LESSON 3

The Solar System

Quick Write

Recall the criteria for effective scientific models–simplicity and predictive power –discussed in Chapter 1, Lesson 2. After reading the opening passage about the Planet X theory, jot down your thoughts on whether or not Planet X meets the criteria for a good scientific model.

Learn About

- terrestrial planets
- the outer planets and dwarf planets
- comets, asteroids, and kuiper belt objects

What lies beyond Pluto? According to Caltech scientists, there could be a planet! They believe "Planet X" to be about the size of Neptune, with a mass 10 times greater than that of Earth and an orbit 20 times farther from the Sun (on average) than Neptune. This means it could take between 10,000 and 20,000 years to make an unusual elliptical orbit around the Sun.

The existence of Planet X is only theoretical, and scientists do not have direct evidence yet. So why do scientists believe this planet possibly exists? Researchers studying the Kuiper Belt, *a ring of icy bodies outside of Neptune's orbit*, have observed that some of the dwarf planets and other small, icy objects tend to follow orbits that group together. One possible explanation for this behavior is a planet with controlling gravity. In 2015, Caltech astronomers Konstantin Batygin and Mike Brown announced their prediction–a planet with controlling gravity may be responsible for the unique orbits of smaller objects in the Kuiper Belt.

Researchers have not yet collected observable evidence. They continue to use mathematical modeling and computer simulations. Such tools help them further understand Planet X's orbit and the impact on its surroundings.

Batygin and Brown nicknamed the object "Planet Nine," but it has long been referred to as Planet X during scientific hunts for objects beyond Neptune. If Planet X is ever found, naming rights will be given to those who discover the planet.

Identifying the planet's location with powerful telescopes is the next logical step.

A distant view of Planet X looking back toward the Sun.
Courtesy of NASA/Caltech/R. Hurt (IPAC)

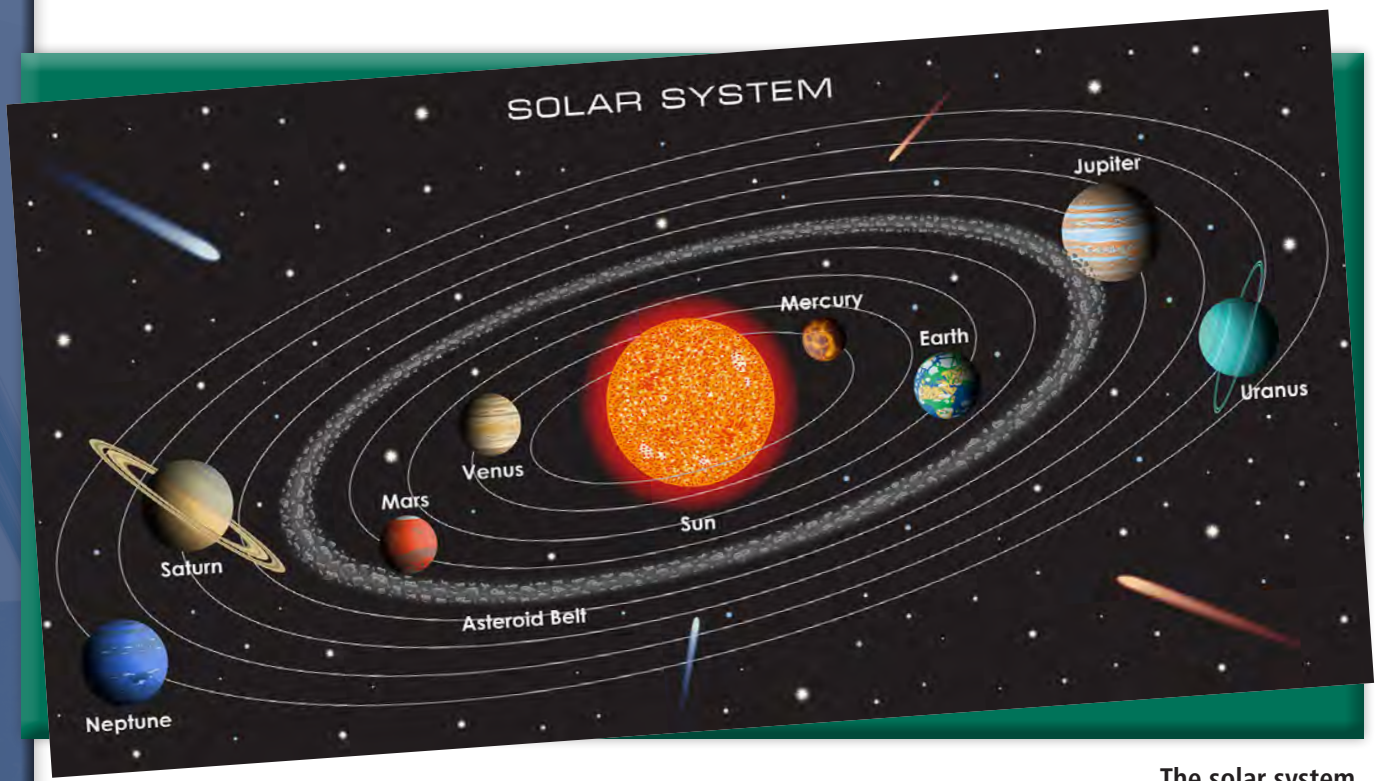
Vocabulary

- Kuiper Belt
- greenhouse effect
- red planet
- opposition
- chasms
- differential rotation
- oblate
- Galilean satellites
- Cassini Division
- sublimate
- asteroid belt
- trojan asteroids
- nucleus
- coma
- short-period comets
- long-period comets
- Oort Cloud
- meteoroid
- meteor
- meteorite

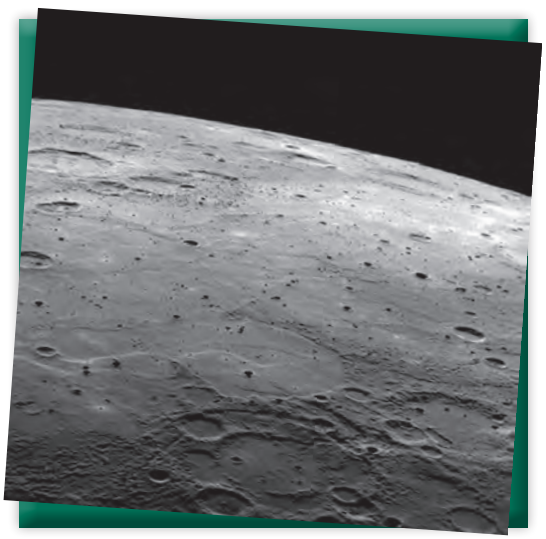
Terrestrial Planets

Recall the definition of terrestrial planets covered in a previous lesson. Terrestrial planets are small and dense, with rocky surfaces and a great deal of metals in their core. Terrestrial planets include Mercury, Venus, Earth, and Mars. They are closer to the Sun, they have few (if any) moons, and they have no rings.

We discussed Earth in a previous lesson. Our focus here will be Mercury, Venus, and Mars. Let's start with Mercury, since it is closest to the Sun.



The solar system.
D1min/Shutterstock



A picture of Mercury taken by the space probe, Messenger, in 2008. The crater walls are not as steep as those on the Moon, the craters are not as deep, and the ejected material landed closer to the impact site because of Mercury's greater surface gravity.
NASA, JHU APL, CIW

Mercury

Mercury is a little more than one-third the size of Earth. If Earth were scaled down to the size of a tennis ball, Mercury would be about the size of a large marble. Using that same scale, Mercury would be about 304 miles away from the Sun.

From Earth, Mercury usually appears as a yellowish bright star. At night, we can see it in the western sky, setting about an hour after the sun. In the morning, it appears in the eastern sky, rising about an hour before the Sun.

Even though Mercury is closest to the Sun, it is not the hottest planet in our solar system. But it is the fastest planet, orbiting around the Sun every 88 Earth days. In fact, Mercury gets its name from one of the fastest ancient Roman gods!

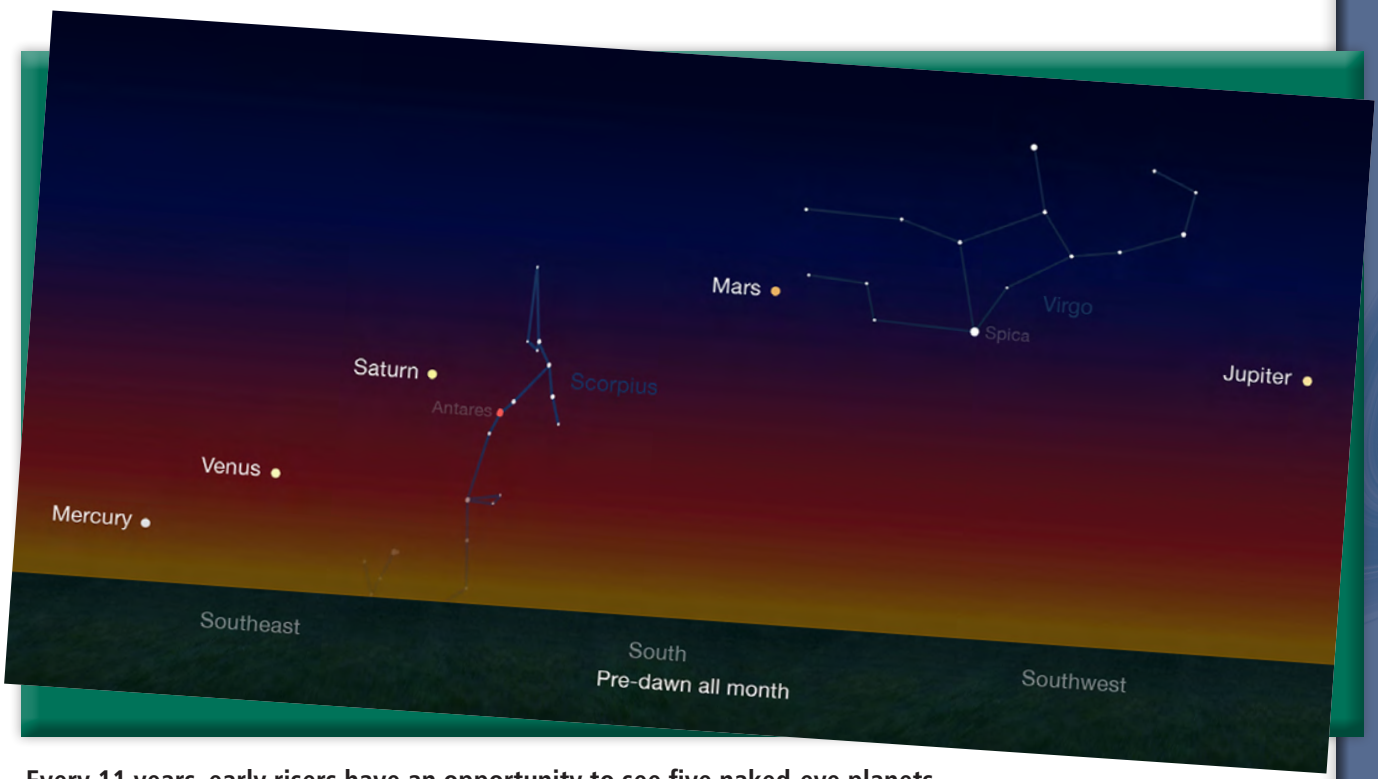
Mercury's surface is much like Earth's moon, marked by billions of years of asteroid impacts. Large asteroids crashed into the planet long ago.

