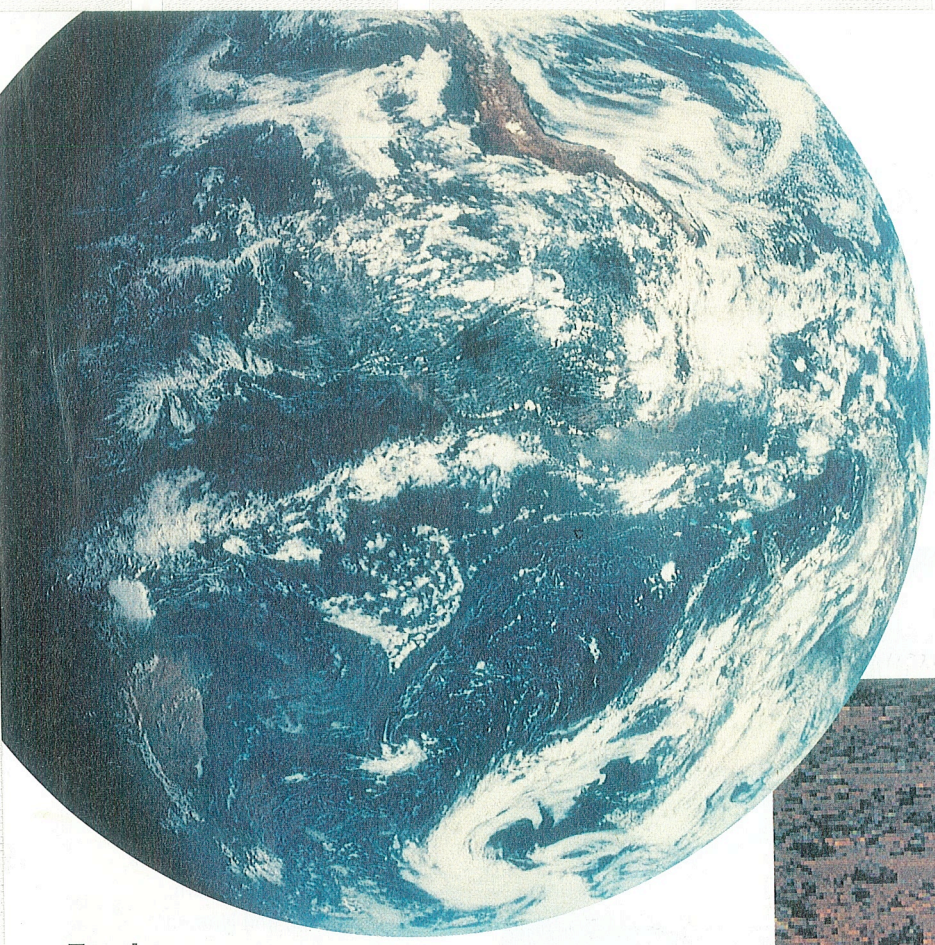
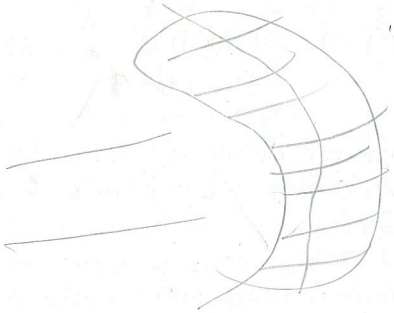
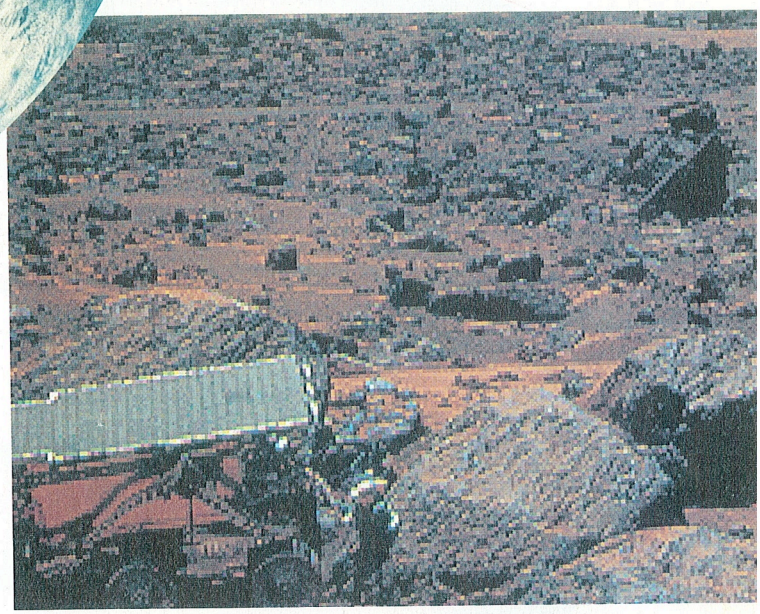






