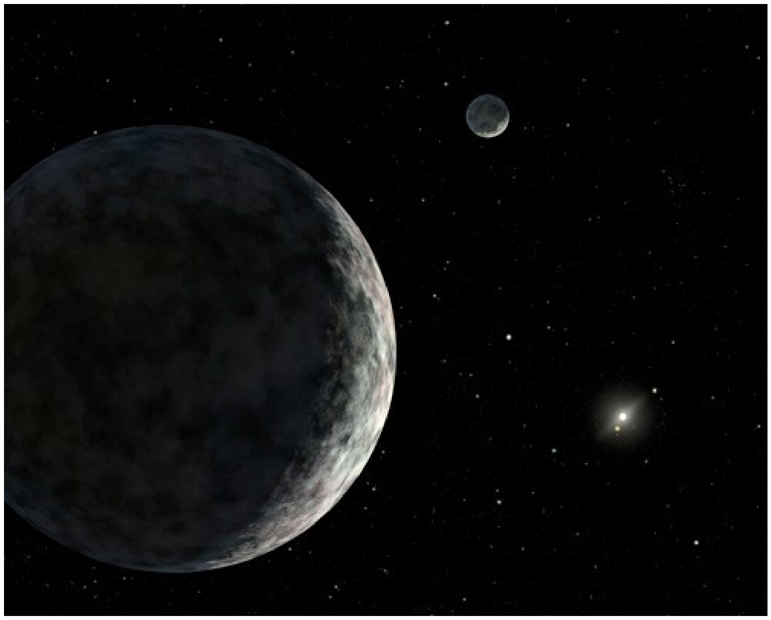
http://solarsystem.nasa.gov/multimedia/display.cfm?IM_ID=2323

Comets are cosmic snowballs of frozen gases, rock, and dust roughly the size of a small town. When a comet's orbit brings it close to the sun, it heats up and spews dust and gases into a giant glowing head larger than most planets. The dust and gases form a tail that stretches away from the sun for millions of kilometers.

10 Need-to-Know Things About Comets:

1. If the Sun were as tall as a typical front door, Earth would be the size of a nickel, dwarf planet Pluto would be the size of a head of a pin and the largest Kuiper Belt comet (about 100 km across, which is about one-twentieth the size of Pluto) would only be about the size of a grain of dust.
2. Short-period comets (comets that orbit the sun in less than 200 years) reside in the icy region known as the Kuiper Belt beyond the orbit of Neptune from about 30 to 55 AU. Long-period comets (comets with long, unpredictable orbits) originatein the far-off reaches of the Oort Cloud, which is five thousand to 100 thousand AUs from the Sun.
3. Days on comets vary. One day on comet Halley varies between 2.2 to 7.4 Earth days (the time it takes for comet Halley to rotate or spin once). Comet Halley makes a complete orbit around the Sun (a year in this comet's time) in 76 Earth years.
4. Comets are cosmic snowballs of frozen gases, rock, and dust.
5. A comet warms up as it nears the Sun and develops an atmosphere or coma. The coma may be hundreds of thousands of kilometers in diameter.
6. Comets do not have moons.
7. Comets do not have rings.
8. More than 20 missions have explored comets from a variety of viewpoints.
9. Comets may not be able to support life themselves, but they may have brought water and organic compounds -- the building blocks of life -- through collisions with Earth and other bodies in our solar system.
10. Comet Halley makes an appearance in the Bayeux Tapestry from the year 1066, which chronicles the overthrow of King Harold by William the Conqueror at the Battle of Hastings.

21. Other Objects in our Solar System- Kuiper Belt and Oort Cloud



Artist's concept of Eris and its moon. The Sun is in the distance. Image credit: Robert Hurt (IPAC)

http://solarsystem.nasa.gov/images/lilalarge_Sedna_500x400.jpg

The Kuiper Belt is a disc-shaped region of icy objects beyond the orbit of Neptune -- billions of kilometers from our Sun. Pluto and Eris are the best known of these icy worlds. There may be hundreds more of these ice dwarfs out there. The Kuiper Belt and even more distant Oort Cloud are believed to be the home of comets that orbit our Sun.

