

• A gas giant made of hydrogen and helium with no solid surface, with a strong magnetic field and electrical activity, a huge storm cloud called the Great Red Spot, and fast winds

Saturn ~

- 837.5 million miles from the Sun at its closest point, 936.2 million miles at its farthest point
- Revolves around the Sun every 10,759.2 days (29.5 years)
- The second largest planet, with a diameter of 78,382 miles
- 220°F average surface temperature
- 18 moons (the largest is Titan)
- Visible to the naked eye
- A gas giant made of hydrogen and helium, with a complex ring system made of rock and ice fragments, powerful electromagnetic fields, and a relatively dry atmosphere with fierce winds
- Its density is so low it would float in water

Uranus ~

- 1,699 million miles from the Sun at its closest point, 1,867 million miles at its farthest point
- Revolves around the Sun every 30,685.4 days (84 years)
- Diameter of about 32,000 miles
- 323°F average surface temperature
- 18 moons (the largest are Oberon, Titania, Umbriel, and Ariel)
- Discovered in 1781 by Sir William Herschel
- Spinning on its side, it is gaseous and has a narrow, nearly opaque system of rings made of ice and dust, and an atmosphere with traces of methane

Neptune ~

- 2,770 million miles from the Sun at its closest point, 2,822 million miles at its farthest point
- Revolves around the Sun every 60,189 days (164.8 years)
- Diameter of 30,608 miles
- 330°F average surface temperature
- 8 moons (the largest is Triton)
- Discovered in 1846 by Johann Galle, using calculations derived in 1845 by John Couch Adams and Urbain Le Verrier
- Gaseous with no solid surface, it has fierce winds and storms, methane clouds, and an atmosphere composed mostly of hydrogen

Pluto ~

- 2,763 million miles from the Sun at its closest point, 4,587 million miles at its farthest point
- Revolves around the Sun every 90,465 days (247.7 years)
- The smallest planet, with a diameter of 1,414 miles
- 369°F average surface temperature
- One moon (Charon)
- Discovered in 1930 by Clyde Tombaugh
- Has an eccentric, elongated orbit, a surface of frozen methane, and apparently a thin, nitrogen-methane atmosphere when closer to the Sun
- May be captured asteroid not formed with rest of the Solar System

Things to Think About

- Why do we want to explore other planets and find out about their origin? What do we hope to learn and gain?
- When the Voyager spacecraft left the solar system, they carried various messages for any aliens who might encounter them. What would you include in such a message?
- The Apollo program to land people on the Moon cost the United States \$24 billion. Was it worth it? Could the money have been better spent elsewhere?
- The 12 men who walked on the Moon have written and/or created art about their experiences. Research their work, and imagine what it must have felt like to see what no human had ever seen before. What would

it be like to be the first person to walk on Mars?

• Since the end of the Apollo program in 1972, planetary exploration has relied on unmanned space probes and robotic explorers. Are these sufficient, or can true exploration be undertaken only by humans? Given the danger and expense, should we send people to explore the planets?

• In the 1990s, NASA switched its focus in planetary exploration from launching only a few big billion-dollar projects using large, expensive spacecraft to a policy of “faster, cheaper, better,” launching a larger number of smaller, relatively inexpensive craft with more modest goals. Following this strategy, the agency had great success in 1996-97 with the *Pathfinder* and *Sojourner* mission to Mars. However, in late 1999 two missions to land unmanned probes — the *Mars Climate Observer* and the *Mars Polar Lander* — completely failed, apparently because of errors and mismanagement. In retrospect, is the “faster, cheaper, better” policy totally wrong? What would you do if you were in charge of NASA?

• Why are meteorites so important to planetary astronomers? What have we already learned from them?

• What is the significance of finding water on the Moon?

Internet Resources

marssociety.com — The site of the Mars Society, dedicated to exploring and settling on Mars.

pds.jpl.nasa.gov/planets — Welcome to the Planets, a collection of images from NASA's planetary exploration program.

seds.lpl.arizona.edu/billa/trip — The Nine Planets, an overview of the solar system's planets and their moons.

spaceflight.nasa.gov/index-m.html — Information on NASA's missions to explore the solar system.

Other Resources

For students:

Couper, Heather and Nigel Henbest. *DK Space Encyclopedia.* Dorling Kindersley, 1999.

Fradin, Dennis Brindell. *The Planet Hunters: The Search for Other Worlds.* Margaret K. McElderry Books, 1997.

Levy, David H. *Stars & Planets.* Time-Life Books, 1996.

For adults:

Light, Michael. *Full Moon.* Knopf, 1999.