Earth

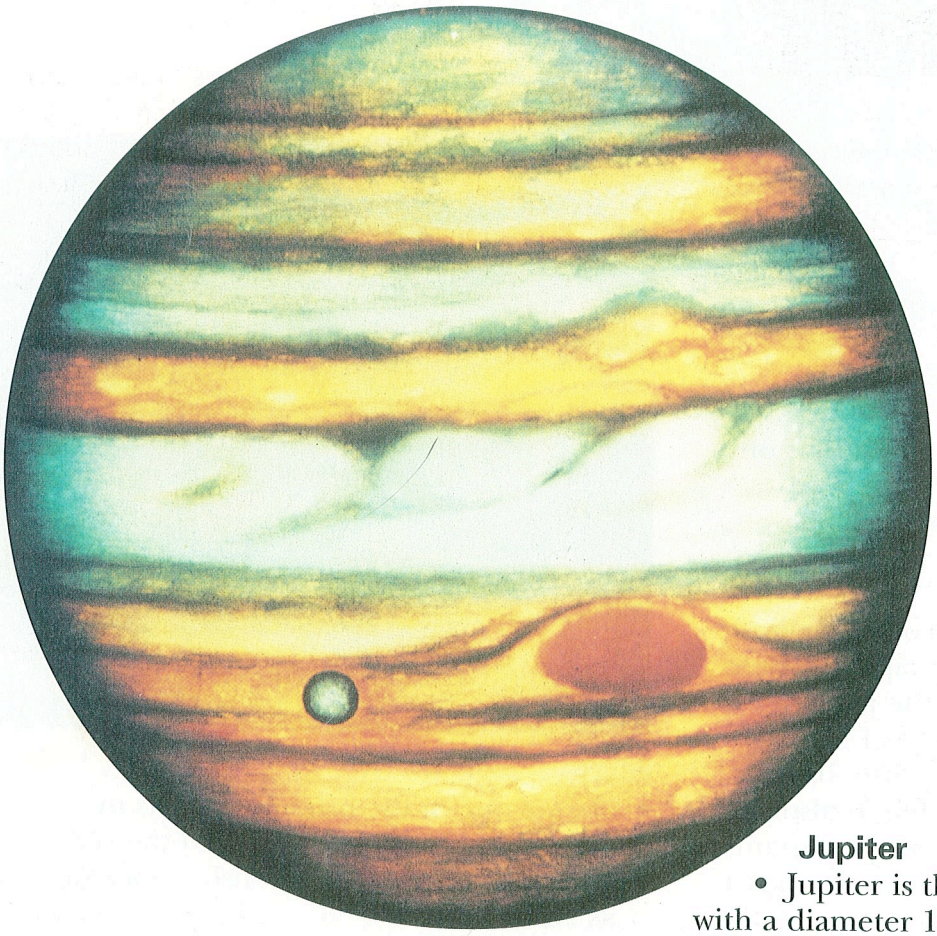
- From our point of view, the conditions on Earth are ideally suited for life, but we should remember that it is actually the other way around: life is ideally suited for Earth.
- Earth's unique atmosphere contains mostly nitrogen, oxygen, and water vapour. There is also a small amount of ozone in the atmosphere which filters some of the damaging radiation from the Sun, but lets enough through to support life. It also keeps the temperatures relatively constant between day and night, although there is a wide variation of temperatures between the poles and the equator (–85°C to about 65°C).
- Vast amounts of liquid water in the lakes, rivers, and oceans cover over 70% of the planet's surface.
- Much of the land surface has soil, resulting from erosion and organic material, covering the solid rock. This is an ideal medium for the growth of land plants.
- There are some active volcanoes and earthquakes changing the face of the planet, but it is mostly considered to be stable.

Mars

- Mars is one of the brighter objects in the sky and is sometimes called the red planet because of the reddish colour of its rusty soil.
- In 1997 the space probe *Pathfinder* landed on Mars, carrying a small vehicle called the *Sojourner* rover, which drove around exploring, sending images back to Earth, and collecting all kinds of data.
- Although it is very dry and barren now, there is evidence that Mars once had volcanoes, glaciers, and floods of water. Scientists have been especially interested in the possibility of some form of life there, and they have studied Mars more closely than any other planet, except Earth. No signs of life have yet been found, however.