10 Need-To-Know Things About the Regions Beyond Neptune

1. The Kuiper Belt and the Oort Cloud are regions of space. The known icy worlds and comets in both regions are much smaller than Earth's moon.
2. The Kuiper Belt and the Oort Cloud surround our Sun, a star. The Kuiper Belt is a doughnut-shaped ring, extending just beyond the orbit of Neptune from about 30 to 55 AU. The Oort Cloud is a spherical shell, occupying space at a distance between five and 100 thousand AU.
3. Long-period comets (which take more than 200 years to orbit the Sun) come from the Oort Cloud. Short-period comets (which take less than 200 years to orbit the Sun) originate in the Kuiper Belt.
4. There may be hundreds of thousands of icy bodies larger than 100 km (62 miles) and an estimated trillion or more comets within the Kuiper Belt. The Oort Cloud may contain more than a trillion icy bodies.
5. Some dwarf planets within the Kuiper Belt have thin atmospheres that collapse when their orbit carries them farthest from the Sun.
6. Several dwarf planets in the Kuiper Belt have tiny moons.
7. The are no known rings around worlds in either region of space.
8. The first mission to the Kuiper Belt is New Horizons. New Horizons will reach Pluto in 2015.
9. Neither region of space is capable of supporting life as we know it.
10. Both the Kuiper Belt and the Oort Cloud are named for the astronomers who predicted their existence during the 1950s: Gerard Kuiper and Jan Oort.

22. Beyond Our Solar System

Our Sun is one of at least 100 billion stars in the Milky Way, a spiral galaxy about 100,000 light years across. The stars are arranged in a pinwheel pattern with four major arms, and we live about two-thirds of the way up one of them. Many, if not most, of the stars, host their own families of planets. More than a thousand of these extrasolar (or exoplanets) have been discovered and thousands more are awaiting confirmation.

All of the stars in the Milky Way orbit a supermassive black hole at the galaxy's center, which is estimated to be approximately four million times as massive as our Sun. Fortunately, it is a safe distance of around 28,000 light years away Earth. The Milky Way zips along a galactic orbit at an average speed of about 514,000 miles per hour (828,000 km/hr.). It takes about 230 million years for our solar system to make one revolution around the galactic center.

Beyond Our Galaxy

The Milky Way is part of the Local Group, a neighborhood about 10 million light years across, consisting of more than 30 galaxies that are gravitationally bound to each other. Aside from our galaxy, the most massive one in this group is Andromeda, which appears to be on course to collide with the Milky Way in about four billion years.

Scientists studying galaxies observed that the stars in the outer parts are orbiting the galactic centers just as quickly as the stars further in, a violation of Newton's well-established laws of gravitation. They deduced that something other than the stars and clouds of gas and dust is known to comprise galaxies was providing extra gravity – lots of it. They calculated that there must be five times as much of this mysterious *dark matter,* detectable only by its gravitational pull, as there is of the matter we already knew about.

The Local Group is only one of many, many clusters of galaxies, and they are all moving away from each other as more and more space comes into being between them. This means the universe itself is expanding. That discovery is what led to the theory of the *Big Bang* origin of the universe.

Scientists expected that the gravitational attraction of everything in the universe would put the brakes on the rate of expansion, and eventually the expansion would stop or even reverse. But in the 1990s, scientists discovered that the expansion is actually getting faster. The force responsible for this surprising acceleration was dubbed *dark energy*. No one is sure what it is, but one possibility is that it is energy contained within the very vacuum of space.

Since matter and energy are equivalent (as expressed in Einstein's famous equation, $E=MC^2$) scientists have been able to calculate that whatever dark energy is, it comprises about 68 percent of everything in the universe. Dark matter accounts for another 27 percent, leaving only five percent for protons, neutrons, electrons, and photons – in other words, everything we see and understand.

Scientists calculate that there are at least 100 billion galaxies in the observable universe, each one brimming with stars. On a very large scale, they form a bubbly structure, in which vast sheets and filaments of galaxies surround gargantuan voids.

23. NASA Missions and Additional Videos

How does NASA Map the Solar System?

<u>Additional Resources: Tutorial Videos</u>

PBS Phil Plait's Crash Course Astronomy

Introduction to Astronomy- "Welcome to the first episode of Crash Course Astronomy. Your host for this intergalactic adventure is the Bad Astronomer himself, Phil Plait."

Naked Eye Observations- "Today on Crash Course Astronomy, Phil invites you to head outside and take a look at all the incredible things you can see with your naked eye."

