ES5a. Students know the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.

ES5b. Students know the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.

A Tour of the Solar System

Make believe you are coming to the **solar system** as a stranger. You are on a tour. There is a tour guide to provide information. You have a window to look out. The tour is about to start. What will you see?

The first view of the solar system is from space. From here the whole solar system can be seen. The most surprising thing is that the solar system is mostly empty. The matter is concentrated in tiny dots. And the dots are far apart. Most of the dots are **planets.** From far away, that is what you see.

There is a **star** in the center of the solar system. Four small planets **orbit** pretty close to the star. These are the rocky **terrestrial planets.**

Next there is a region of small bits of matter orbiting the star. This is the **asteroid** belt.

Out farther, four big gas planets orbit the star. These are the **gas giants.**

Beyond the gas giants is a huge region of different-size icy chunks of matter called the **Kuiper Belt.** Some of the chunks are big enough to be planets. Others have orbits that send them flying through the rest of the solar system. That's all that can be seen from out in space.

Sizes and distances of solar-system objects are not drawn to scale.

The Sun

The **Sun** is a star. It is just like the stars you can see in the night sky. The Sun is at the center of the solar system. Everything else in the solar system orbits the Sun. The Sun rules.

The Sun is an average star. It is much like millions of other stars in the **Milky Way** galaxy. The Sun formed about 5 billion years ago. A cloud of gas began to spin. As it spun, it formed a sphere. The sphere got smaller and smaller. As it got smaller, it got hotter. Eventually the sphere got so hot it started to radiate light and heat. A star was born.

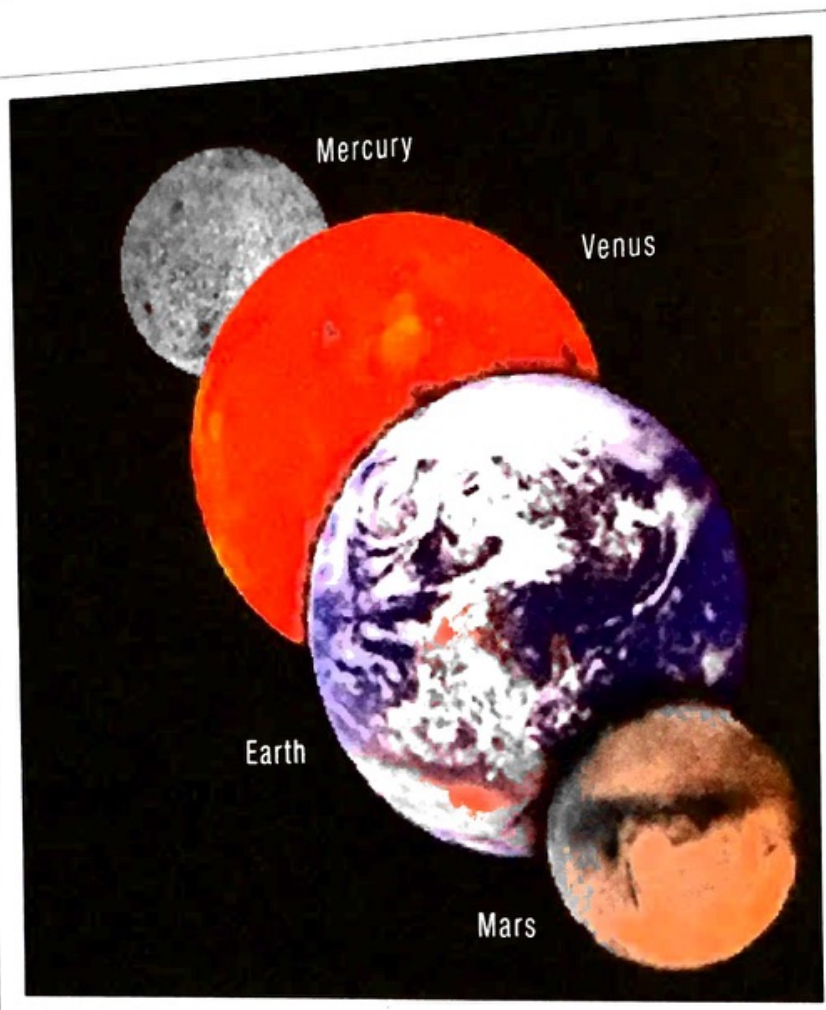
The Sun is made mostly of **hydrogen** (72%) and **helium** (26%). And it is huge. The diameter is about 1,384,000 kilometers (860,000 miles). The diameter is the distance from one side of the Sun to the other through the center. That's about 109 times the diameter of Earth. (See Earth compared to the Sun at the bottom of the picture on the left.)

The Sun is incredibly hot. Scientists have figured out that the temperature at the center of the Sun is 15,000,000°C (27,000,000°F). The temperature of the Sun's surface is lower, about 5,500°C (10,000°F). Hydrogen atoms constantly combine to form helium atoms in **thermonuclear reactions.** These reactions create heat and light energy. About 3.6 tons of the Sun's **mass** is being changed into heat and light every second. This energy radiates out from the Sun in all directions. A small amount of it falls on Earth.

Another name for the Sun is Sol. That's why the whole system of planets is called the solar system. The solar system is named for the ruling star. The reason the Sun rules is its size. The Sun has 99.8% of the total mass of the solar system. All the other solar-system objects travel around the Sun in **predictable** almost-circular paths called orbits. The most obvious objects orbiting the Sun are the planets.

Terrestrial Planets

The terrestrial planets are the four planets closest to the Sun. The terrestrial planets are small and rocky.

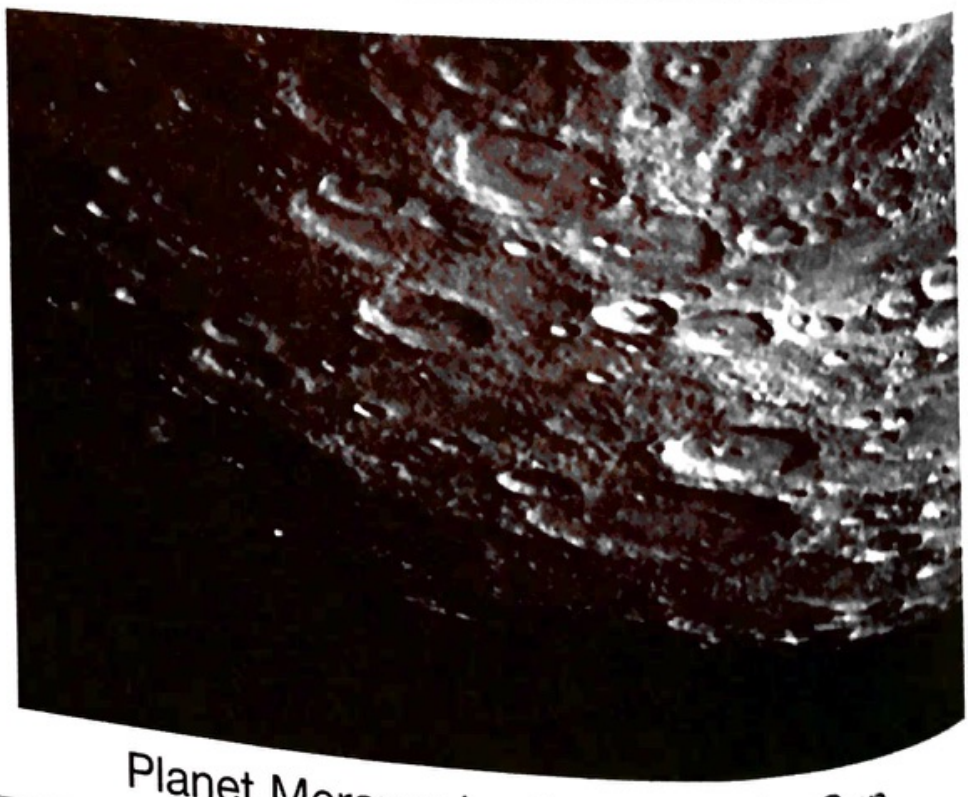


Relative sizes of the terrestrial planets

Mercury

Mercury is closest to the Sun. Mercury is smaller than Earth and has no **satellite** (moon). By human standards, it is an uninviting place. Mercury is very hot on the side facing the Sun and very cold on the dark side. It has no atmosphere or water.