The Outer Planets

Lying in the vast regions of the solar system beyond the four inner planets are the remaining five planets. They are called the **outer planets**. Four of these, Jupiter, Saturn, Uranus, and Neptune, are large, and their atmospheres consist mainly of the gases hydrogen and helium, which have low densities. For this reason, these four planets are called the **gas giants**. The gas giants appear to lack solid surfaces. Deep inside the atmosphere of these giant planets, the gases may become more dense, eventually becoming liquids and solids. The cores of these planets may contain metals, as those of the inner planets do. The outermost planet, Pluto, is unique among the outer planets.

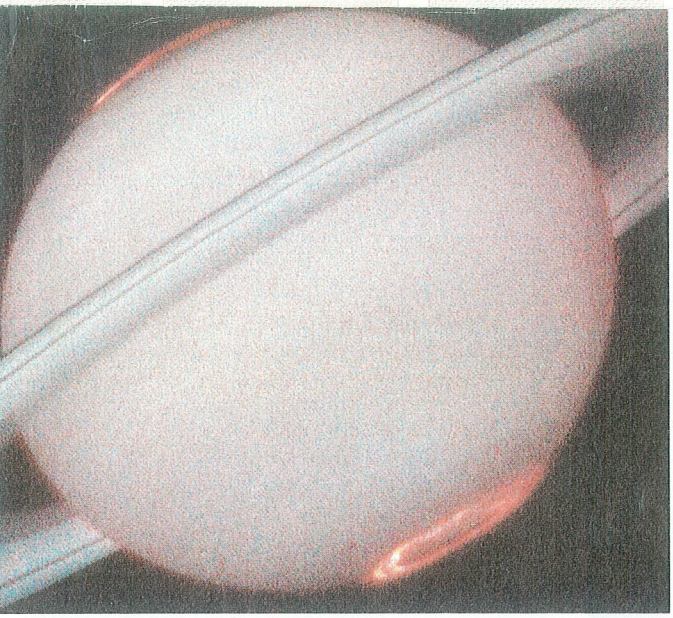


Did You Know

A space probe launched toward Neptune now would take about 30 years to get there. Why, then, did *Voyager 2* take only 12 years to travel the distance? The reason is that Jupiter, Saturn, Uranus, and Neptune were lined up in a way that allowed their forces of gravity to increase the probe's speed. This alignment occurs only once every 176 years!

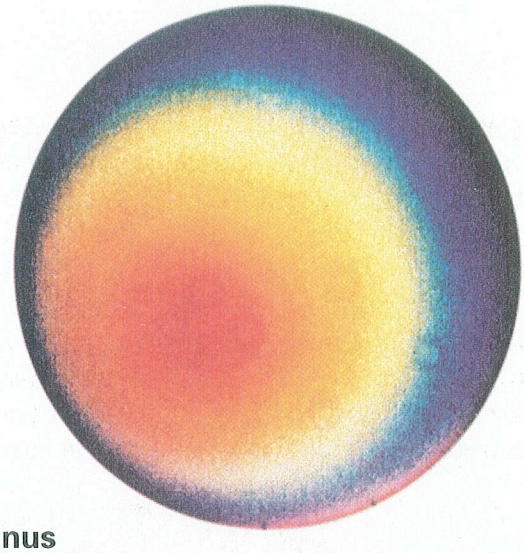
Jupiter

- Jupiter is the largest of all the planets: with a diameter 11 times that of Earth it has a greater mass than all the other planets combined. Its large size, plus the large amount of light reflected by its clouds, makes Jupiter very bright in the night sky.
- Jupiter's most interesting features are its coloured bands and the Great Red Spot, a huge hurricane fed by constant high winds. Larger than the size of two Earths, this hurricane already existed hundreds of years ago, when people first looked at Jupiter through telescopes, and it still shows no sign of dying away.
- Jupiter and its 16-or-so moons have been observed from close range by several space probes: *Pioneers 10* and *11*, *Voyagers 1* and *2*, and *Galileo*. You might even be able to see four of these moons—Io, Europa, Ganymede, and Callisto—through binoculars. What you can't see from Earth, however, are Jupiter's orbiting rings of rocks.