Cycles in the Sky- "This week, we build on our naked eye observations from last week and take a look at the cyclical phenomena that we can see at work in the universe."

Moon Phases- "In this episode of Crash Course Astronomy, Phil takes you through the cause and name of the Moon's phases."

Eclipses- "The big question in the comments last week was, "BUT WHAT ABOUT ECLIPSES?" Today, Phil breaks 'em down for you."

Telescopes- "Today Phil explains how telescopes work and offers some astronomical shopping advice."

The Gravity of the Situation- "In today's episode, Phil looks at how gravity plays out across the universe."

Tides- "What is the relationship between tides and gravity? How do planets and their moons become tidally locked? What would happen if you were 300km tall? These are important questions."

Introduction to the Solar System- "In today's Crash Course Astronomy, Phil takes a look at the explosive history of our cosmic backyard. We explore how we went from a giant ball of gas to the system of planets and other celestial objects we have today."

The Sun- "Phil takes us for a closer (eye safe!) look at the two-octillion ton star that rules our solar system. We look at the Sun's core, plasma, magnetic fields, sunspots, solar flares, coronal mass ejections, and what all of that means for our planet."

The Earth- "Phil starts the planet-by-planet tour of the solar system right here at home, Earth."

The Moon- "Join Phil for a tour of our capital-M Moon, from surface features, inside to the core, and back in time to theories about its formation."

Mercury- "Mercury is the closest planet to the sun. It has no atmosphere and is, as such, covered in craters. It's also incredibly hot but, surprisingly, has water ice hiding beneath its surface."

Venus- "Venus is a gorgeous naked-eye planet, hanging like a diamond in the twilight -- but its beauty is best looked at from afar. Even though Mercury is closer to the Sun, Venus is the hottest planet in the solar system, due to a runaway greenhouse effect, and has the most volcanic activity in the solar system. Its north and south poles were flipped, causing it to rotate backward and making for very strange days on this beautiful but inhospitable world."

Mars- "The fourth planet from the Sun and the outermost of the terrestrial planets, Mars has long been a popular spot for missions and imagination. Phil walks you through the planet's topography, core, and features. We'll take a look back to Mars' past and makes predictions for its future, including the possibilities for human life."

Jupiter- "Jupiter is the biggest planet in our solar system. The gas giant is NOT a failed star, but a really successful planet! It has a dynamic atmosphere with belts and zones, as well as an enormous red spot that's actually a persistent hurricane. Jupiter is still warm from its formation, and has an interior that's mostly metallic hydrogen, and it may not even have a core."

Jupiter's Moons- "Before moving on from Jupiter to Saturn, we're going to linger for a moment on Jupiter's moons. There are 67 known moons and four huge ones that we want to explore in greater detail. Ganymede is the largest larger, in fact than any other moon in the solar system and the planet Mercury! Callisto, orbiting the farthest out, is smaller but quite similar to Ganymede in many ways. Io, meanwhile, is most noteworthy for its tremendous volcanic activity. There's also water on Ganymede and Europa!"

Saturn- "Saturn is the crown jewel of the solar system, beautiful and fascinating. It is a gas giant and has a broad set of rings made of ice particles. Moons create gaps in the rings via their gravity. Saturn has dozens of moons, including Titan, which is as big as Mercury and has a thick atmosphere and lakes of methane; and Enceladus which has an undersurface ocean and eruptions of water geysers. While we are still uncertain, it is entirely possible that either or both moons may support life."

Uranus and Neptune- "We're rounding out our planetary tour with ice giants Uranus and Neptune. Both have small rocky cores, thick mantles of ammonia, water, and methane, and atmospheres that make them look greenish and blue. Uranus has a truly weird rotation and relatively dull weather, while Neptune has clouds and storms whipped by tremendous winds. Both have rings and moons, with Neptune's Triton probably being a captured iceball that has active geology."

Asteroids- "Now that we've finished our tour of the planets, we're headed back to the asteroid belt. Asteroids are chunks of rock, metal, or both that were once part of smallish planets but were destroyed after collisions. Most orbit the Sun between Mars and Jupiter, but some get near the Earth. The biggest, Ceres is far smaller than the Moon but still big enough to be round and have undergone differentiation."