Mercury is covered with craters. The **craters** are the result of thousands of collisions with objects flying through space. The surface of Mercury looks a lot like Earth's Moon.

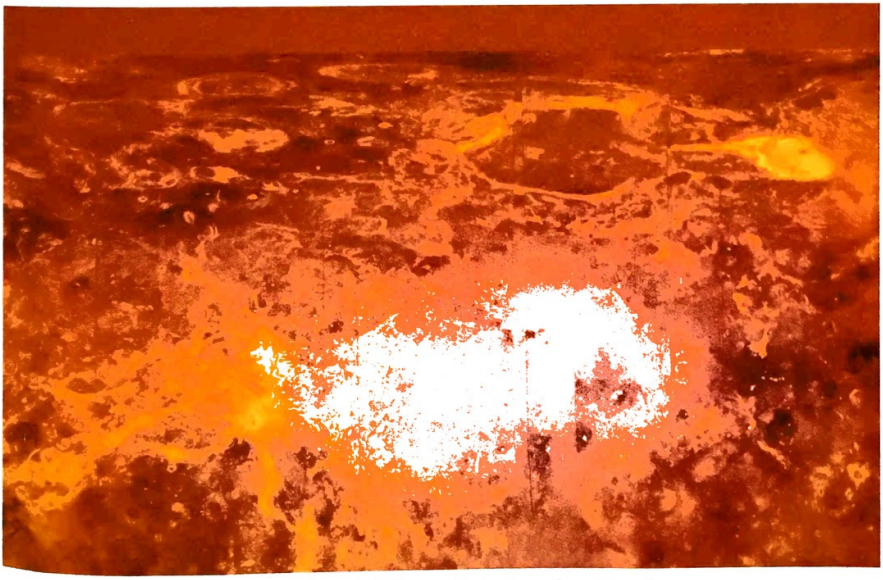


Planet Mercury is closest to the Sun.

Venus

Venus is the second planet from the Sun. Venus is about the same size as Earth and has no satellites. The surface of Venus is very hot all the time. It is hot enough to melt lead, making it one of the hottest places in the solar system.

There is no liquid water on Venus. But Venus does have an atmosphere of carbon dioxide. The dense, cloudy atmosphere makes it impossible to see the planet's surface. Modern radar, however, allows scientists to take pictures through the clouds. We now know that the surface of Venus is dry, cracked, and covered with volcanoes.



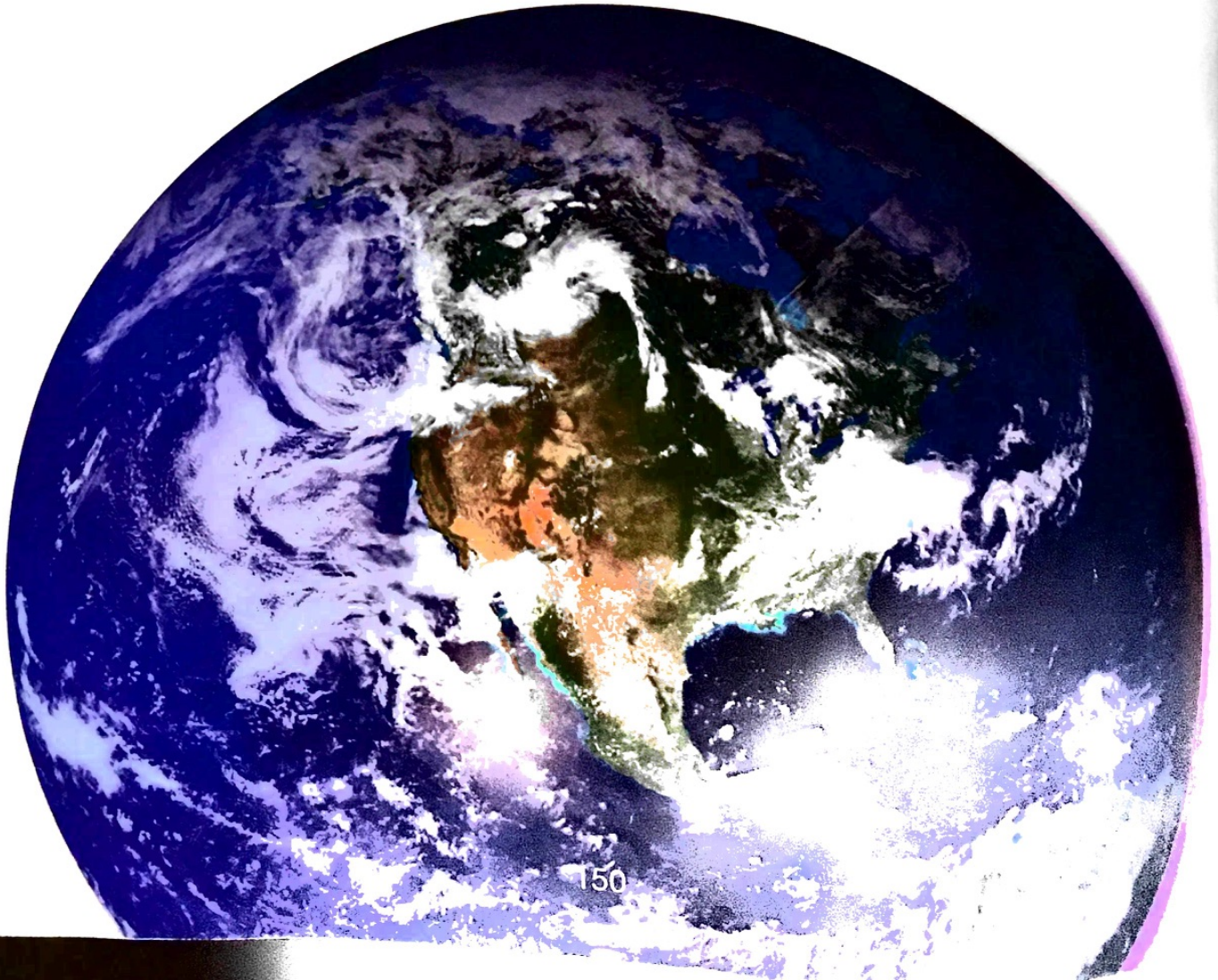
The surface of Venus is hot and cratered.

Earth

Moon

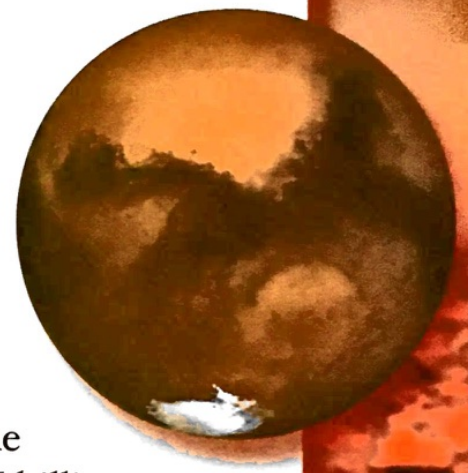
Earth is the third planet from the Sun. Earth has a moderate (mild) temperature all the time. It has an atmosphere of nitrogen and oxygen, and it has liquid water. As far as we know, Earth is the only place in the universe that has life. Earth also has one large satellite called the **Moon,** or Luna. The Moon orbits Earth once a month. The Moon is responsible for the tides in Earth's oceans. The Moon is the only **extraterrestrial** place humans have visited.

Earth is 150 million kilometers (93 million miles) from the Sun. This is a huge distance. It's hard to imagine that distance, but think about this. Sit in one end zone of a football field and curl up into a ball. You are the Sun. A friend goes to the other end zone and holds up the eraser from a pencil. That's Earth. Get the idea? Earth is tiny, and it is a long distance from the Sun. Still, the solar energy that reaches Earth provides the right amount of energy for life as we know it.