They created very large impact craters, including the Caloris Basin. We can also find extinct volcanoes, huge plains, and vast cliffs on the surface of Mercury.

At 3,033 miles in diameter, Mercury is the smallest of the eight planets. Determined by gravitational pull, its mass is only 0.553 of Earth's mass, this means that if you weighed 150 pounds (lbs.) on Earth, you would only weigh 57 lbs. on Mercury. That's because Mercury's gravitational pull is only about .378 of Earth's. Like the Earth, iron and nickel form Mercury's core, making it high in density. Researchers believe a rocky mantle surrounds the core, topped by a solid crust scarred by asteroid impacts.

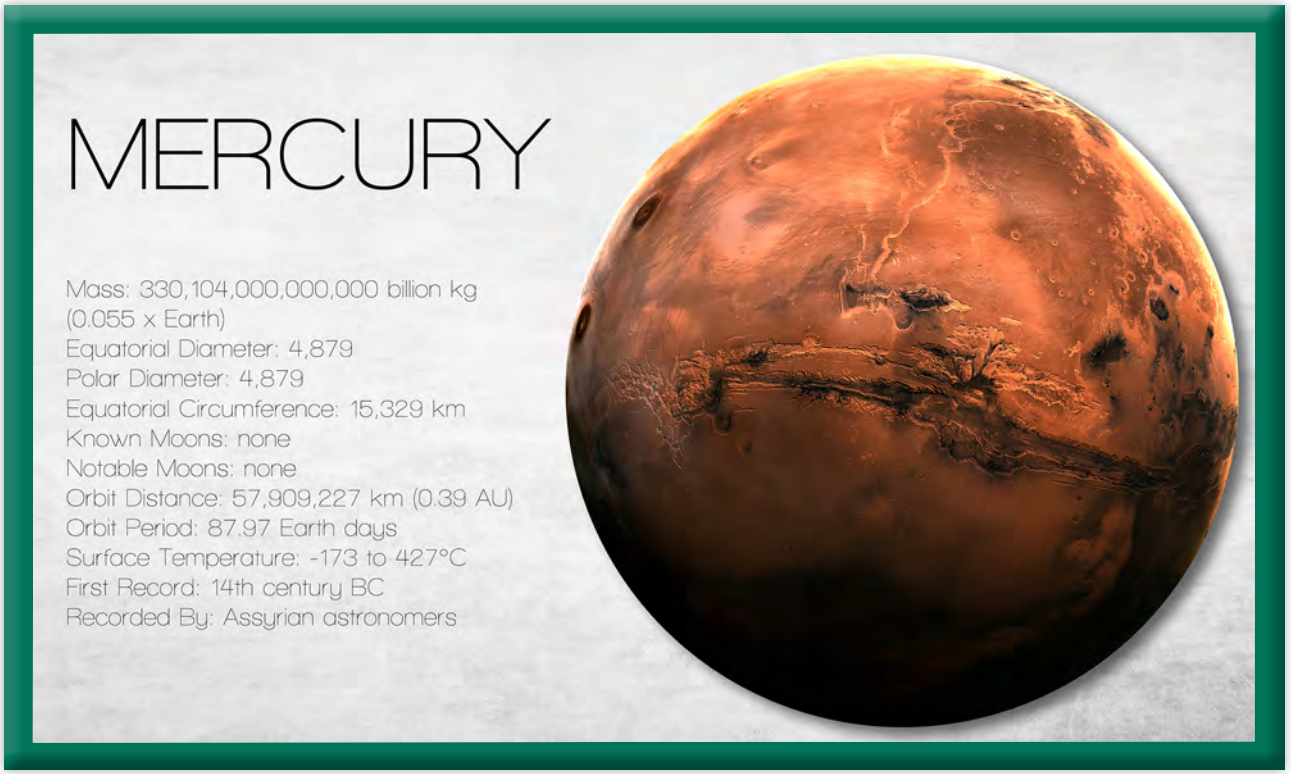
Two missions have visited Mercury. The first, Mariner 10, was in 1974-1975. The second, MESSENGER (MErcury Surface, Space ENvironment, GEochemistry and Ranging), flew past Mercury three times before going into orbit around Mercury in 2011. These missions gave us clear pictures of the planet's surface. They also detected a weak magnetic field on Mercury.

Mercury's egg-shaped orbit takes the planet as close as 29 million miles and as far as 43 million miles from the Sun. Remember that Mercury orbits the Sun every 88 Earth days. It also rotates every 59 Earth days, rotating three times in two orbits. That means there are 176 Earth days between one Mercury sunrise and the next!



Every 11 years, early risers have an opportunity to see five naked-eye planets in early morning skies during late January through February.

Courtesy of NASA/JPL-Caltech



Mercury – Facts and Figures

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Venus

Venus was named after the Roman goddess of love and beauty. The second planet from the Sun, Venus is like Earth in size and structure. Venus is one of the easiest planets to observe from Earth because it is so bright. Except for the Sun and the Moon, Venus is the brightest object in the sky. It appears either before sunrise or after sunset and is often referred to as the Morning Star and Evening Star.

Thick clouds cover the surface of Venus and hide a harsh environment of extreme temperatures and pressures. The landscape is deserted, dry, and formed by large lava flows and tens of thousands of volcanoes. Venus is also covered in craters that are more than 0.9 to 1.2 miles across.

The diameter of Venus is 95 percent of Earth's and its mass is 82 percent of Earth's. With so much volcanic rock on its surface, scientists believe Venus must have a dense metallic core. Venus may be similar in size to Earth and

Did You Know?

Early researchers believed Venus would be a tropical paradise. The clouds of sulfuric acid around Venus made it impossible to view the surface, but the location, orbit, and similarities to Earth made researchers believe its environment to be favorable. In the 1960s, scientists finally observed the extreme temperatures and hostile environments of Venus. Scientists do believe that Venus once had oceans, but that they eventually evaporated as the temperature on the planet increased.

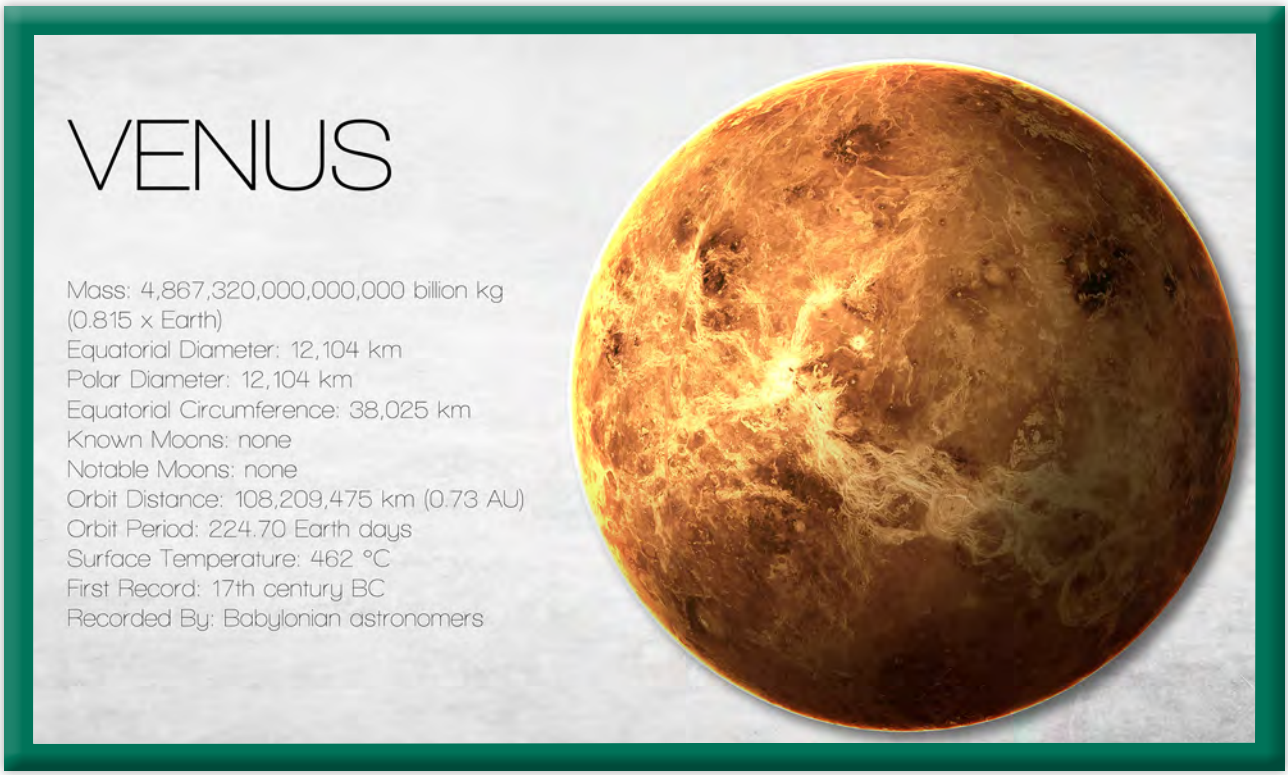
has a similarly-sized core, but its magnetic field is much weaker than Earth's. So is its gravitational pull. If you weighed 150 lbs. on Earth, you would weigh 136 lbs. on Venus. Although much closer to Earth, Venus' gravitational pull is not as strong as the planet Earth.