McNab, David and James Younger. *The Planets.* Yale University Press, 1999

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EXPANDING THE UNIVERSE

THE PLANETS

The solar system — the Sun and its collection of nine orbiting planets — formed some 5 billion years ago. We are now at the dawn of a new era in exploring those planets and answering some of the many questions about them. Already we have examined meteorites from other worlds for signs of life, landed men on the Moon, and launched spacecraft to look for evidence of volcanic eruptions on Mars and to explore the moons of Jupiter, as well as photographed all the planets in the solar system and launched probes to all except Pluto. Discover what the *Voyager* and *Pioneer* spacecrafts told us about the outer planets, and what the *Viking*, *Pathfinder*, *Mariner* and *Magellan* spacecraft have revealed about the inner planets. Perhaps what we accomplish in the next years will help pave the way for manned missions to Mars so that, eventually, people will walk on its surface as they have walked on the Moon.



Vocabulary

Apollo 11 — The first manned mission to the Moon, in July 1969.

Apollo program — The U.S. space program that landed 12 men on the Moon from 1969 to 1972.

asteroid — A rocky body, less than 600 miles in diameter, orbiting the Sun.

Big Bang — The immense explosion in which the universe is thought to have been born, and in which all matter, space, and time were created.

Cassini — An unmanned space probe launched toward Saturn in 1997. It is scheduled to reach the planet in 2004 where it will study Saturn's atmosphere, rings, and moons.

gravity — A force that attracts objects in the Universe toward one another.

Hubble Space Telescope — A telescope with a mirror 2.4 meters wide orbiting the Earth, launched by the shuttle Discovery in 1990, that has provided many wonderful images of a variety of astronomical phenomena.

Huygens probe — A probe supplied by the European Space Agency, launched with the *Cassini* spacecraft to Saturn in 1997, that is set for release to Saturn's moon Titan in November 2004.

Io — Jupiter's innermost moon, discovered by Galileo in 1610, that has the most volcanic activity of all the moons and planets and may have a thin atmosphere.

Lunar Prospector — An unmanned 1998 mission to the Moon that mapped it, studied its composition, and discovered evidence of water ice at both its poles.

Mariner 10 — An unmanned mission, launched in November 1973, that arrived at Mercury in March 1974 and photographed the planet.

meteorite — A chunk of material from space that enters the Earth's atmosphere and reaches the ground. Most meteorites on Earth are believed to be from the asteroids or comets, but some may be from the Moon or Mars.

Milky Way — The galaxy in which our own solar system is located.

moon — A natural satellite orbiting a planet. The Earth has only one, but other planets have many.

NASA — The National Aeronautics and Space Administration, the branch of the U.S. government that oversees space exploration.

Pathfinder — An unmanned mission to Mars, launched in December 1996, that reached the planet in July 1997 and deployed the roving *Sojourner*.

planet — A large body that orbits a star. Earth is an example.

protoplanet — A young planet, or the collection of original material from which a planet is formed.

Shoemaker-Levy 9 — A chain of comet fragments which collided with Jupiter in July 1994 leaving dark spots from Jupiter's inner atmosphere visible from Earth.

shooting stars — Another term for meteors, which are dust particles from comets or asteroids that burn up in the Earth's atmosphere leaving a fiery trail.

Sojourner — A small robotic rover deployed on Mars in July 1997 by the Pathfinder lander. Sojourner spent three months roaming the surface and examining a wide variety of rocks there.

solar system — A star and the bodies orbiting it—planets, moons, etc. In our solar system, nine planets circle the Sun: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.

Sun — The star at the center of our solar system. It is an average star which, at some 5 billion years old, is middle-aged.

Titan — Saturn's largest moon. It may have water ice and a thin atmosphere.

PLANETARY MISSIONS DATELINE

January 1959 — The Russian *Luna 1* satellite is the first man-made object to achieve escape velocity from the Earth on its way to the Moon.

February 1961 — The Russian spacecraft *Venera* is the first to fly by Venus.

August 1962 — *Mariner 2* is launched to Venus.

July 1964 — *Ranger 7* is launched to the Moon; it returns 4,000 photos of the surface.

November 1964 — *Mariner 4* is launched; it becomes the first successful U.S. attempt to fly by Mars.

February 1965 — *Ranger 8* is launched to the Moon; it returns 7,000 photos of the surface.

April 1967 — *Surveyor 3* is launched to the Moon, where it scoops and tests the soil.

June 1967 — *Mariner 5* is launched to Venus; it returns information on the atmosphere.

February 1969 — *Mariner 6* is launched to Mars; it returns 75 photographs of the surface.

March 1969 — *Mariner 7* is launched to Mars; it returns 126 photographs of the surface.

July 1969 — *Apollo 11* lands the first people on the Moon.

May 1971 — *Mariner 9* is launched to Mars; it arrives in November 1971 and becomes the first craft to orbit and map the planet.

March 1972 — *Pioneer 10* is launched to Jupiter; it arrives there in December 1973 and exits the solar system in June 1983, after investigating the system's outer planets. It is the first man-made object to leave the solar system.

December 1972 — *Apollo 17* becomes the last manned mission to the Moon. Various geological experiments were performed including the discovery of orange lunar soil.

April 1973 — *Pioneer 11* is launched to Jupiter and Saturn; it returns much information until its transmission ends in September 1995.