"CORRECTION: In the episode, we say that 2010 TK7 is 800 km away. However, 2010 TK7 stays on average 150 million kilometers from Earth, but that can vary wildly. Sorry about that!"

Comets- "Today on Crash Course Astronomy, Phil explains comets. Comets are chunks of ice and rock that orbit the Sun. When they get near the Sun the ice turns into gas, forming the long tail, and also releases dust that forms a different tail. We've visited comets up close and found them to be lumpy, with vents in the surface that release the gas as ice sublimates. Eons ago, comets (and asteroids) may have brought a lot of water to Earth -- as well as the ingredients for life."

The Oort Cloud- "Now that we're done with the planets, asteroid belt, and comets, we're heading to the outskirts of the solar system. Out past Neptune are vast reservoirs of icy bodies that can become comets if they get poked into the inner solar system. The Kuiper Belt is a donut shape aligned with the plane of the solar system; the scattered disk is more eccentric and is the source of short-period comets, and the Oort Cloud which surrounds the solar system out to great distances is the source of long-period comets. These bodies all probably formed closer into the Sun and got flung out to the solar system's suburbs by gravitational interactions with the outer planets."

Meteors- "Today Phil helps keep you from ticking off an astronomer in your life by making sure you know the difference between a meteor, meteorite, and meteoroid. When the Earth plows through the stream emitted by a comet we get a meteor shower. Meteors burn up about 100 km above the Earth, but some survive to hit the ground. Most of these meteorites are rocky, some are metallic, and a few are a mix of the two. Very big meteorites can be a very big problem, but there are plans in the works to prevent us from going the way of the dinosaurs."

Light- "In order to understand how we study the universe, we need to talk a little bit about light. Light is a form of energy. Its wavelength tells us its energy and color. Spectroscopy allows us to analyze those colors and determine an object's temperature, density, spin, motion, and chemical composition."

Distances- "How do astronomers make sense out of the vastness of space? How do they study things so far away? Today Phil talks about distances, going back to early astronomy. Ancient Greeks were able to find the size of the Earth and from that the distance to and the sizes of the Moon and Sun. Once the Earth/Sun distance was found, parallax was used to find the distance to nearby stars, and that was bootstrapped using brightness to determine the distances to much farther stars."

Stars- "Today Phil's explaining the stars and how they can be categorized using their spectra. Together with their distance, this provides a wealth of information about them including their luminosity, size, and temperature. The HR diagram plots stars' luminosity versus temperature and most stars fall along the main sequence, where they live most of their lives."

Exoplanets- "Today Phil explains that YES, there are other planets out there and astronomers have a lot of methods for detecting them. Nearly 2000 have been found so far. The most successful method is using transits, where a planet physically passes in front of its parent star, producing a measurable dip in the star's light. Another is to measure the Doppler shift in a star's light due to reflexive motion as the planet orbits."

Brown Dwarfs- "While Jupiter is nowhere near massive enough to initiate fusion in its core, there are even more massive objects out there that fall just short of that achievement as well called brown dwarfs. Brown dwarfs have a mass that places them between giant planets and small stars. They were only recently discovered in the 1990's, but thousands are now known. More massive ones can fuse deuterium, and even lithium, but not hydrogen, distinguishing them from "normal" stars. Sort of."

Correction: In the illustration at 9:30 in the video below, the numbers listed after the star names are the year of discovery, not distance.

Low Mass Stars- "Today we are talking about the life -- and death -- of stars. Low mass stars live a long time, fusing all their hydrogen into helium over a trillion years. More massive stars like the Sun live shorter lives. They fuse hydrogen into helium, and eventually helium into carbon (and also some oxygen and neon). When this happens they expand, get brighter, and cool off, becoming red giants. They lose most of their mass, exposing their cores, and then cool off over many billions of years."

White Dwarfs and Planetary Nebulae- "Explanation fo White Dwarfs and describes planetary nebulae."

Gamma Rays- 'Gamma-ray bursts are not only incredible to study, but their discovery has an epic story all its own. Today Phil takes you through some Cold War history and then dives into what we know. Bursts come in two rough varieties: Long and short. Long ones are from hypernovae, massive stars exploding, sending out twin beams of matter and energy. Short ones are from merging neutron stars. Both kinds are so energetic they are visible for billions of light years, and both are also the birth announcements of black holes."

These videos are constantly being updated. Please check Phil Plait's site.

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