Why is Venus's magnetic field so weak? One reason is its very slow and backward rotation. This planet is unusual because it spins the opposite direction of Earth and most other planets. It takes about 243 Earth days to spin around just once. Because it is so close to the Sun, a year goes by in just 225 days. That means, a day on Venus is just slightly longer than a year on Venus. With the day and year lengths being similar, a day on Venus is not like a day on Earth. On Earth, the Sun rises and sets once a day. On Venus, the sun rises and sets every 117 Earth days.

Made up mostly of carbon dioxide—along with nitrogen and small amounts of water—Venus's atmosphere is also very different than Earth's. The atmosphere forms large dense clouds above Venus's polar regions. These clouds contain sulfuric acid and create a strong greenhouse effect. The greenhouse effect *is the exchange of incoming and outgoing radiation that warms a planet.*

Greenhouse effect is like a car parked outside on a cold and sunny day. The Sun warms up the inside of the car. The heat is trapped inside the car when the windows are rolled up and the car doors are closed. The greenhouse effect is a similar concept. The Sun provides the heat, but the atmosphere traps the heat inside and warms up the planet. As a result of the greenhouse effect, Venus's surface temperatures are higher than 880°F.

Through a telescope, Venus shows phases that change as it orbits the Sun.
Daniel Herron/Courtesy of NASA.gov.



Venus – Facts and Figures

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Mars

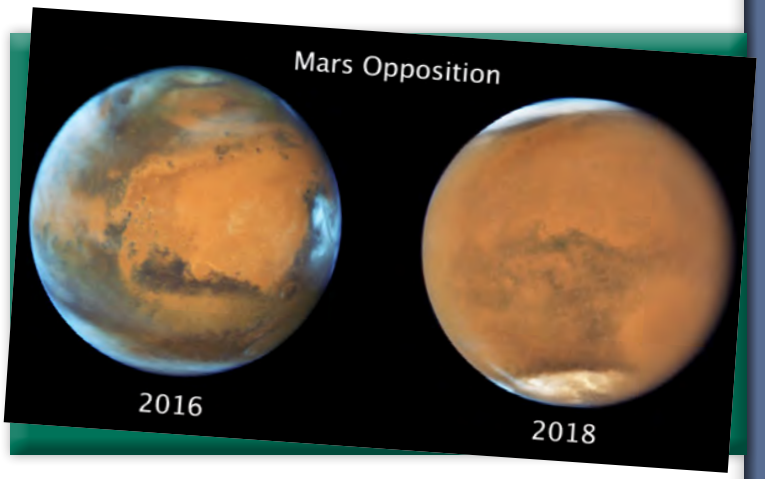
The last of the terrestrial planets, Mars is fourth from the Sun, and the second smallest planet. Named after the Roman god of war, Ares, Mars is also called the "red planet." This is *because of the rust in the iron-filled Martian soil*. Solar winds from the Sun often cause dust storms. These make Mars's appearance change and produce large areas of sand dunes. Mars is easiest to see from Earth when it is in opposition, meaning when it is *on the opposite side of the Earth from the Sun*. Its opposition occurs about every 2.2 years.

Earth is 93 million miles from the Sun. In comparison, the average distance from Mars to the Sun is about 142 million miles. Mars also travels in an elliptical orbit. Its distance from the Sun changes from about 130 to 155 million miles. Because it is farther from the Sun than Earth, one revolution for Mars takes 687 days.

The axis of rotation for Mars is tilted very much like Earth's. Earth's tilt is about 23.5 degrees, and Mars is tilted by 25.2 degrees. Like Earth, the north pole on Mars tilts away from the Sun during winter for the northern hemisphere. Because of its irregular orbit, its northern hemisphere is closer to the Sun during the winter. This causes less difference in summer and winter temperatures. Mars rotates in the same direction as Earth, from west to east, with Mars taking only about 40 minutes longer.

The diameter of Mars is about one-half the Earth's diameter. Picture the Sun's diameter as the height of a door. Earth would appear as the size of a dime, and Mars would be about the size of an aspirin.

Let's compare mass, density, and gravity on Mars and Earth. Mars's mass is only one-tenth that of Earth's. Its density is about 0.7 as great as Earth's, and its gravity is much lower, .375 of the gravity on Earth. What does this mean? A person weighing 150 pounds on Earth would only weigh about 56.5 lbs. on Mars. That person could jump higher on Mars. So, every basketball player could easily dunk the ball, even if the rim of the goal was set at 20 feet high!



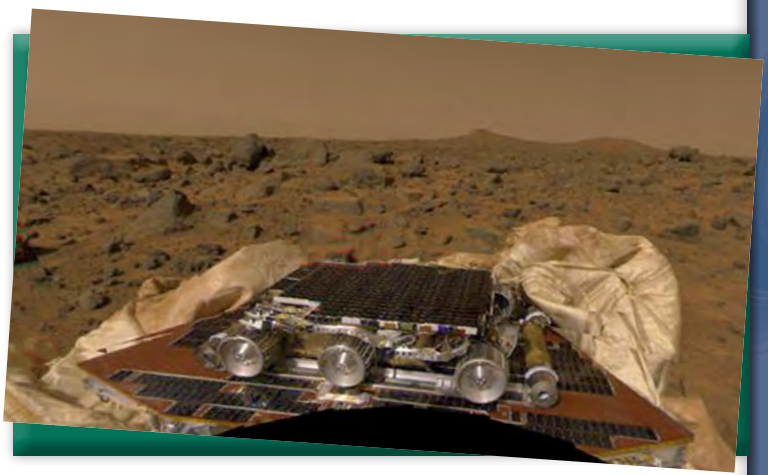
Comparison of Mars's appearance near its 2016 and 2018 oppositions. In 2016, the Martian atmosphere was clear. The 2018 image shows almost the same face of Mars. Surface features obscured by dust, the planet's cloud-hidden south pole is tilted more toward the Sun.

Courtesy of NASA, ESA, and STScI

Mars has some magnetic iron, as Earth does, but has no magnetic field because it does not have an iron core. Instead, its iron is evenly scattered throughout the planet. The lack of a magnetic field has caused the Sun's solar winds to blow away much of Mars's atmosphere and water vapor.

The atmosphere is about 100 times thinner than Earth's, with about 95 percent carbon dioxide and very little water vapor. Because of its cold temperatures, it does have small polar ice caps. Earth's overall average temperature is about 57^{0}F. For Mars, the average is about -81^{0}F. At its equator, the temperatures change from about 70 degrees Fahrenheit at noon to negative 225 degrees at night.

Even though Mars is smaller than Earth, it has the highest mountain of any planet in the solar system. Mt. Everest is about five miles high. Mars's volcanic mountain, Olympus Mons, is about 15 miles high with a base that is about 400 miles across. That is almost as far as the distance between Boston and Washington, DC!



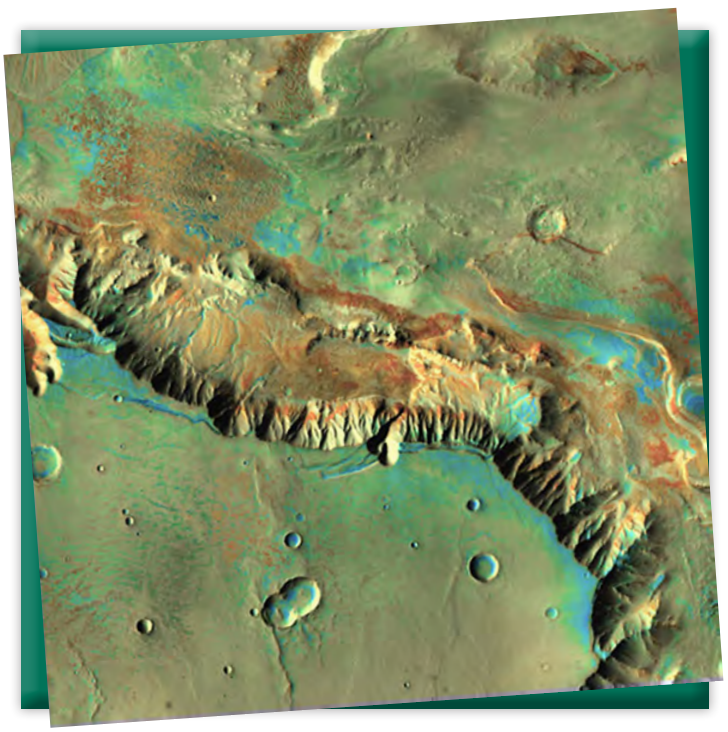
The Sojourner planetary rover that was sent to Mars in 1997 onboard the Pathfinder spacecraft examined soil samples and found some iron and the same quartz material that is in our sand..

Courtesy of NASA.gov.

Did You Know?

Mars Pathfinder was launched on December 4, 1996 and landed on Mars on July 4, 1997. It was designed as a technology demonstration of a new way to deliver an instrumented lander and the first-ever robotic rover to the surface of the red planet. Pathfinder not only accomplished this goal but also returned an unprecedented amount of data and outlived its primary design life.

Both the lander and the 23-pound (10.6 kilogram) rover carried instruments for scientific observations and to provide engineering data on the new technologies being demonstrated. Included were scientific instruments to analyze the Martian atmosphere, climate, geology, and the composition of its rocks and soil. Mars Pathfinder used an innovative method of directly entering the Martian atmosphere, assisted by a parachute to slow its descent through the thin Martian atmosphere and a giant system of airbags to cushion the impact.