November 1973 — *Mariner 10* is launched; it passes Venus in February 1974 and arrives at and begins photographing Mercury in March 1974. It was the first spacecraft to go to Mercury.

August 1975 — *Viking 1* is launched to Mars; it lands in July 1976 and operates for 6 years.

September 1975 — *Viking 2* is launched to Mars; it lands in September 1976 and operates for 3 years.

August 1977 — *Voyager 2* is launched to the outer planets; it encounters Jupiter in July 1979, Saturn in August 1981, Uranus in January 1986, and Neptune in August 1989.

September 1977 — *Voyager 1* is launched; it encounters Jupiter in March 1979 and Saturn in November 1980.

May 1978 — *Pioneer-Venus 1* is launched to Venus; it enters orbit in December 1978 and functions for 14 years, mapping the planet's surface, clouds, and atmosphere.

May 1989 — The shuttle *Atlantis* launches *Magellan* to Venus; it lands in August 1990 and functions for four years, collecting information on the planet's surface and atmosphere until October 1994.

October 1989 — The shuttle *Atlantis* launches *Galileo* to Jupiter; it arrives in December 1995, releases a probe into the outer atmosphere, and studies a few of the moons as well as Jupiter's magnetic field.

April 1990 — The shuttle *Discovery* launches the Hubble Space Telescope.

September 1992 — The *Mars Observer* is launched to study the planet's geoscience and climate; it fails mysteriously just as it approached Mars in August 1993.

November 1996 — The *Mars Global Surveyor* is launched to Mars; it arrives and begins orbiting in September 1997 on a mapping mission.

December 1996 — The *Mars Pathfinder* is launched to Mars; it lands in July 1997 and deploys the roving *Sojourner*, which collects soil and rock samples.

October 1997 — *Cassini* is launched to Saturn, carrying the Huygens probe to its moon Titan; they are to arrive in July 2004.

January 1998 — The *Lunar Prospector* is launched to and begins orbiting the Moon, where it detects hydrogen, probably from frozen water, at the poles.

July 1998 — The Japanese *Nozomi* spacecraft (originally called Planet-B) is launched to study Mars's atmosphere and ionosphere.

December 1998 — The *Mars Climate Observer* is launched; it reaches Mars in September 1999 but disappears, having apparently crashed as a result of an error in calculation.

January 1999 — The *Mars Polar Lander* is launched to land near Mars's south pole icecap; it reaches Mars in December 1999 but disappears.

Triton — Neptune's largest moon. It also may have water ice and a thin atmosphere.

Valles Marineris — A huge canyon south of the equator of Mars, which, with a length comparable to the width of the United States, is thought to be the largest canyon in the solar system.

Voyager 1 — An unmanned mission to Jupiter and Saturn, launched in September 1977, that encountered Jupiter in March 1979 and passed near Saturn in November 1980.

Voyager 2 — An unmanned mission, launched in August 1977, that encountered Jupiter in July 1979, Saturn in August 1981, Uranus in January 1986, and Neptune in August 1989.

Facts About the Planets

Mercury ~

- 28.6 million miles from the Sun at its closest point, 43.4 million miles at its farthest point
- Revolves around the Sun every 88 days
- The second smallest planet, with a diameter of 3,032 miles
- 333°F average surface temperature
- No moons
- Visible to the naked eye
- Has a heavily cratered surface, an iron core, an extremely thin atmosphere composed of hydrogen and helium, and possible water ice near its poles

Venus ~

- 66.8 million miles from the Sun at its closest point, 67.7 million miles at its farthest point
- Revolves around the Sun every 225 days
- Slightly smaller than the Earth, with a diameter of 7,522 miles
- 865°F average surface temperature
- No moons
- Visible to the naked eye
- Has a cratered surface, evidence of volcanoes, and a dense, white atmosphere composed mostly of carbon dioxide with sulfuric acid clouds

Earth ~

- 91.4 million miles from the Sun at its closest point, 94.5 million miles at its farthest point
- Revolves around the Sun every 365 days
- Diameter of 7,928 miles
- 45°F average surface temperature
- One moon (the Moon)

Mars ~

- 128.4 million miles from the Sun at its closest point, 154.9 million miles at its farthest point
- Revolves around the Sun every 687 days (1.9 years)
- Diameter of 4,213 miles
- 80°F average surface temperature
- Two moons (Phobos and Deimos)
- Visible to the naked eye
- Has mountains and craters, evidence of volcanic activity and abundant water in the past, polar icecaps, and a thin atmosphere composed mostly of carbon dioxide

Jupiter ~

- 460.3 million miles from the Sun at its closest point, 507.1 million miles at its farthest point
- Revolves around the Sun every 4,332.6 days (11.9 years)
- The largest planet, with a diameter of nearly 89,000 miles
- 160°F average surface temperature
- 16 moons (the largest are Io, Europa, Ganymede, and Callisto)
- Visible to the naked eye