Mars

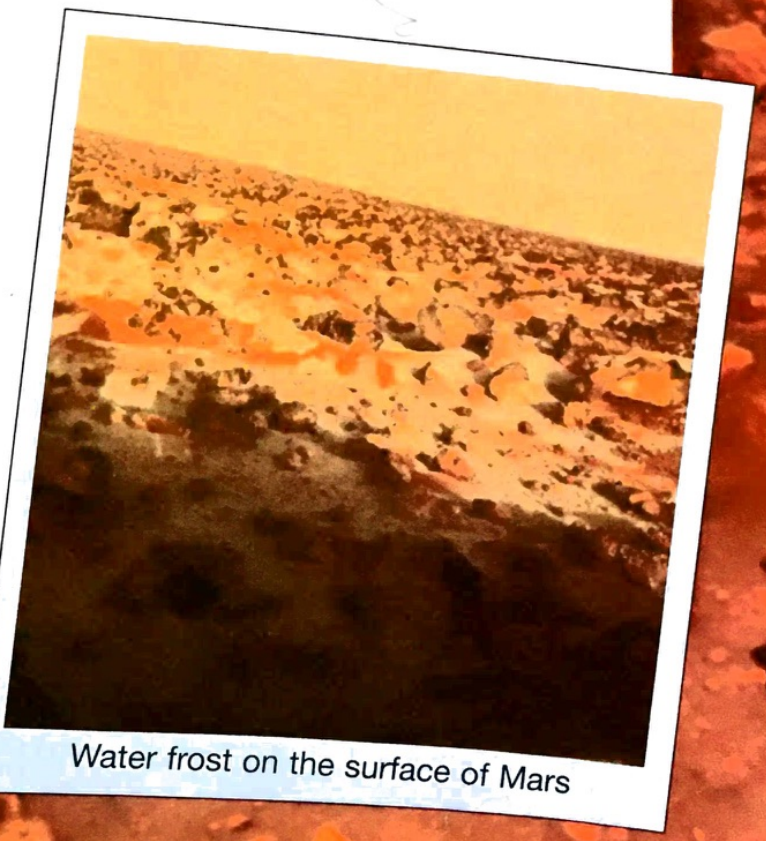
Mars is the fourth planet from the Sun and has two small satellites, Phobos and Deimos. Mars is a little like Earth, except it is smaller, colder, and drier. There are some places on Mars that are like Death Valley in California. Other places on Mars are more like Antarctica and the volcanoes of Hawaii.



Mars is sometimes called the Red Planet because of its red soil. The soil contains iron oxide, or rust. The iron oxide in the soil tells scientists that Mars probably had liquid water at one time. But liquid water has not been on Mars for 3.5 billion years. It has frozen water in polar ice caps that grow and shrink with the seasons on Mars.

Mars is the next likely place humans will visit. But exploring Mars will not be easy. Humans can't breathe the thin atmosphere of carbon dioxide. And explorers will need to wear life-support spacesuits for protection against the cold.

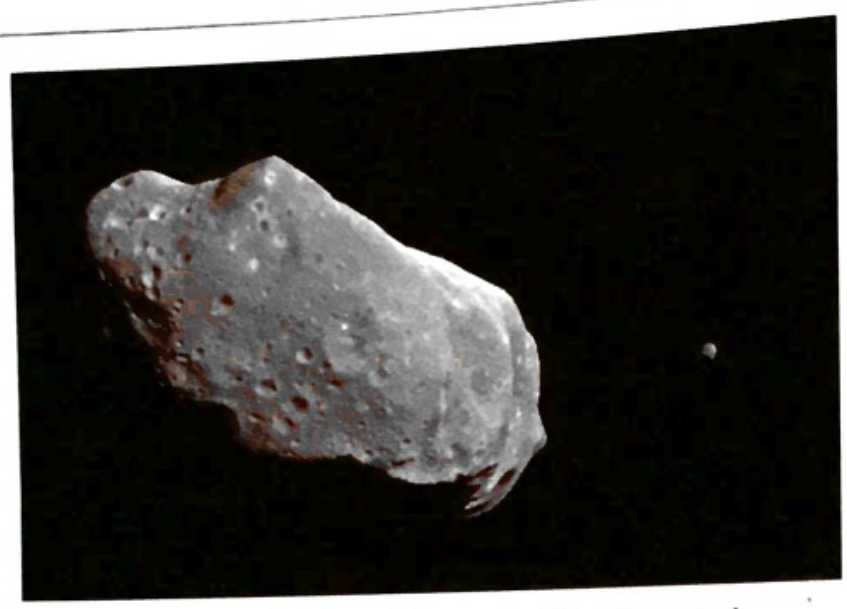
Several robotic landers, such as *Viking, Spirit, Opportunity,* and *Sojourner,* have observed Mars and sent back information about the surface and possibility of water. There is evidence that there is a lot of frozen water just under the surface.



Water frost on the surface of Mars

Asteroids

Beyond the orbit of Mars there are millions of chunks of rock and iron called asteroids. They all orbit the Sun in a region called the asteroid belt. The asteroid belt is like the boundary of the terrestrial planets. The planets farther out are quite different from the terrestrial planets.

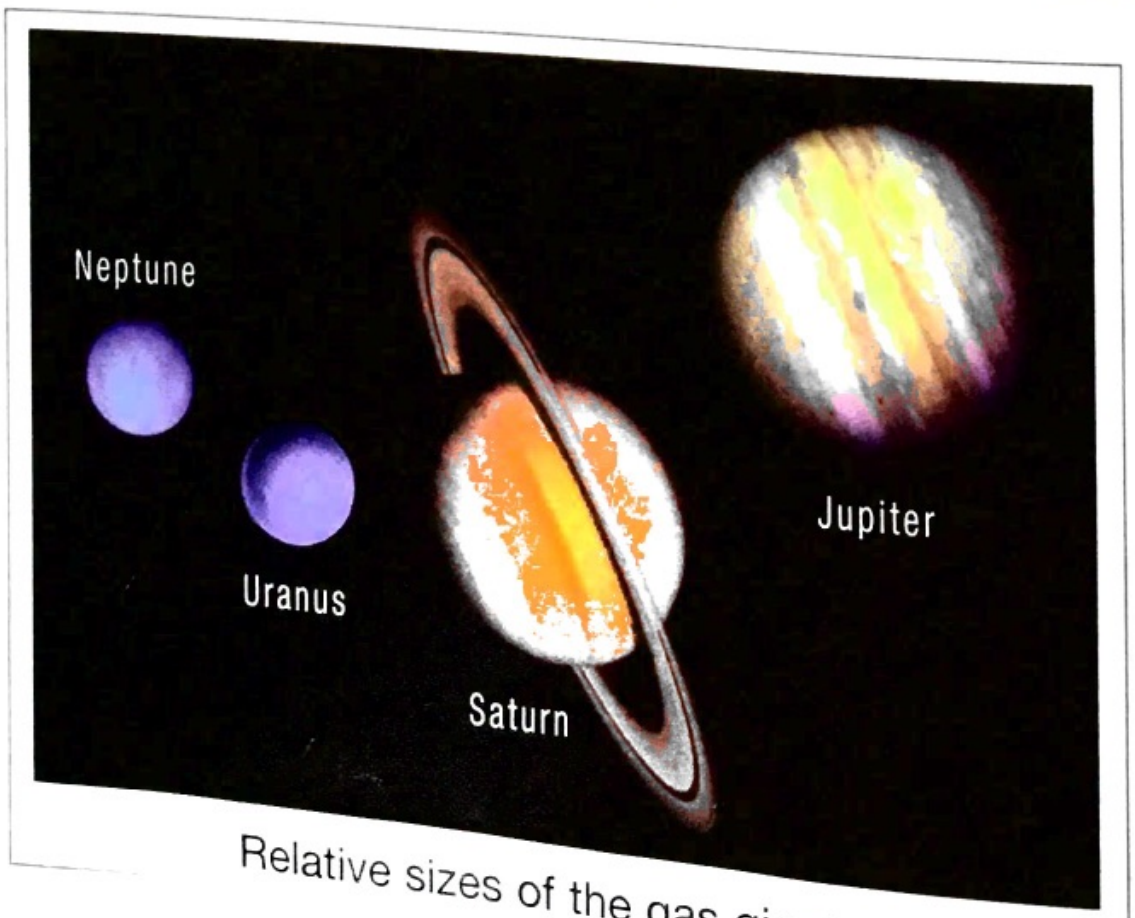


Asteroid Ida with satellite Dactyl

Some asteroids even have moons. When the spacecraft *Galileo* flew past asteroid Ida in 1993, scientists were surprised to find it had a satellite. They named the tiny moon Dactyl. The biggest asteroid is Ceres. It is about 960 kilometers (600 miles) around.