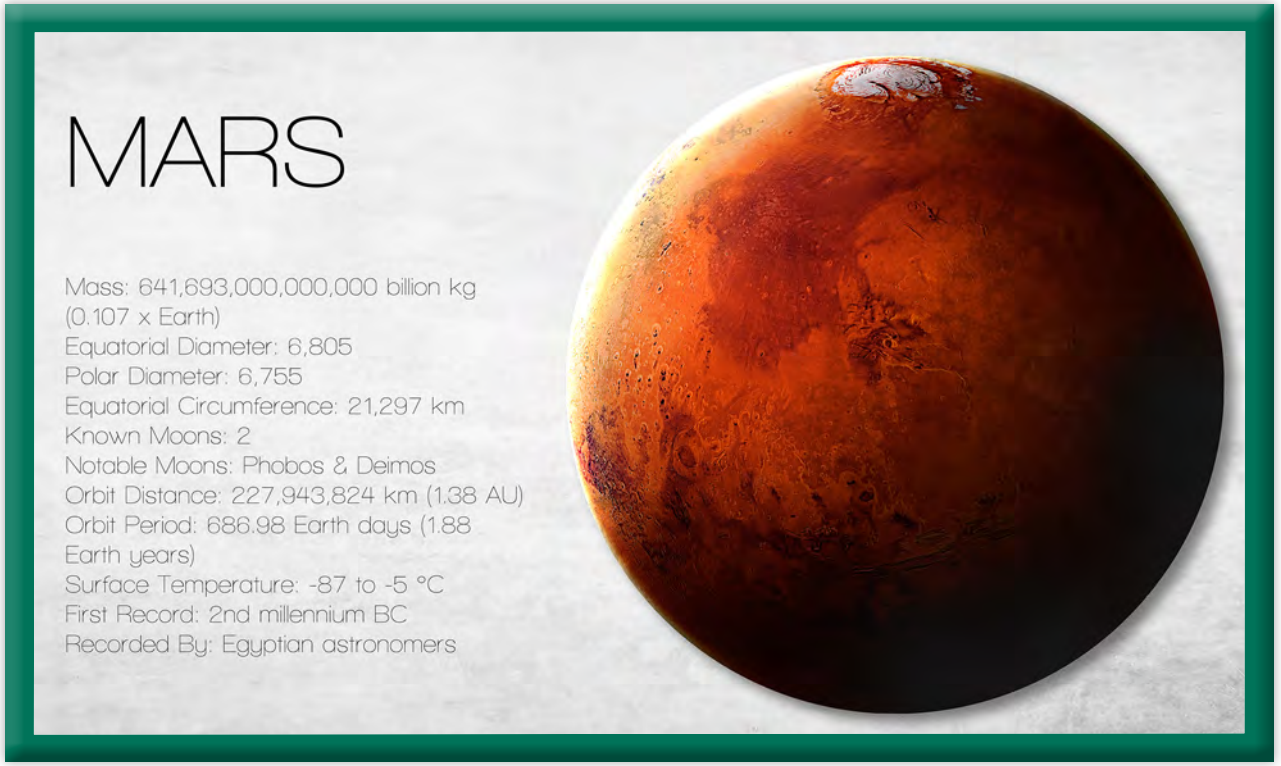


Valles Marineris is a chasm vastly larger than Earth's Grand Canyon that also has many layers of rock that serve as windows into the past.

Courtesy of NASA/JPL-Caltech/ASU

Mars also has a giant crater, Valles Marineris. This crater extends outward from the mountain for about 3,000 miles, more than 10 times longer than the Grand Canyon. Spacecraft sent to Mars have also discovered chasms or *channels that appear to have been made by water or glaciers* up to 3.5 billion years ago.

Mars has two moons, but they are very small and irregular in shape, much like an ordinary rock. The larger one is Phobos, named after the Greek word for fear, and is only about 17 miles across at its widest point. The smaller one is Deimos, named for the Greek word for terror. They both travel around Mars in the same direction that our Moon travels around Earth. We'll discuss more about the exploration of Mars in later chapters.



Mars – Facts and Figures
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TABLE 1.1 Terrestrial Planets

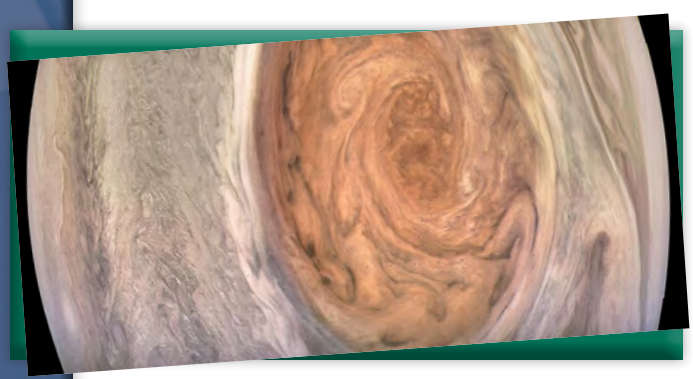
	Mercury	Venus	Earth	Mars
Distance from the Sun	36 million miles	67 million miles	93 million miles	142 million miles
Orbit Length	88 Earth days	225 Earth days	365 days	687 Earth days
Length of Day	59 Earth days	243 Earth days	1 Earth day	24.6 Earth days
Diameter	3,033 miles	7,521 miles	7,917 miles	4,221 miles
Surface Temperature	-292°F to 806°F	867°F	57°F	-225°F to 70°F
Atmospheric Composition	42% Oxygen 29% Sodium 22% Hydrogen 6% Helium 1% Trace Gases	96.4% Carbon Dioxide 3.4% Nitrogen .015% Sulfur Dioxide .007% Argon .002% Water Vapor	78% Nitrogen 21% Oxygen	95.3% Carbon Dioxide 2.7% Nitrogen 1.6 % Argon

The Outer Planets and Dwarf Planets

In Chapter 2, Lesson 2, we learned that the outer planets, or Jovian planets, are large and gaseous. These include Jupiter, Saturn, Uranus, and Neptune. With lower average density, they all have ring systems and many moons. Made mostly of hydrogen and helium, we often refer to them as the "gas giants."

Jupiter

Jupiter is the largest of the gas giants. Compared to Earth, Jupiter is 11 times wider. It is about five times farther from the Sun than Earth. Jupiter takes almost 12 Earth years to cycle around the Sun, and it spins on its axis about every 10 hours.



Jupiter's atmospheric bands are impacted by storms and winds of up to 388 miles per hour. The largest of the storms is the Great Red Spot. The storm itself is twice the size of Earth!

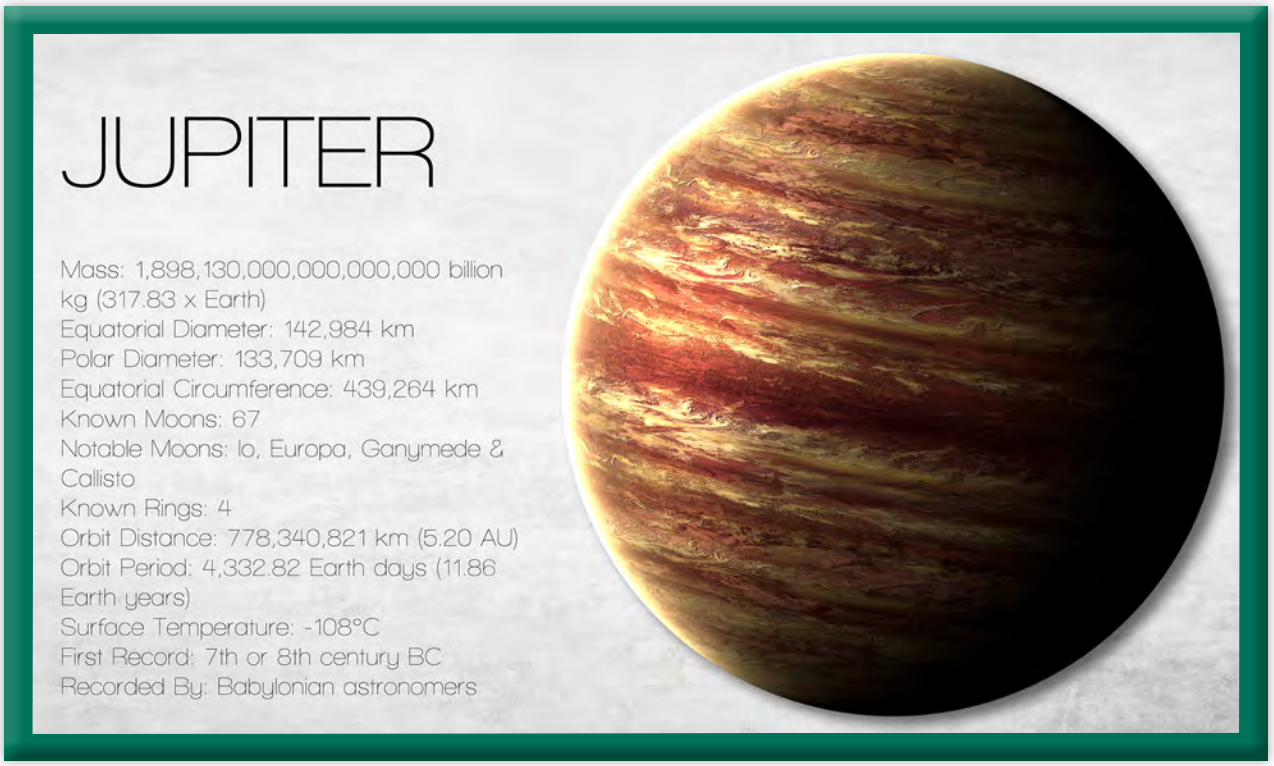
NASA/JPL-Caltech/SwRI/MSSS/Kevin Gill

Unique to Jupiter is its differential rotation. Differential rotation *is seen when a rotating object moves with different periods of rotation*. The giant planet has a system of bands that move at different speeds depending on their closeness to the equator. Jupiter is also oblate, or *somewhat flattened at its poles*. Jupiter's equator tilts three degrees from the vertical. This means it spins nearly upright and does not have seasons.

Made up mostly of hydrogen, Jupiter also contains helium and small amounts of methane, ammonia, and water vapor. Electric currents in an inner layer of metallic hydrogen create a strong magnetic field.

3D illustration of Jupiter's moons. Elements of this image furnished by NASA.

Victor Josan/Shutterstock



Jupiter – Facts and Figures
Vadim Sadovski/Shutterstock

Hydrogen is usually a gas, but with Jupiter's temperature and pressure, the hydrogen acts more like a metal and conducts electricity. At its center, Jupiter is extremely hot, up to 43,000°F. However, the temperature at the level of the planet's clouds is about -234°F.