Saturn

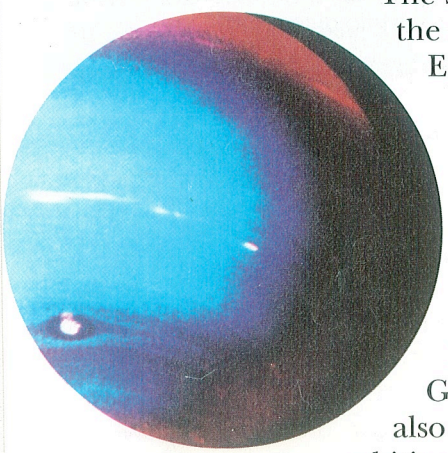
- Saturn, at about five-sixths the diameter of Jupiter, is the second largest planet in the solar system. The least dense of all the planets, it is possible that it has no solid core.
- Saturn's atmosphere is cloudy and, because of its quick rotation, windy. Saturn is farther from the Sun than Jupiter, so its average temperature is lower: about –180°C.
- For hundreds of years, people thought that Saturn was the only planet with rings. Detailed images sent by *Pioneer 11* and the two *Voyager* space probes showed that there are actually over 1000 separate rings. Astronomers are not certain whether the rings formed at the same time as the planet or are the crumbled remains of one of Saturn's many moons or some other object that came too close to the planet.