Gas Giants

The next four planets are the gas giants. They do not have rocky surfaces like the terrestrial planets. So there is no place to land or walk around on them. They are much bigger than the terrestrial planets. What we have learned about the gas giants has come from probes sent out to fly by and orbit around them. Even though the gas giants are all made of gas, each one is different.

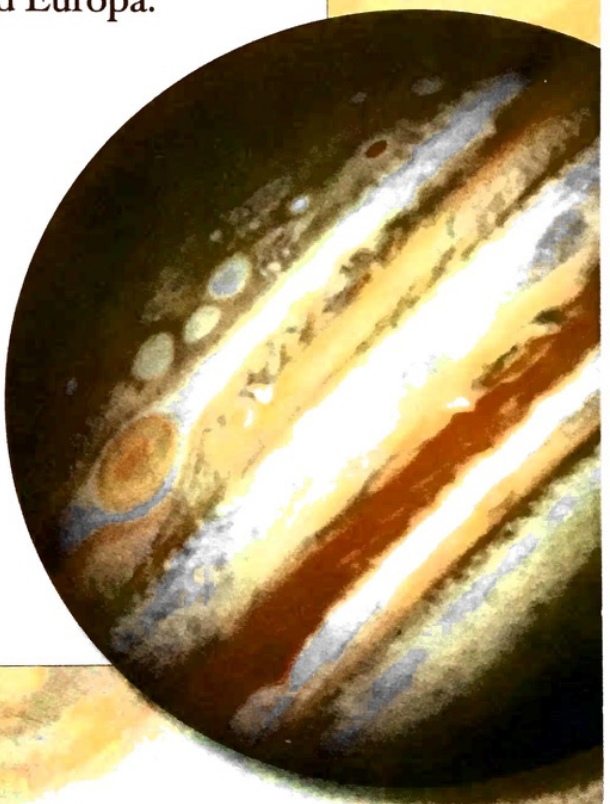


Relative sizes of the gas giants

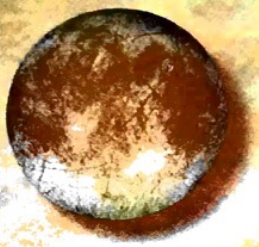
Jupiter

Jupiter is the fifth planet from the Sun. Jupiter is the largest planet in the solar system. It is 11 times larger in diameter than Earth. Sixty-three moons have been found to orbit Jupiter. The four largest moons are Ganymede, Callisto, Io, and Europa.

Jupiter's atmosphere is cold and poisonous. It is mostly hydrogen and helium. The stripes and swirls on Jupiter's surface are cold, windy clouds of ammonia and water. Its Great Red Spot is a giant storm as wide as three Earths. This storm has been raging for hundreds of years. On Jupiter, the atmospheric pressure is so strong it squishes gas into liquid. Jupiter's atmosphere could crush a metal spaceship like a paper cup.



Jupiter

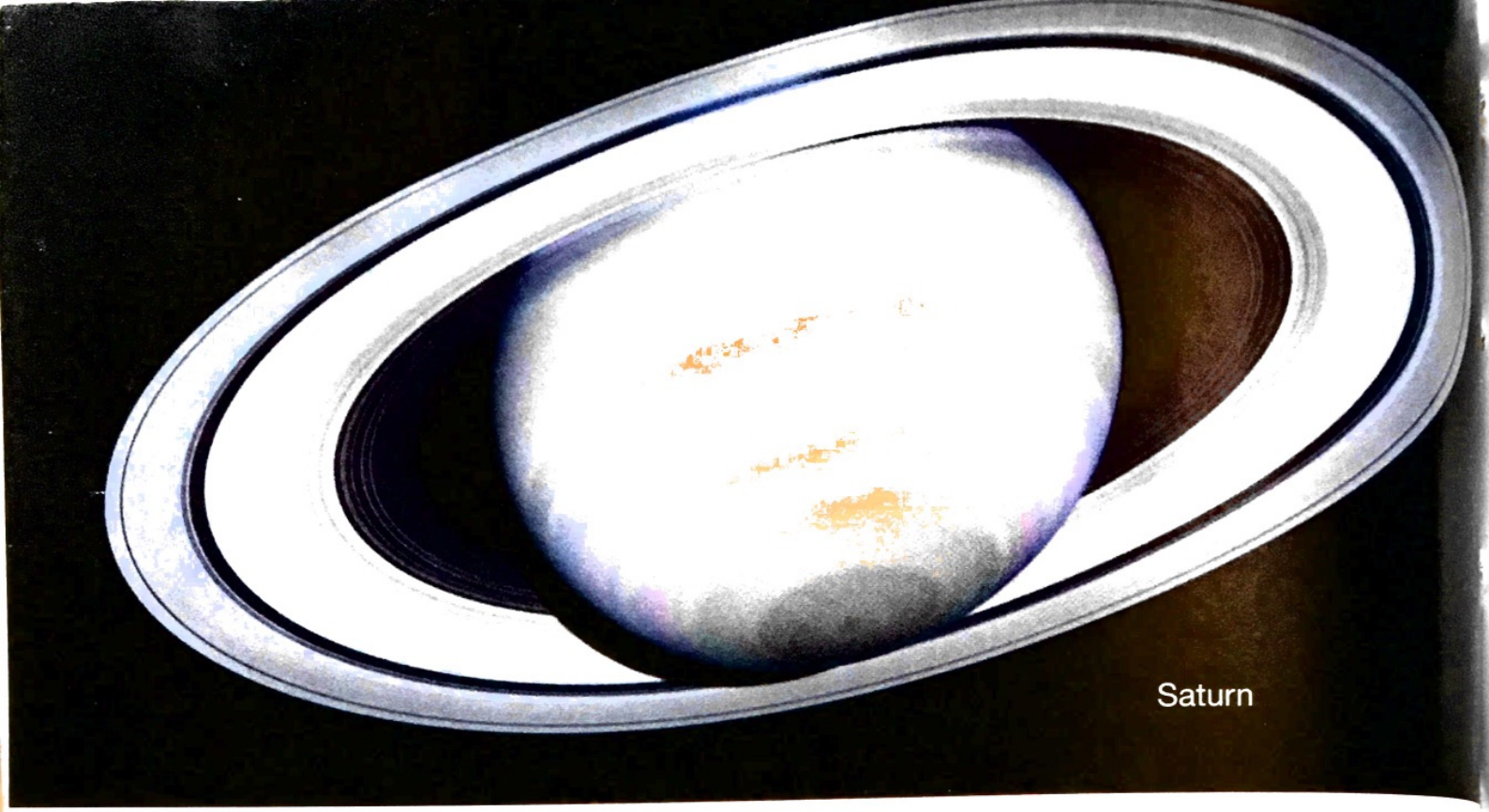


Europa

Ganymede

Callisto

Io

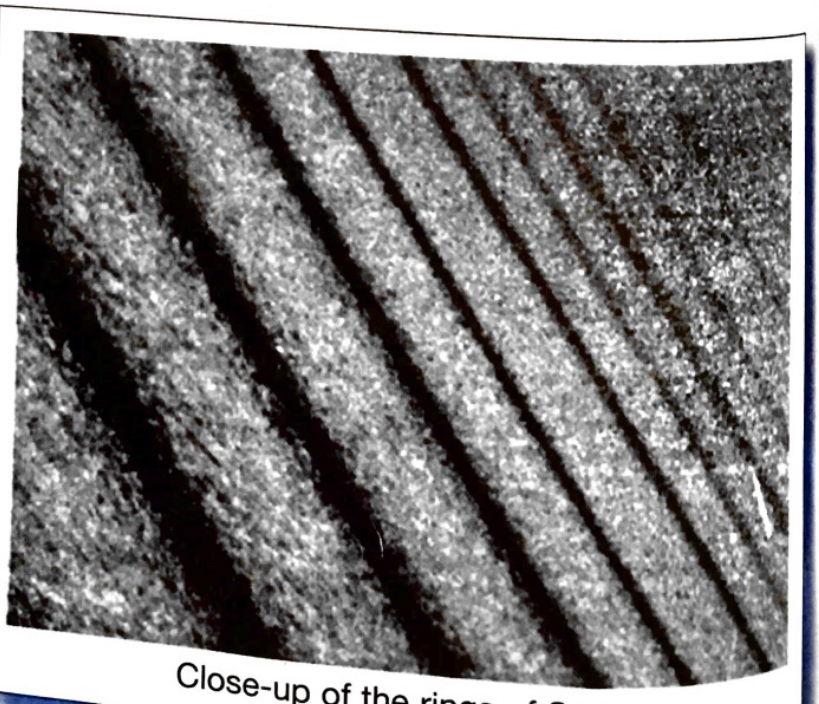


Saturn

Saturn

Saturn is the sixth planet from the Sun. Saturn is the second biggest planet and is very cold. There are at least 46 satellites orbiting Saturn. Saturn is made up mostly of hydrogen, helium, and methane. It doesn't have a solid surface. It has clouds and storms like Jupiter, but they are harder to see because they move so fast. Winds in Saturn's upper atmosphere reach 1,825 kilometers per hour (1,135 miles per hour).