Did You Know?

In 1979, NASA's Voyager I discovered Jupiter's faint, thin rings. Composed of small, dark particles, they are difficult to see except when backlit by the Sun. Data from the Galileo spacecraft in 1996 suggested that Jupiter's rings may have been created by dust from meteoroids crashing into the planet's inner moonlets.

Jupiter has 53 named moons, and scientists now believe Jupiter could have as many as 79 moons. The four largest moons are known as Galilean satellites, *because they were first observed by Galileo in 1610*. These moons, Io, Ganymede, Callisto, and Europa, are some of the most curious objects in our solar system. Volcanically active, Io has volcanic vents, lava flows, and lava plumes. Ganymede is the largest moon in the solar system, even bigger than the planet Mercury. Craters and ringed objects caused by asteroid impacts cover Callisto's surface. Europa just might be the most fascinating of Jupiter's moons. With a liquid water ocean beneath an icy crust, Europa may hold some of the elements needed to sustain life.

Saturn. Elements furnished by NASA
Vadim Sadovski /Shutterstock

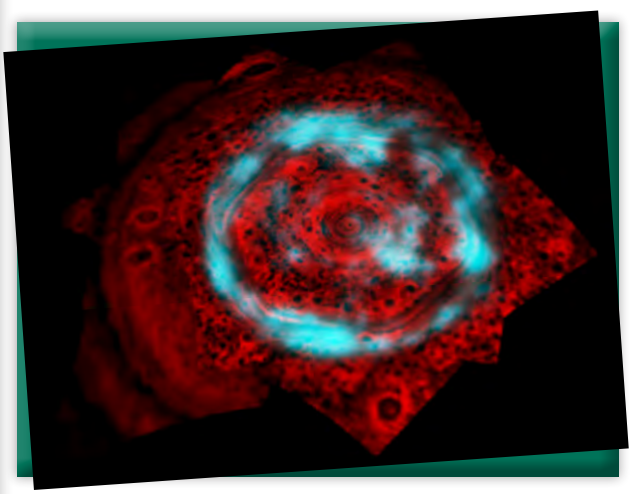
Saturn

Saturn is the second largest and the sixth planet from the Sun. It has a small solid center or core, likely made of iron, but its core is still about 10 to 20 times larger than Earth's. Even with its dense core, we classify Saturn as a "gas planet." It is mostly made of gases, mainly hydrogen (about 96 percent) and helium (about three percent). About nine times wider than Earth, Saturn's density is so low because of these gases. If it were possible, Saturn would float in water! However, Saturn still has a strong gravitational pull, so if you weighed 150 lbs. on Earth you would weigh 137 lbs. on Saturn.

After Jupiter, Saturn is the second fastest spinning planet. It spins or rotates in about 10.5 hours. Because it spins so fast and is made of gases, Saturn also has an oblate shape like Jupiter. Although it rotates very fast, it takes about 29.5 years to revolve around the Sun because it is so far out in the solar system. Like Earth's axis of rotation tilt, Saturn's tilt is 27 degrees.

Saturn has a magnetic field about 600 times stronger than ours. That causes it to have northern and southern lights or auroras, like we have on Earth, as Saturn attracts charged particles thrown off from the Sun.

We have long been fascinated by Saturn's distinct rings. The rings were first written about by Galileo in 1610 when he observed them with a weak 20x telescope. Over the years, the rings seemed to disappear and then appear again, as Saturn's position shifted.



This image of the northern polar region of Saturn shows both the aurora and underlying atmosphere, seen at two different wavelengths of infrared light as captured by NASA's Cassini spacecraft.
Courtesy of NASA/JPL/University of Arizona

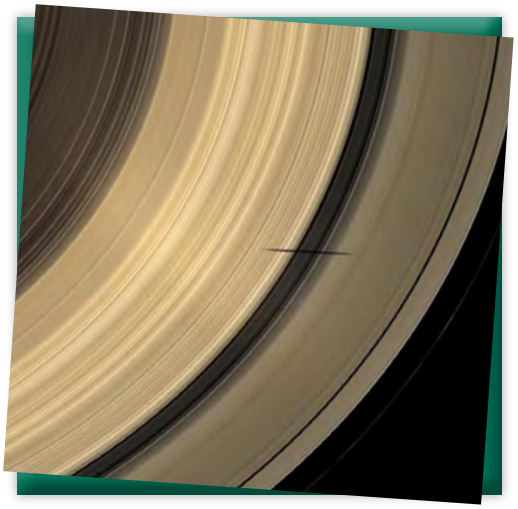
Dutch astronomer Christiaan Huygens described the rings around Saturn some 40 years later. They were thin and flat but separate from each other within a flat plane. Every 15 years or so, as the planets orbit the Sun, our Earth passes across the plane of Saturn's rings. Galileo would see them if he was looking upward or downward into that plane. When he was observing them from the edge of the plane, they were not visible.

Imagine looking at a target with a bull's-eye marked on it. From several yards away, the bull's-eye is easy to see.

However, if the target is tilted so you are looking at the edge of it, it would be hard to see it at all.

Scientists believe that Saturn's rings are made of water, ice, and rock from the size of sand grains up to about 30 feet in diameter. They are probably fragments from comets, asteroids, or broken moons. The rings are close together except for a gap. The Cassini Division is *the space between the second and third rings of Saturn*. This space may be caused by the orbits of small moons which apply a pull of gravity on the particles within the rings.

Saturn has more than 60 moons. Titan is Saturn's largest moon. It lies outside of the rings and is the second largest moon in the solar system, second only to Ganymede (Jupiter's largest moon).



NASA Cassini spacecraft captures the shadow of Saturn moon Mimas as it dips onto the planet rings and straddles the Cassini Division in this natural color image.

Courtesy of NASA/JPL/Space Science Institute

Did You Know?

In 2004, NASA's Cassini spacecraft first orbited Saturn, to reveal much about its system of rings and moons. In 2017, Cassini was purposely plunged into Saturn's atmosphere, allowing data to be collected directly from Saturn's atmosphere.

SATURN

Mass: 568,319,000,000,000,000 billion kg (95.16 x Earth)
Equatorial Diameter: 120,536 km
Polar Diameter: 108,728 km
Equatorial Circumference: 365,882 km
Known Moons: 62
Notable Moons: Titan, Enceladus, Iapetus, Mimas, Tethys, Dione & Rhea.
Known Rings: 30+ (7 Groups)
Orbit Distance: 1,426,666,422 km (9.58 AU)
Orbit Period: 10,755.70 Earth days (29.45 Earth years)
Surface Temperature: -139 °C
First Record: 8th century BC
Recorded By: Assyrians

Saturn – Facts and Figures

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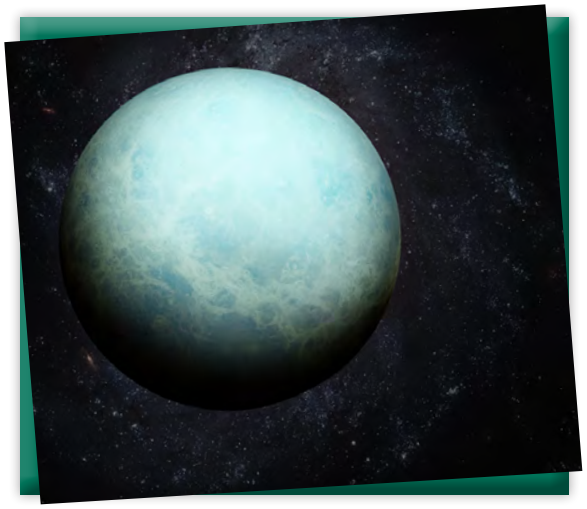


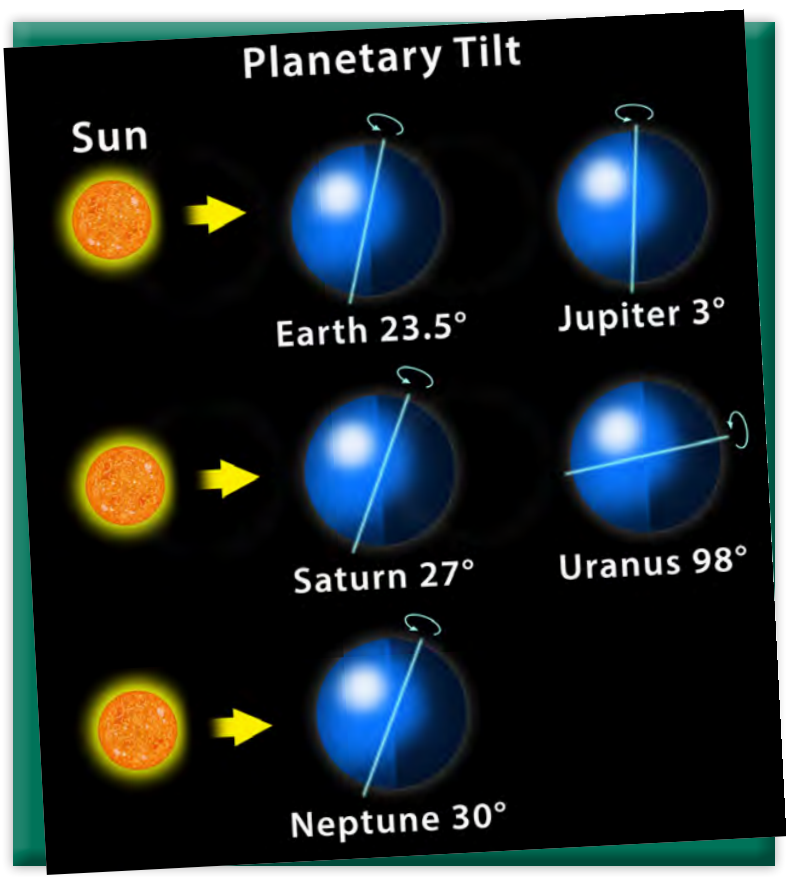
Uranus is the seventh planet from the Sun and the third largest in the solar system. It is a giant planet. Uranus has 27 known satellites. Elements of this image furnished by NASA.

NASA images/Shutterstock

Uranus

Uranus is the seventh planet from the Sun, and its orbit is between those of Saturn and Neptune. It is also the third largest planet based on its radius and is four times wider than Earth. By comparison, if you imagine Earth as the size of a tennis ball, Uranus would be the size of a basketball. It has the fourth largest mass of all planets in our solar system with a mass about 63 times greater than Earth's. Of the large Jovian planets, Uranus and Neptune are the "ice giants." Large and extremely cold, temperatures on Uranus reach the coldest of any planet in the solar system.

Discovered in 1781 by William Herschel, Uranus was the first planet to be detected using a telescope. If conditions are perfect and you know exactly where to look, Uranus can just barely be seen from Earth without a telescope.



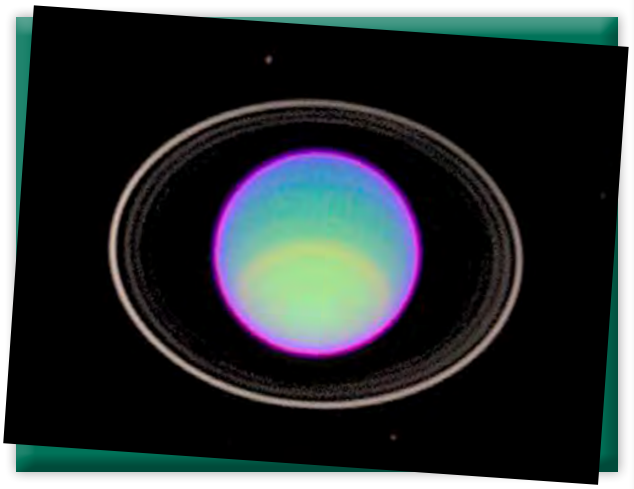
The rotational axis of Uranus is tilted almost parallel to its orbital plane.

Uranus has a rocky core containing metals like iron and nickel. Like Earth, it has a second layer called the mantle, but its mantle is made of water, methane, and ammonia. Its atmosphere consists of about 83 percent hydrogen, 15 percent helium, and two percent methane. It has extremely strong winds, sometimes reaching about 500 miles per hour.

The rotation of Uranus is unusual for two reasons. Other planets have an axis of rotation that passes through their north and south poles. The axis tilts from about 0 to about 30 degrees, so the planets spin like a top. The rotation axis of Uranus is 98 degrees, so it turns more like a wheel.

Instead of its equator always pointing toward the Sun as with other planets, the north or south poles of Uranus sometimes points toward the Sun. This affects the seasons. Its moons do revolve around its equator like those of the other planets.

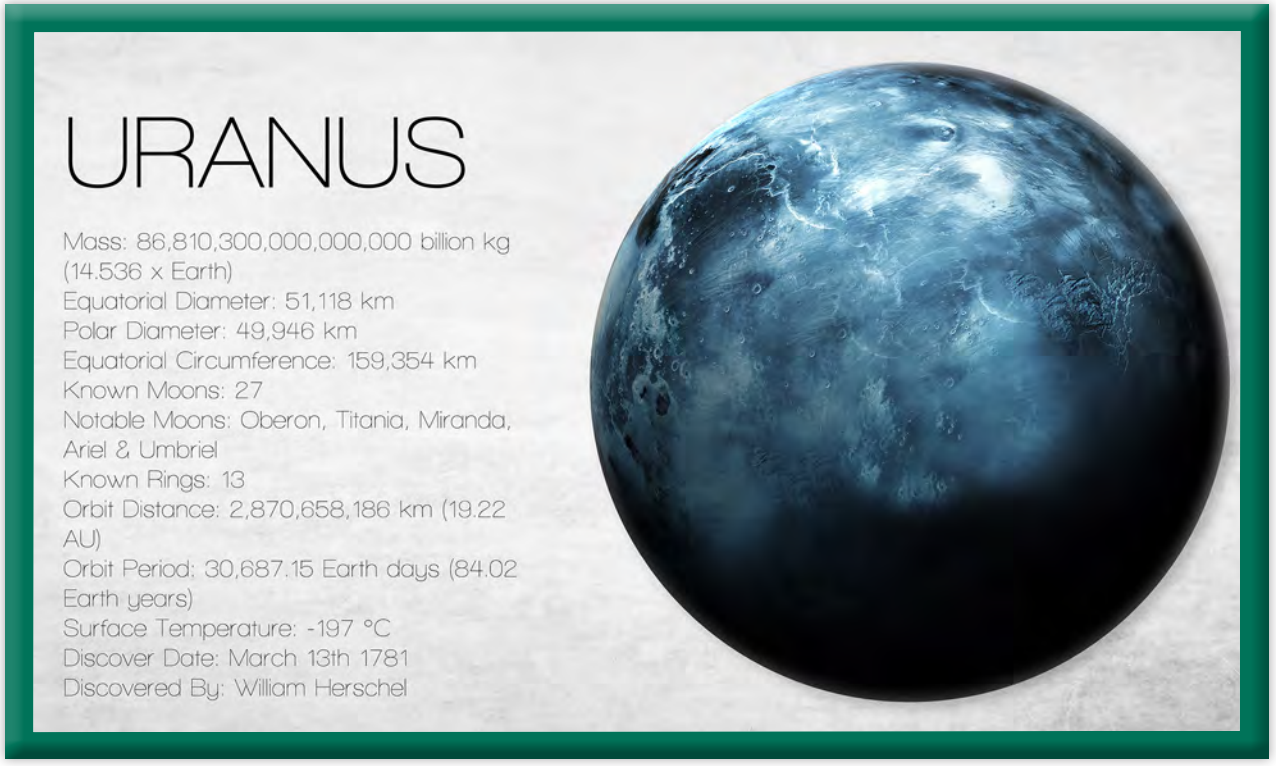
The other strange thing about its rotation is its retrograde rotation. Recall that this is also true for Venus. As the other planets rotate west to east, these two spin east to west. Its rotation time is 17 hours, 14 minutes compared to our rotation of 24 hours. While Earth revolves around the Sun in one year, Uranus takes 84 Earth years for one orbit.



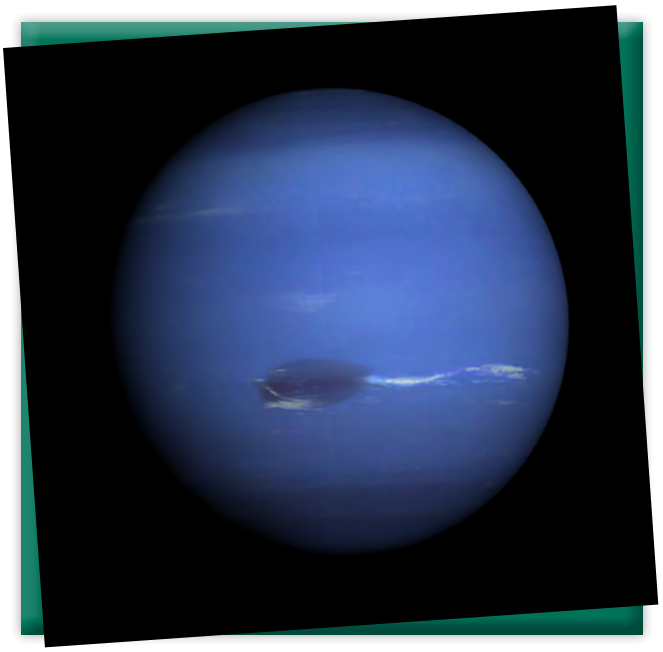
Using infrared filters, Hubble captured detailed features of three layers of Uranus atmosphere.
Courtesy of NASA/JPL/STScI

NASA's Voyager 2 is the only spacecraft that has traveled near Uranus. In 1986, it provided a lot of information about the outer regions of this planet. Uranus has 27 moons made of ice and rock. The largest moon is Titania, which is about one-eighth the diameter of Earth.

Uranus has 13 rings of unknown composition. Eleven of those are inner rings, which are dark and narrow, but the two outer rings are brightly colored. The rings have sharply outlined edges instead of being hard to see. That seems to be because they have shepherd moons, one moon on each side of the ring, which hold the rings together.

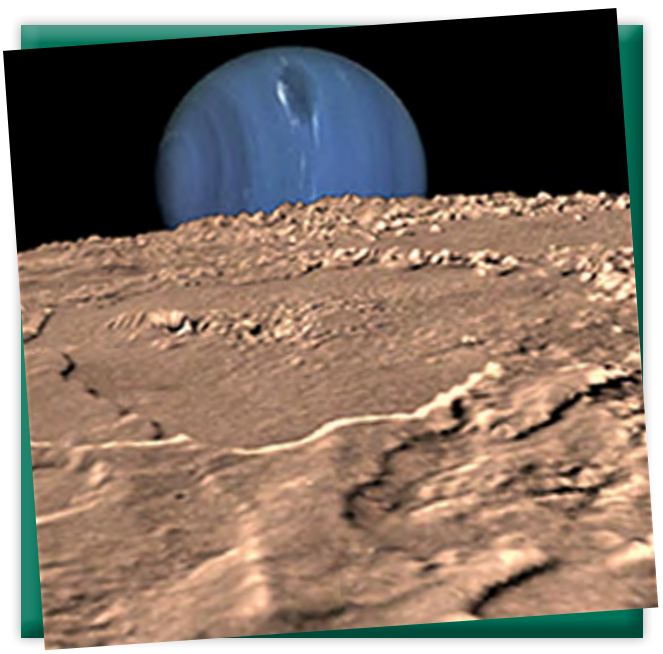


Uranus – Facts and Figures
Vadim Sadovski/Shutterstock



Neptune. An image constructed using the best available imagery from Voyager 2. Elements of this image furnished by NASA.

MarcelClemens/Shutterstock



This composite illustration is of the planet Neptune, as seen from its moon Triton. Neptune's south pole is to the left; clearly visible in the planets' southern hemisphere is a Great Dark Spot, a large anti-cyclonic storm system. This three-dimensional view was created using images from the Voyager spacecraft.