The most dramatic feature of Saturn is its ring system. The largest ring reaches out 200,000 kilometers (125,000 miles) from Saturn's surface. The rings are made of billions of small chunks of ice and rock. All the gas giants have rings, but the others are not as spectacular as Saturn's.

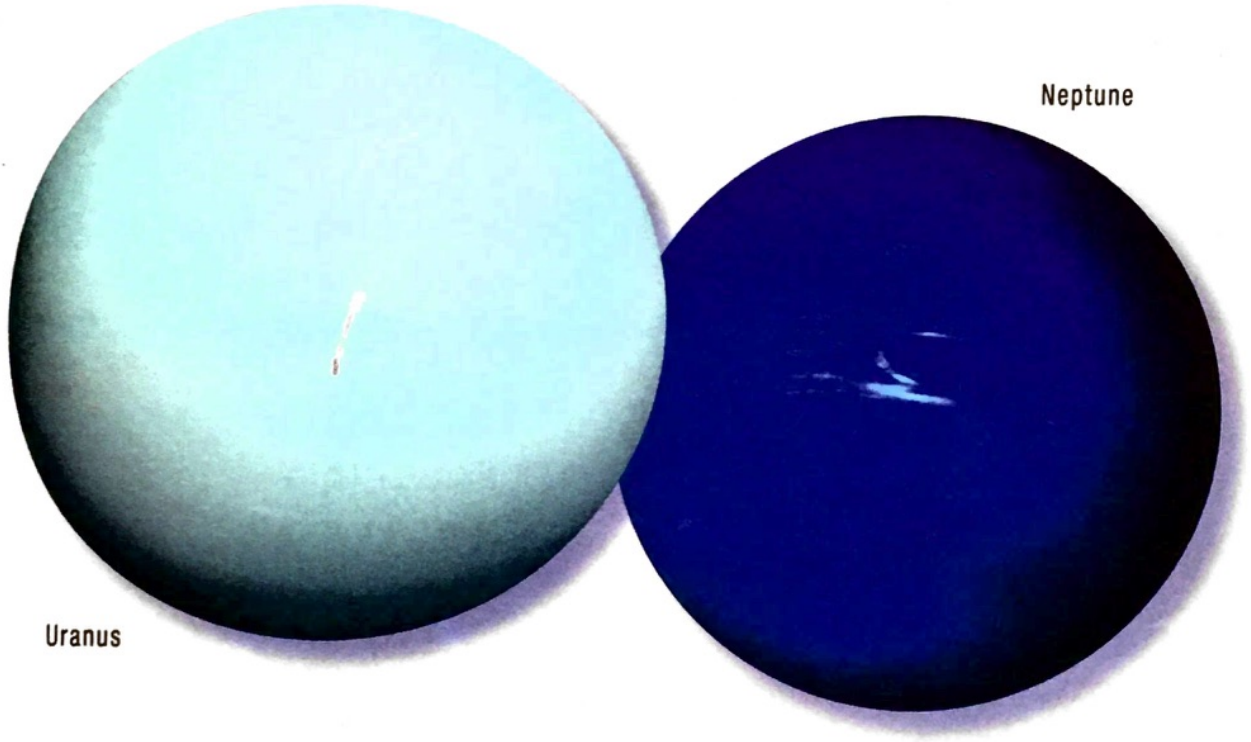


Close-up of the rings of Saturn

Uranus

Uranus is the seventh planet from the Sun. Uranus has 27 moons and 11 rings. Uranus is very cold and windy, and would be poisonous to humans. It is smaller and colder than Saturn.

Uranus has clouds that are extremely cold at the top. Below the cloud tops there is a layer of extremely hot water, ammonia, and methane. Near its core, Uranus heats up to 4,982°C (9,000°F). Uranus appears blue because of the methane gas in its atmosphere.



Neptune

Neptune is the eighth planet from the Sun. Neptune has 13 moons and 4 thin rings. Neptune is the smallest of the gas giants, but is still the fourth largest planet in the solar system.

Neptune is made mostly of hydrogen and helium with some methane. Neptune may be the windiest planet in the solar system. Winds rip through the clouds at more than 2,000 kilometers per hour (1,200 miles per hour). Scientists think there might be an ocean of super-hot water under Neptune's cold clouds. It does not boil away, because of the incredible pressure.

Kuiper Belt

Pluto

Out beyond the gas giants is a disk-shaped zone of icy objects called the Kuiper Belt. Some of the objects are fairly large. **Pluto** is one of the Kuiper Belt objects. Some scientists considered Pluto a planet because it is massive enough to pull itself into a sphere. Others did not consider Pluto a planet. To them, Pluto was just one of the large pieces of debris in the Kuiper Belt. Scientists now call Pluto a dwarf planet.

Pluto has a thin atmosphere. It is so cold on Pluto that the atmosphere actually freezes and falls to Pluto's surface when it is farthest from the Sun. Even though Pluto is smaller than Earth's Moon, it has its own satellite. It is called Charon and is about half the size of Pluto.

Pluto and its moon Charon

Eris

In July 2005, astronomers at the California Institute of Technology announced the discovery of a new planet-like object. It is called Eris. Like Pluto, Eris is a Kuiper Belt object and a dwarf planet. But Eris is more than twice as far away from the Sun as Pluto! The picture to the right is an artist's idea of what the Sun would look like from a position close to Eris.

A painting showing that the Sun would look like a bright star from Eris

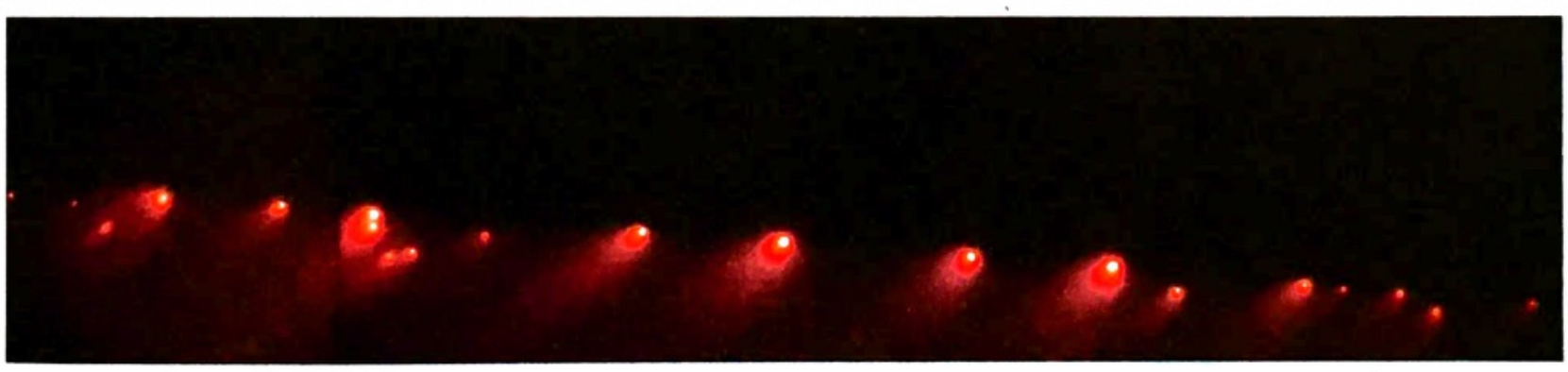
Comets

Comets are big chunks of ice, rock, and gas. Sometimes comets are compared to dirty snowballs. Scientists think comets might have valuable information about the origins of the solar system.