Courtesy of NASA

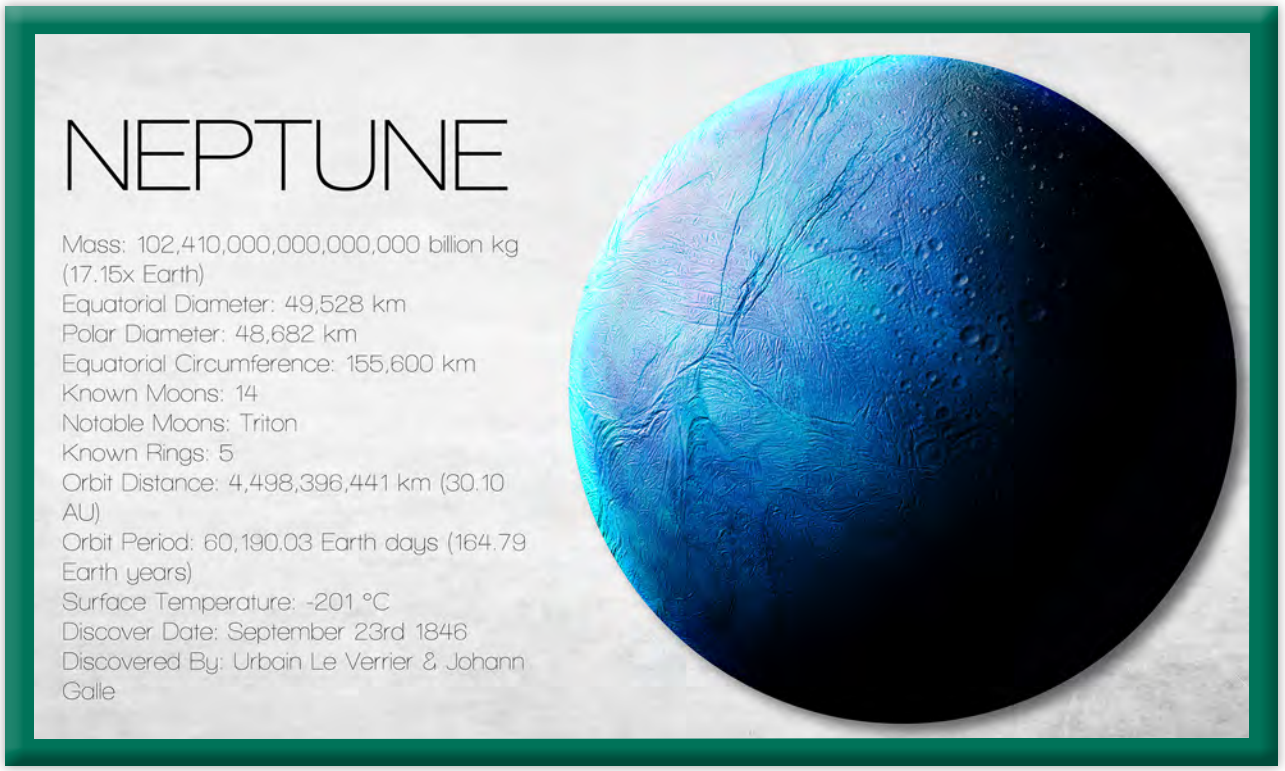
Neptune

At long last, we have Neptune, the eighth planet from the Sun and the most distant planet in our solar system. Like Uranus, it is also four times wider than Earth. Neptune is dark, cold, and full of wind and ice. It is mostly made up of icy materials, water, methane, and ammonia, outside its small rocky core. Of the Jovian planets, it is the densest. Hydrogen, helium, and methane form Neptune's atmosphere.

Inspired by the work of mathematician Urbain Le Verrier, Johann Galle discovered Neptune in 1846 at the Berlin Observatory. Much of what we know about Neptune today is based on NASA's Voyager 2. No other spacecraft has orbited the planet to study it up close.

Neptune spins every 16 hours and it takes about 165 years to revolve around the Sun because it is so far out in the solar system. Neptune's axis of rotation is like Earth's, with a tilt of 28 degrees. Neptune has seasons, although each season lasts over several decades. Neptune also has a strong magnetic field and its main axis is tipped over by about 47 degrees compared with its rotation axis.

Neptune has 13 moons. Triton is the only large moon in our solar system to orbit its planet in the opposite direction (clockwise) of its planet's rotation. A second major moon of Neptune is Nereid. It orbits in the same direction as Neptune's rotation, but it has the most eccentric orbit in our solar system. Neptune also has five known rings, extending from 25,500 to 40,000 miles from the planet.



Neptune – Facts and Figures
Vadim Sadovski/Shutterstock

Pluto and Dwarf Planets

Pluto was once considered to be a planet until scientists reclassified it. Remember that a planet, by definition, meets three requirements. It orbits the Sun, it is large enough to be a spherical shape, and it is large enough to have cleared away other objects of a similar size near its orbit. Because Pluto is not large enough to have cleared away other objects, we call it a dwarf planet. Our solar system has five dwarf planets. Haumea, Makemake, and Eris are three dwarf planets that orbit around Neptune. Another dwarf planet, Ceres, orbits much closer to the Sun.

American astronomer Clyde Tombaugh discovered Pluto in 1930 at the Lowell Observatory in Arizona. Tombaugh took pictures of the night sky to see if anything moved against the background stars. Over time, he found a star that seemed to change position.

Smaller than our Moon, Pluto is covered with red snow mountains, valleys, plains craters, and its landmark heart-shaped glacier. Pluto's orbit is unique in that it is elliptical and tilted. Its average distance from the Sun is 3.67 billion miles. From 1979 to 1999, Pluto was near perihelion, bringing the planet closer to the Sun than Neptune. A day on Pluto is about 153 hours. Like Venus and Uranus, Pluto also shows a retrograde rotation.

Did You Know?

Because of Pluto's elliptical orbit, Pluto is sometimes closer to the Sun than Neptune.

NASA's New Horizons spacecraft captured this image of Pluto on July 14, 2015.

Courtesy of NASA/JHUAPL/SWRI

Pluto has a weak atmosphere that includes molecular nitrogen, methane, and carbon monoxide. When Pluto is at perihelion, its surface sublimates and rises briefly to form a thin atmosphere. Sublimate refers to *the direct change from a solid to a gas*. Pluto has low gravity–about six percent of Earth's. As a result, the atmosphere is much more extended in altitude than ours. Pluto becomes much colder during aphelion (when it is farthest from the Sun), causing gases to condense on the surface.

Pluto has five known moons and no rings. The largest moon is Charon. Because Charon is about half the size of Pluto the two are often called a double planet.

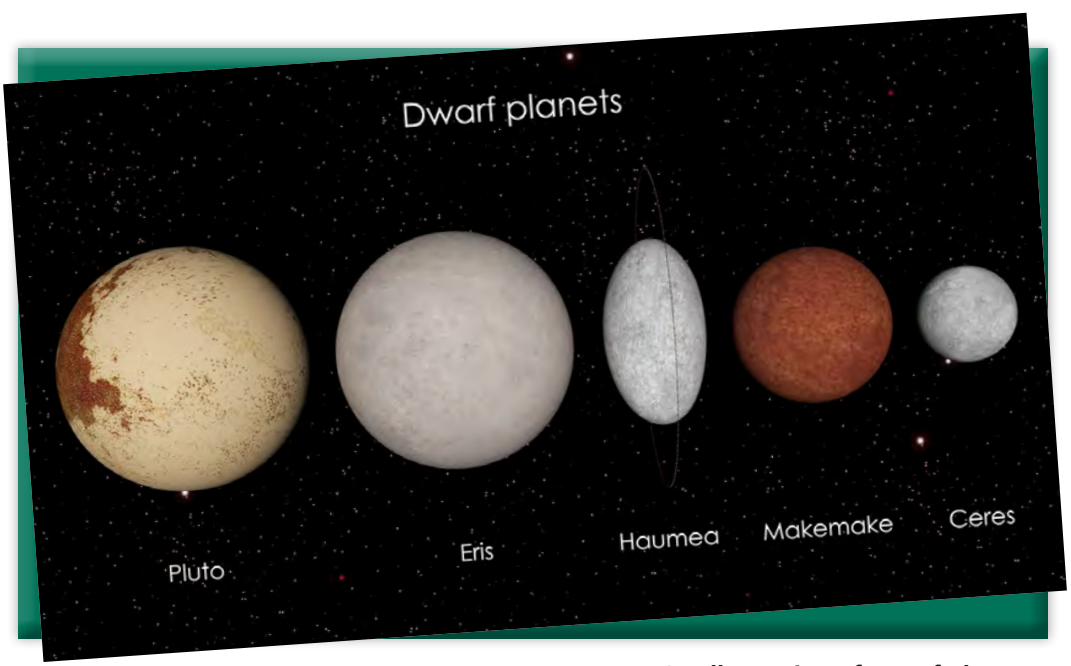
Remember, Pluto is one of five dwarf planets in our solar system. Although nearly the same size as Pluto, the dwarf planet of Eris is almost three times farther from the Sun. Much like Pluto, there is still debate over its status as a planet.

Next, we have the dwarf planets Haumea and Makemake. Haumea is also close in size to Pluto but is shaped like a football due to its super-fast rotation. Makemake is a little smaller than Pluto, but almost as bright.

Lastly, we have the Sun-orbiting Ceres. Ceres also happens to be the largest asteroid in the asteroid belt at 580 miles in diameter. The asteroid belt consists of the *randomly scattered asteroids between the orbits of Mars and Jupiter*.

Did You Know?

Pluto was reclassified as a dwarf planet in 2006. Scientists are reconsidering the decision based on a lack of scientific literature to support the actual definition of a planet.



3D Illustration of Dwarf Planets.

Meletios Verras/Shutterstock

Asteroids, Comets and Meteors

Asteroids

Asteroids are large rocks ranging in size from about one mile up to a few hundred miles in diameter. There are millions of them, but only a few, like Ceres and Vesta, are large enough to have names.

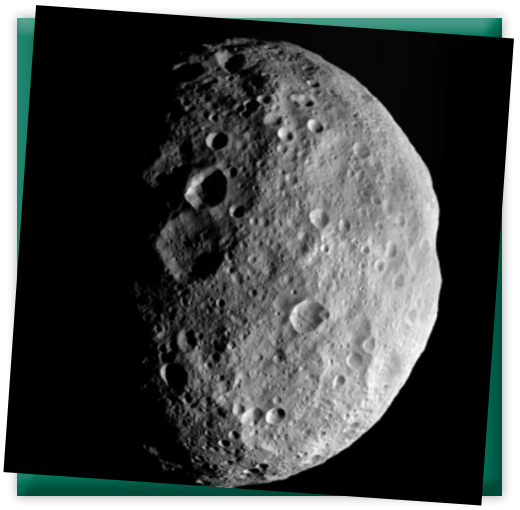
It was once thought that asteroids formed when a planet exploded, but there is no theory that explains why a planet would explode, and the total mass of the asteroids would not even be as large as our Moon. Some asteroids do collide, which causes them to break into the smaller pieces that we see today.