Comets have been called dirty snowballs.

Comets orbit the Sun in long, oval paths. Most of them travel way beyond the orbit of Pluto. A comet's trip around the Sun can take hundreds or even millions of years, depending on its orbit. A comet's tail shows up as it nears the Sun and begins to warm. The gases and dust that form the comet's tail always point away from the Sun.

Comet orbits can cross those of the planets. In July 1994 a large comet, named Comet Shoemaker-Levy 9, was on a collision course with Jupiter. As it got close to Jupiter, the comet broke into 21 pieces.


Comet Shoemaker-Levy 9 broke into pieces as it got close to Jupiter.

The pieces slammed into Jupiter for a week. Each impact created a crater in Jupiter's surface larger than planet Earth.


Two of the 21 larger than Earth-size craters on Jupiter

Review Questions

1. What is the Sun and what is it made of?
2. What is the solar system?
3. Which planets are terrestrial planets? Which planets are gas giants?
4. What is the Kuiper Belt and what is found there?
5. Which planet has the most moons orbiting it?
6. How are asteroids and comets alike and different?

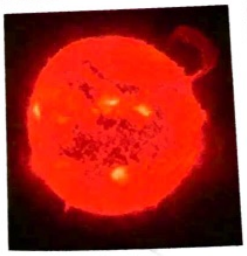
ES5a. Students know the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.

Ramon E. Lopez

As strange as it may sound, there is weather in space. But it's not weather like we have on Earth. There are no clouds, hurricanes, or snowstorms in space. Space weather is the result of activities on the Sun. The Sun is always radiating energy into the solar system. The regular flow of light and gases is called **solar wind.** But what happens when the Sun goes through a period of violent solar flares? That's what Dr. Ramon E. Lopez (1959–) studies.

Ramon E. Lopez

Solar flares, which are huge solar explosions, send intense blasts of electrified gas into Earth's atmosphere. The blasts can produce electric effects in the atmosphere and on Earth's surface. The electricity can disable satellites orbiting Earth and interfere with radio transmissions and cell-phone operation. Space weather can cause blackouts over large areas.



Sun with a large flare

Lopez and his team understand how space weather can damage communication and navigation systems. And they understand how important these systems are to modern society. Will Lopez be able to predict the space weather? Will he be able to warn the world when a dangerous storm is coming from the Sun? Lopez believes that the team he works with may be able to develop a computer program to predict space weather about 30 minutes before it hits Earth. And that may be just long enough to take steps to protect communication and navigation systems from damage.

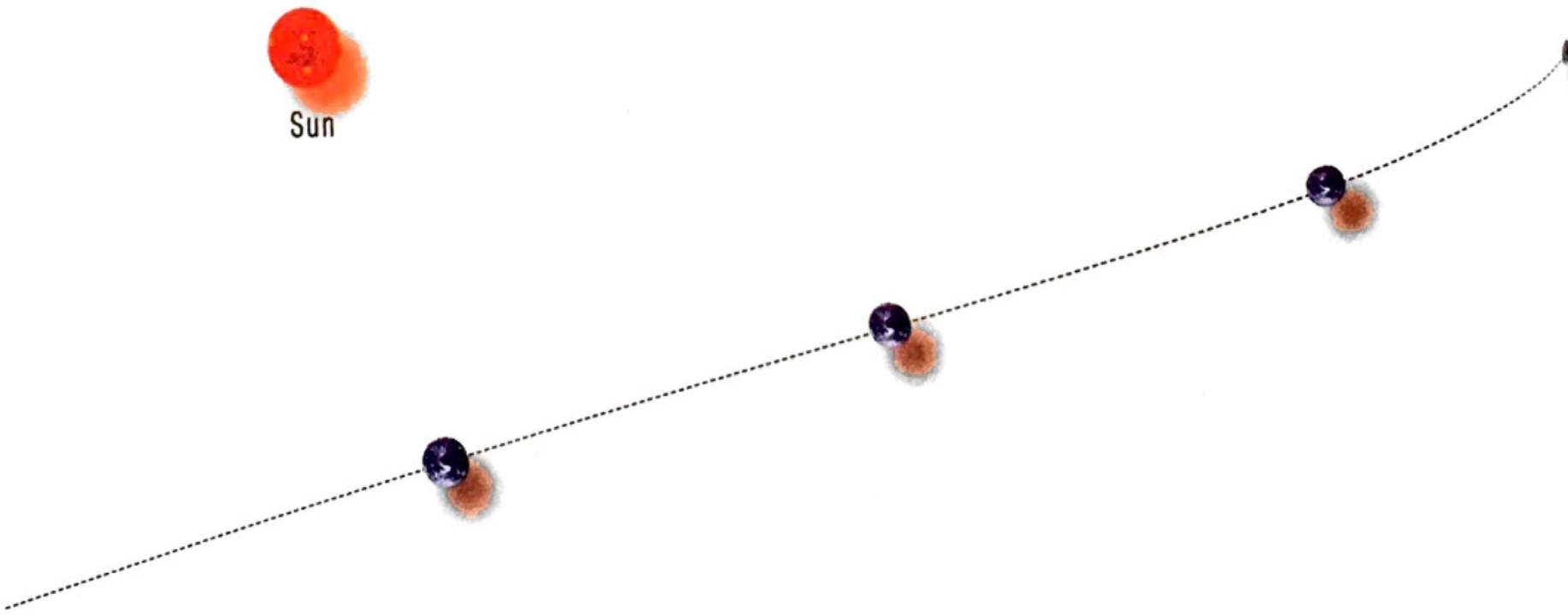
INVESTIGATION 1

ES5c. Students know the path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.

Why Doesn't Earth Fly Off into Space?

Earth travels around the Sun in a predictable, almost-circular path once a year. That's a distance of about 942 million kilometers (584 million miles) each year. That's an incredible 2.6 million kilometers (1.6 million miles) each day! That's fast.

One important thing to know about objects in motion is that they travel only in straight lines. Objects don't change direction or follow curved paths unless a force pushes or pulls them in a new direction. If nothing pushed or pulled on Earth, it would fly off into space in a straight line.

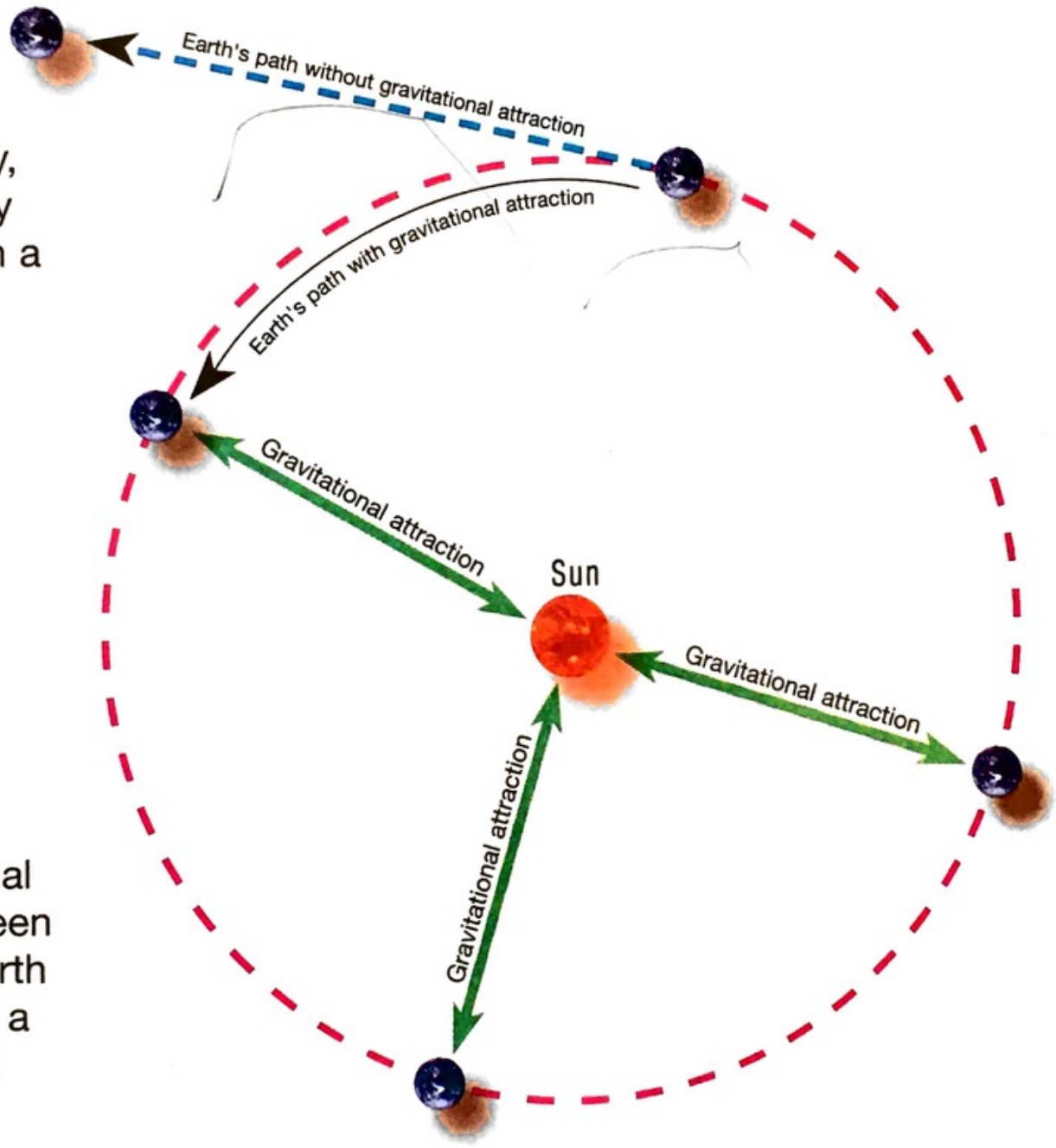


But Earth doesn't fly straight off into space. Earth travels in a circular path around the Sun. In order to travel a circular path, Earth has to change direction all the time. Something has to push or pull Earth to change its direction. What is pushing or pulling our planet Earth? **Gravity.**

Gravity is the force of attraction between masses. The Sun is a mass. Earth is a mass. The force of attraction between the Sun and Earth pulls hard enough to change Earth's direction of travel.

Remember the string-and-ball demonstration? The hand pulled on the string. The string pulled on the ball. The ball traveled in a circular orbit. Gravity is like the string. The **gravitational attraction** between the Sun and Earth pulls on Earth, changing its direction of travel. That's why Earth travels in a circular orbit around the Sun.

With no gravity, Earth would fly off into space in a straight line.



The gravitational attraction between the Sun and Earth keeps Earth in a circular orbit.

Sun's gravity keeps all the planets in their orbits. Otherwise, the planets would fly in straight lines right out of the solar system.

Review Questions

1. **Why do planets stay in orbit around the Sun?**
2. **How is a ball on a string like a planet in its orbit?**
3. **What keeps the Moon in its orbit around Earth?**

Mae Jemison: Astronaut

Dr. Mae Jemison (1956–) was born in Decatur, Alabama. She moved to Chicago, Illinois, as a child, where an uncle introduced her to **astronomy.** In high school Jemison began reading books on astronomy and space travel. She was only 16 years old when she entered college. She earned degrees in chemical engineering and African and Afro-American studies from Stanford University. She went on to earn her medical degree from Cornell University.

Mae Jemison, astronaut

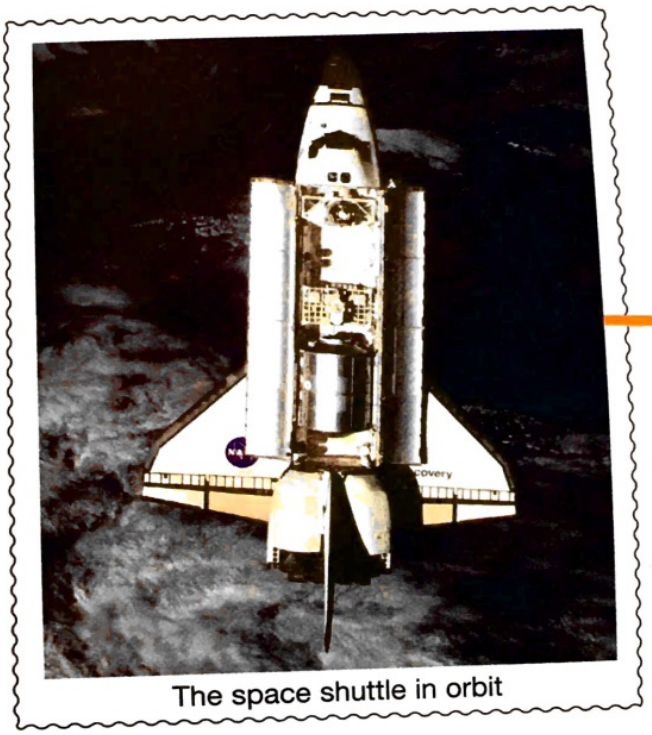
After becoming a doctor, Jemison spent time in western Africa as a Peace Corps physician. But she continued to think about astronomy and space travel. She wanted to be part of the space program.

The official patch of shuttle mission STS-47

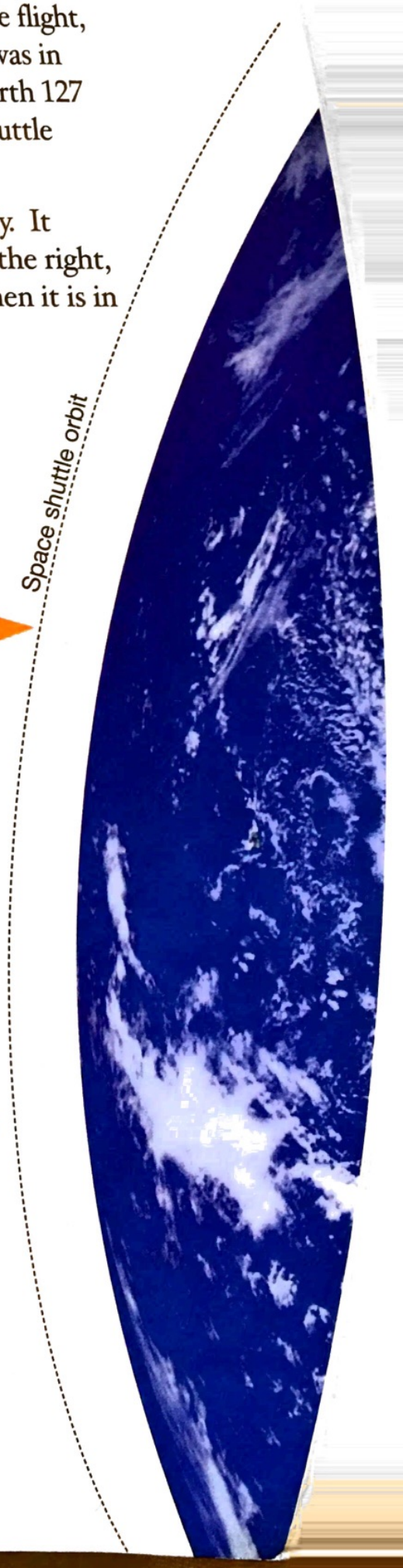
Jemison was admitted into the astronaut program in 1987. On September 12, 1992, Jemison became the first African-American woman in space. She was a science mission specialist on the space shuttle *Endeavour.* Jemison conducted experiments to find out more about the effects of being in space. She studied motion sickness, calcium loss in bones, and weightlessness.

Space shuttle mission STS-47 was the 50th space shuttle flight, but only the second flight for the *Endeavour*. The shuttle was in space for 8 days. During those 8 days, Jemison orbited Earth 127 times at an altitude of 307 kilometers (191 miles). The shuttle traveled 5,234,950 kilometers (3,245,669 miles).

Does the space shuttle actually fly in space? Not really. It orbits Earth in the upper atmosphere. In the picture to the right, you can see how close the shuttle is to Earth's surface when it is in orbit. What keeps the shuttle in orbit?