We categorize asteroids by their position in space and by their chemical composition. Most asteroids orbit within the asteroid belt, and others, called trojan asteroids, are *asteroids that share orbits with larger planets*. There are also near-Earth asteroids that orbit near Earth. The chemical composition classifications of asteroids are C-types, S-types, and M-types. C-type asteroids consist of clay and silicate rocks. S-types include silicate materials and nickel-iron. M-types are metallic (nickel-iron).

Asteroids revolve around the Sun in elliptical orbits with unpredictable rotations. The strong gravity of Jupiter affects their orbits, creating gaps between groups of asteroids in the asteroid belt.

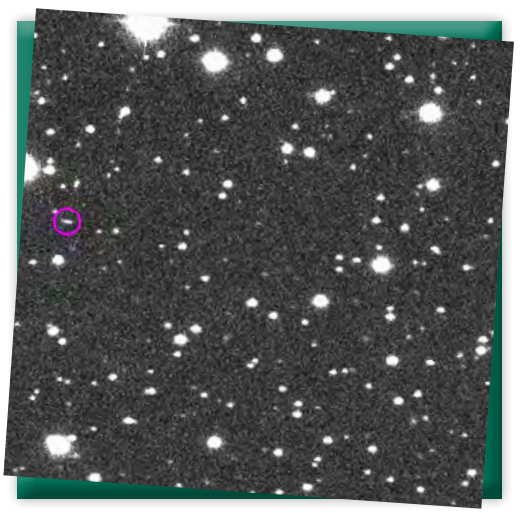
Did You Know?

Double asteroids are two rocky bodies of roughly the same size that orbit each other.



Second to Ceres, Vesta is the next largest asteroid at about 330 miles wide. This image is from the last sequence of images NASA's Dawn spacecraft obtained, looking down at Vesta's north pole as it was departing in 2012.

Courtesy of NASA/JPL-Caltech/UCLA/MPS/DLR/IDA



The image shows how asteroids are typically discovered by detection of their motion relative to background stars.

Courtesy of NASA/JPL-Caltech/CSS-Univ. of Arizona

Comets

Image taken in 1997 of the Comet Hale-Bopp with its two tails.

Courtesy of A. Dimai and D. Ghirardo, (Col Druscie Obs.), AAC

Comets appear in the sky at night like a ball of fire with a tail. They are chunks of ice, rock particles, and dust that orbit around the Sun but a lot farther away than the planets and asteroids.

Every comet has two visible parts, a head and a tail. The head has a small nucleus which is *the center of the comet's head made mostly of ice and frozen carbon dioxide (dry ice)*. The nucleus is surrounded by a coma, which is *a large cloud of gas and dust*. The tail is a long part of that gas and dust that is blown away from the head and always points away from the Sun. The coma and tail form when the comet comes close enough to the Sun for some of the frozen material to melt and vaporize.

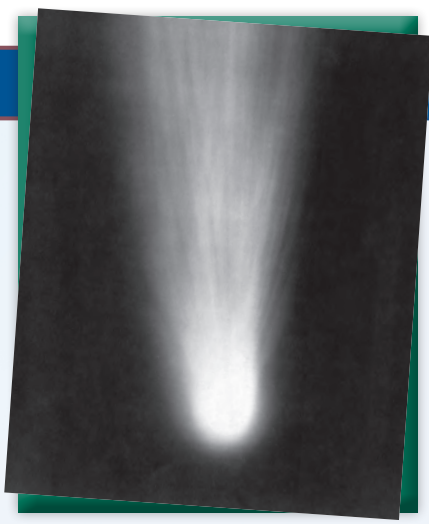
The solar wind from the Sun may actually produce two visible tails. One is made of charged particles and is a light blue. The second one, made of dust, is brighter and whiter and is more visible.

Scientist believe that most comets originate either from the Kuiper Belt or from the Oort Cloud. Recall from earlier in this lesson that the Kuiper Belt is a ring of icy bodies outside of Neptune's orbit. Comets from the Kuiper Belt are called short-period comets because *they take less than 200 years to orbit the Sun.Comets that take more than 200 years to orbit the Sun* are called long-period comets. In fact, comets that move in from the Oort Cloud *a spherical shell surrounding our Sun with a distance of up to 100,000 astronomical units (AU)*, can have orbit periods of millions of years.

The Right Stuff

Halley's Comet

In 1705, the English astronomer Edmond Halley suggested that comets observed in years past were actually the same comet orbiting around the Sun every 75-76 years. Using Newton's theories of gravity and planetary motion, Halley predicted the comet would be visible again in 1758. His predictions proved correct! Sadly, he didn't get to see it because he died 16 years before that happened. Halley's Comet most recently appeared in 1986. Therefore, we should see it again in 2061.

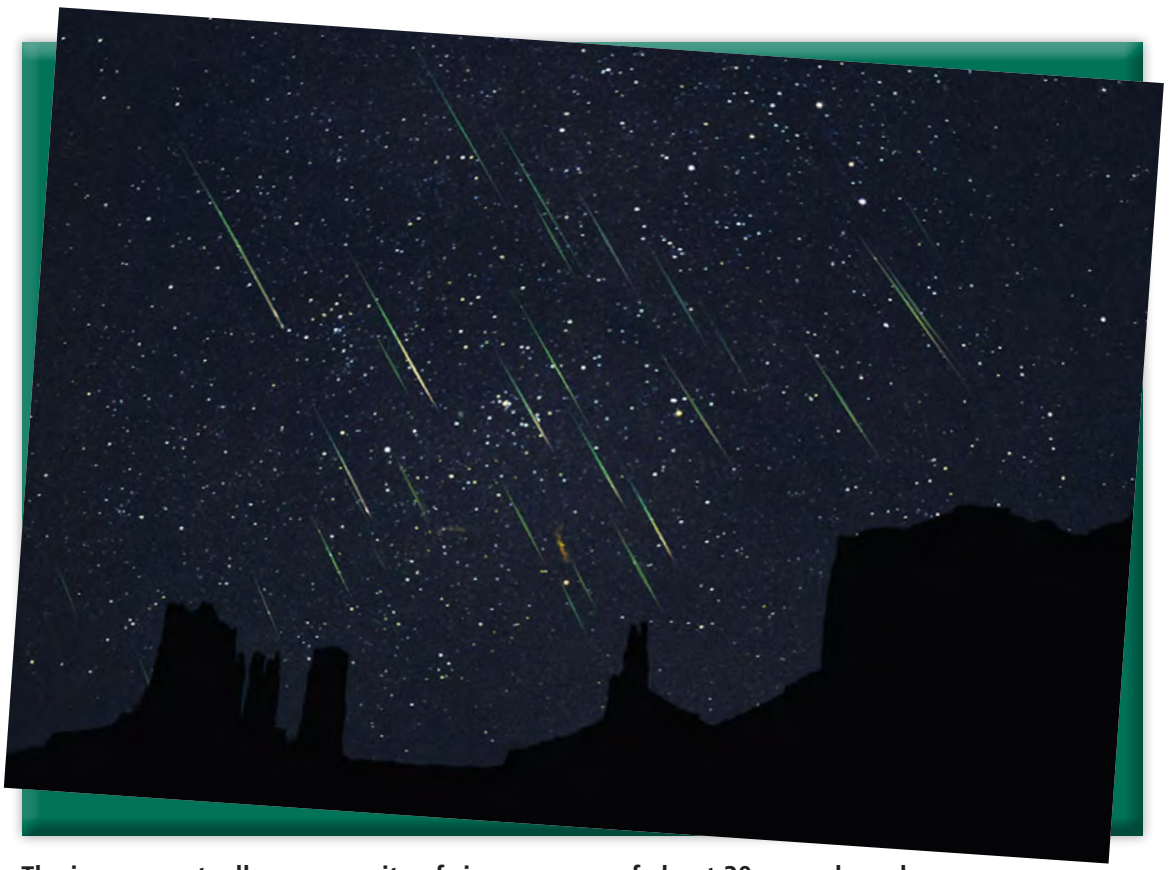


Halley's Comet in 1910.

Everett Historical/Shutterstock

Meteors

In addition to asteroids and comets, there are also meteoroids, meteors, and meteorites. Because the terms are so similar and often confused, let's look at the differences. A meteoroid is *a tiny rocky object in space usually the debris from a comet or an asteroid*. A meteor is *a very small meteoroid, usually smaller than a marble, which burns up as it enters a planet's atmosphere*. It is commonly called a shooting star or a falling star; for many, it presents a wish-making opportunity! Under perfect conditions, a person might see five or six meteors per hour. Sometimes, they occur more often in a meteor shower. A meteor becomes a meteorite if it actually *makes it through the atmosphere and strikes the surface of the planet or moon*.



The image – actually a composite of six exposures of about 30 seconds each – was taken in 2001, a year when there was a very active meteor shower.

Sean M. Sabatini/NASA

In this lesson, we have discussed the components of our solar system, including its planets, dwarf planets, the asteroid belt, icy Kuiper Belt, and the Oort Cloud. In the next lesson we will travel outside of our solar system to explore deep space and the wonders of the universe.

CHECKPOINTS

Lesson 3 Review

Using complete sentences, answer the following questions on a sheet of paper.

1. Describe the surface of Mercury.
2. Compare and contrast the rotation and orbit of Venus with that of Earth.
3. When is the best time to see Mars and why?
4. What is unique about Jupiter's rotation?
5. Describe the composition of Saturn's rings.
6. What is unique about Uranus's rotation?
7. What is the asteroid belt?
8. Explain the appearance of two tails on a comet.
9. What is the difference between a meteor, a meteoroid, and a meteorite?

APPLYING YOUR LEARNING

10. Given the most current research on Pluto, describe in a short paragraph whether Pluto should be a classified as a planet or remain a dwarf planet?