The space shuttle in orbit



Again, gravity. The shuttle travels very fast. Earth's gravity pulls on the shuttle, constantly changing the shuttle's direction of travel. Engineers from the National Aeronautics and Space Administration (NASA) have figured out exactly how fast the shuttle must travel and how high it must be above Earth's surface. They know how strong the force of gravity is. With these data, the space shuttle stays in orbit until the astronauts change the shuttle's speed. Then gravity pulls the shuttle back to Earth. Mission complete.

Summary: Solar System

The **Milky Way** galaxy has hundreds of billions of **stars.** We live just 150 million kilometers (93 million miles) from one of them. That star is Sol, our **Sun.**

The Sun is not alone. **Planets, satellites, asteroids, comets,** and other objects travel in **orbits** around the Sun. The Sun and all the bodies that circle it make up the **solar system.**

The Sun

The Sun is by far the largest object in the solar system. It accounts for 99.8% of the mass in the whole solar system. And the Sun is about 109 times bigger than **Earth** in diameter. But unlike Earth, the Sun is made mostly of **hydrogen** (72%) and **helium** (26%). The light and heat radiating from the Sun are created as hydrogen atoms combine to make helium.

The Sun is an average star.

The Planets

Planets are large natural objects that orbit the Sun. There are two major groups of planets in the solar system. Mercury, Venus, Earth, and Mars are **terrestrial planets.** They are close to the Sun, small, and made of rock. Mercury and Venus have no satellites. Earth has one moon, and Mars has two.

Jupiter, Saturn, Uranus, and Neptune are **gas giants.** The gas giants are far from the Sun, huge, and made of gas. Nothing can land on the surface of a gas giant. They all have rings surrounding them, but Saturn's rings are the easiest to see. All the gas giants have moons. Jupiter, the largest of the solar-system planets, has the most moons, 63. Neptune has the fewest, 13.

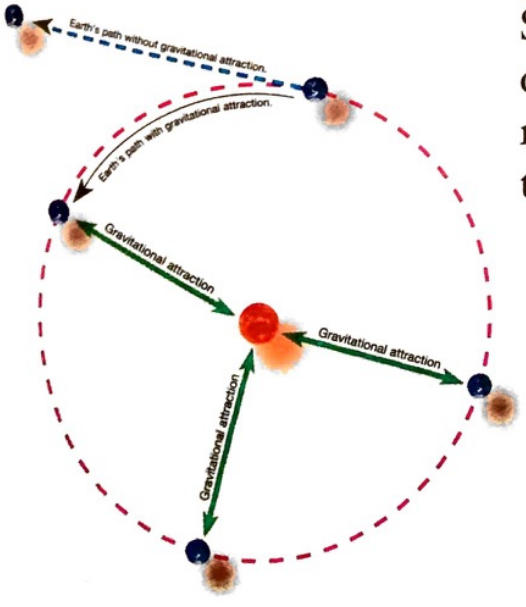
Pluto is a small, icy body beyond the orbits of the gas giants. It is in a region of icy debris called the **Kuiper Belt.** Pluto is smaller than Earth's **Moon.**

Other Solar-System Objects

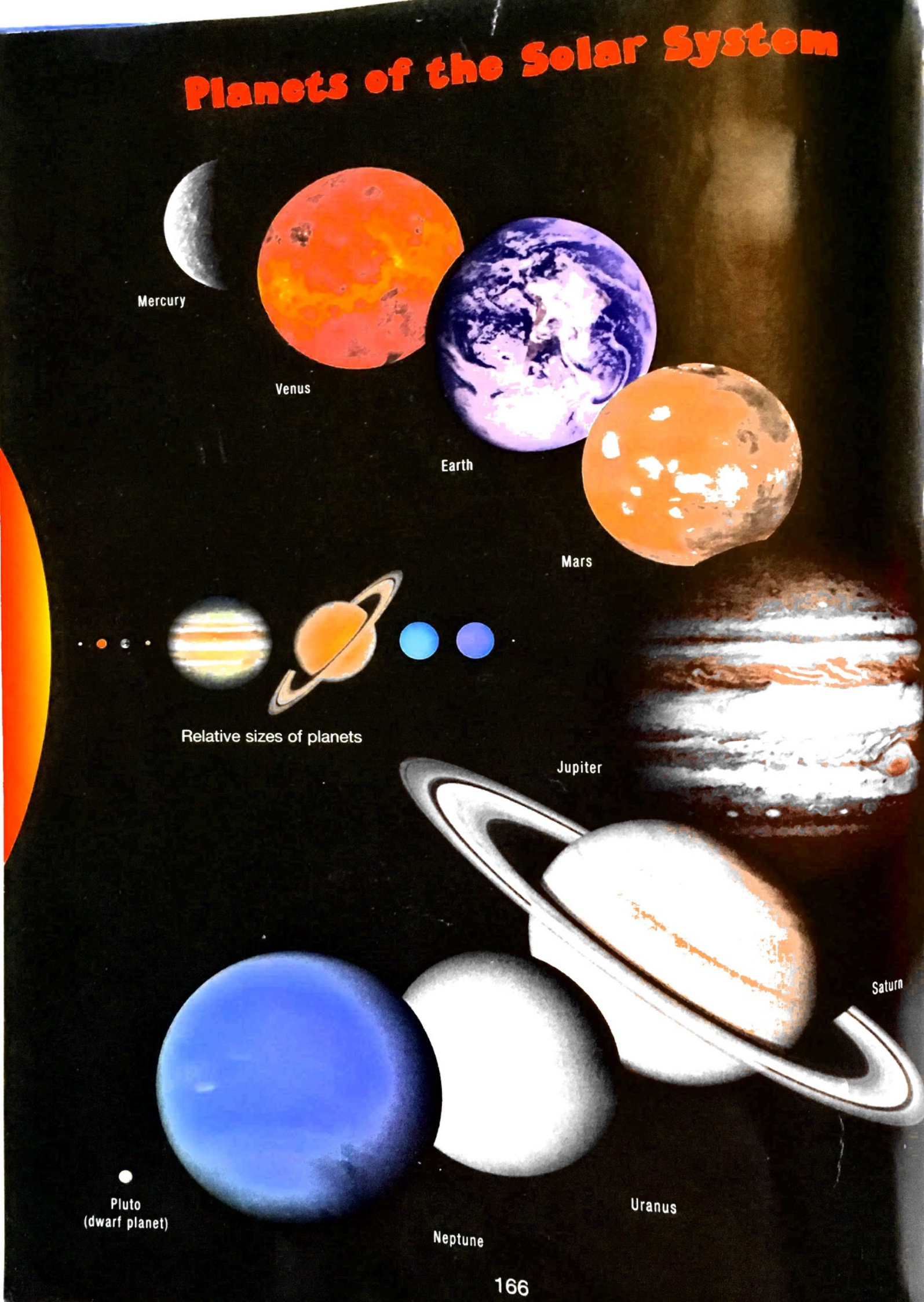
The small terrestrial planets are separated from the gas giants by the asteroid belt. This is a collection of millions of rocky chunks orbiting the Sun. Occasionally one gets knocked out of orbit. Some of the most interesting solar-system objects are comets. They come from the Kuiper Belt or even farther out. Comets have large oval orbits that only rarely bring them into the inner solar system. Some comets come back close to the Sun after a million years.

Everything Goes Around

Moving objects travel in straight lines unless a force acts to change their direction. Planets are moving objects. They should travel in straight lines and fly out of the solar system. But the planets don't fly off into space because Sun's **gravity** pulls on the planets and changes their direction of travel. The result is almost-circular orbits around the Sun.



Planets of the Solar System



Relative sizes of planets

Summary Questions

Now is a good time to review what you have recorded in your science notebook. Think about the solar system and the objects that are found in it.

1. What are the main objects in the solar system? How are they alike or different?
2. What is the Sun? What is it made of? What is its role in the solar system?
3. Why do the planets and other objects in the solar system stay in their orbits?

California Science Standards

ES5a. Students know the Sun, an average star, is the central and largest body in the solar system and is composed primarily of hydrogen and helium.

ES5b. Students know the solar system includes the planet Earth, the Moon, the Sun, eight other planets and their satellites, and smaller objects, such as asteroids and comets.

ES5c. Students know the path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.

Vocabulary

- Milky Way
- star
- Sun
- planet
- satellite
- asteroid
- comet
- orbit
- solar system
- Earth
- hydrogen
- helium
- terrestrial planet
- gas giant
- Kuiper Belt
- Moon
- gravity