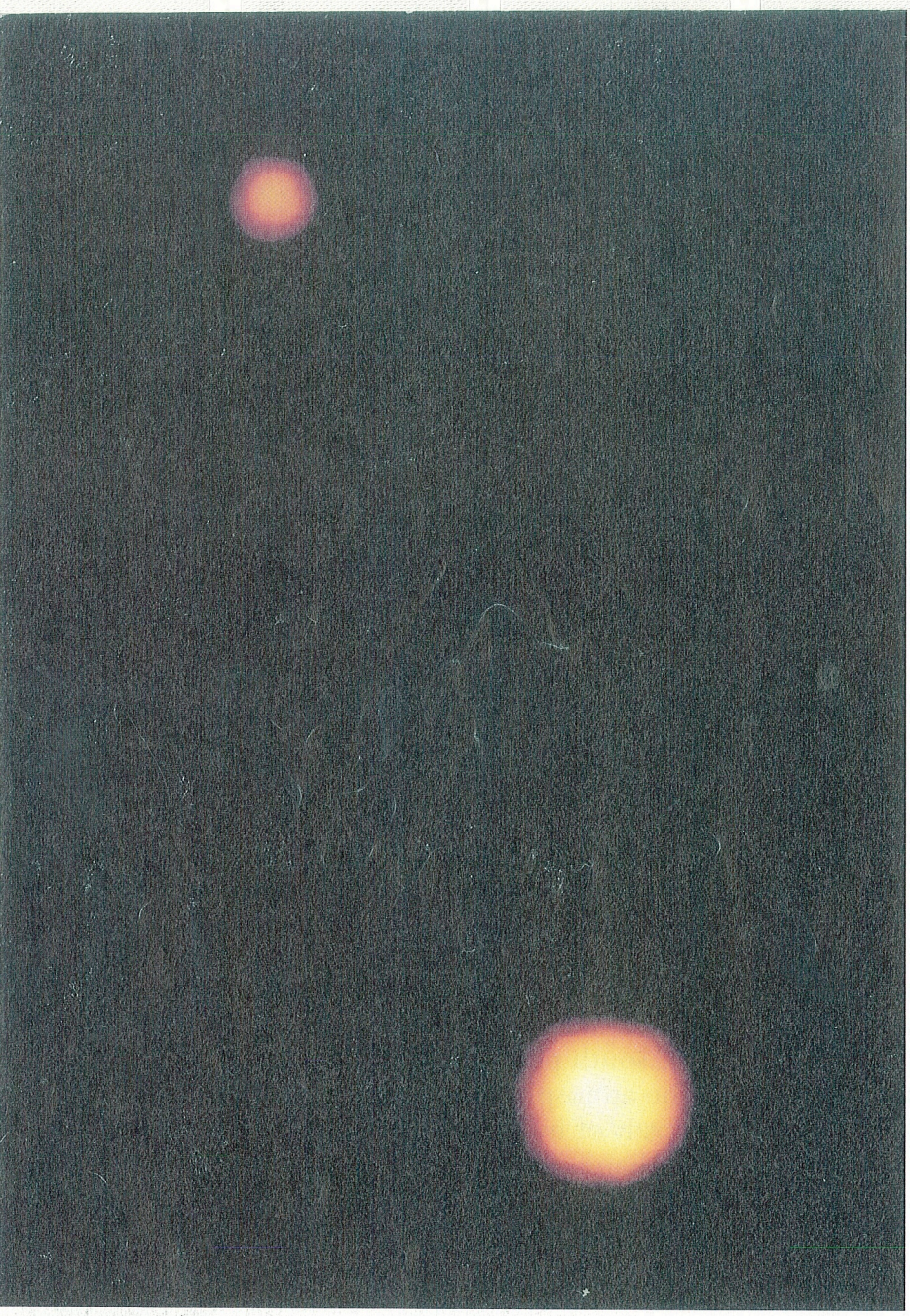
Uranus

- Although Uranus's diameter is almost four times that of Earth, it is so far away that it looks like a faint star. It was actually thought to be a star until its motion was discovered in 1781.
- Astronomers gathered considerable data about Uranus when *Voyager 2* passed near it in 1986.
- Uranus is unusual because its axis of rotation is in nearly the same plane as its orbit. This means that Uranus rotates on its side; the orange patch in the computer-enhanced photograph is a polar hood over the south pole.
- The atmosphere of Uranus is made up mostly of hydrogen, with some helium and methane. It has winds that blow up to about 500 km/h.

Neptune



- The story of the discovery of Neptune, the second farthest planet from the Sun, is one of great scientific achievement. Neptune is so far from Earth that it is barely visible, even through powerful telescopes. After 19th-century scientists established that Uranus was a planet and not a star, they studied its orbit and discovered that the orbit was not a smooth circular path. They hypothesized that some other object must be "tugging" on Uranus, causing its uneven orbit. Using detailed calculations, they predicted where this hidden object must be, searched, and discovered the "missing" planet in 1846.
- In 1989, computer-enhanced images from *Voyager 2* revealed that Neptune has bright blue and white clouds, and a dark region—the Great Dark Spot—that appears to be the centre of a storm. *Voyager 2* also uncovered the existence of at least eight moons and some thin rings orbiting Neptune.



Pluto

- Pluto is an unusual planet because it is not a gas giant and it does not seem to be terrestrial. It was discovered in 1930 after a painstaking search.
- Pluto is so far away that it takes 248 years to orbit the Sun. Although astronomers haven't yet observed a complete orbit, they have seen enough to detect that Pluto's orbit is elliptical and not quite centred on the Sun. Pluto actually passed within the orbit of Neptune, making it the eighth planet from the Sun, from January 1979 until February 1999. Pluto's unusual orbit has led some astronomers to suggest that it may have been a moon of Neptune at one time.
- Images taken by the Hubble Space Telescope have given us our best information yet about tiny, cold, distant Pluto and its moon, Charon.

Understanding Concepts

1. Why are the four closest planets to the Sun called the "terrestrial planets"?
2. Describe two features that make Earth unique among the planets, and two that make it similar to other planets.
3. Why is Jupiter easy to see in the night sky (when viewing conditions are right)?
4. There may be other groups of planets similar to our solar system, but they are very difficult to detect. Why?
5. How would the tilt of Uranus affect its seasons?

Making Connections

6. What are some features of a roving robot you would design for exploration on Mars?
7. List five or six ways that humans have had an impact on Earth and mention how each has had positive and negative results on life on Earth.

Exploring

8. Research the orbits of Mercury and Earth around the Sun. Draw a diagram to illustrate them and use it to explain why Mercury is so difficult to see from Earth.

Reflecting

9. List the steps that were followed in discovering Neptune. How do these steps relate to the process of scientific discovery?

Career Profile

Prize-Winning Astronomer

Mary Lou Whitehorne is a stargazer who, within eight years, captured Canada's highest award for an amateur astronomer—the Chant Medal. How did she do it, and why?

As a Girl Guide in Bedford, Nova Scotia, Whitehorne was interested in the sky but, with no expert to talk to her and no local library, her interest waned. After high school, she graduated in medical laboratory technology and pathology, but left her medical career to raise a family with her husband, Lloyd.

> "It's Terry Dickinson's fault. In 1985, I saw a hokey little star chart in his newspaper column. In it, he said that you could see four moons of Jupiter all aligned on one side–with binoculars. That was all it took and I was hooked."

She went back to school, at age 31, to study at the Astronomy Department of St. Mary's University. She undertook a three-year study of a rare type of star known as a B-emission star. "B-stars" vary in brightness, so she decided to investigate the light they emit. She spent many hours examining their spectra through a telescope to investigate their atomic composition. "It is challenging raising two kids while observing the stars every clear night past midnight," she says, but she did it. She published two scientific papers, winning the 1993 Chant medal for her research efforts.

She has since completed ground school and flight training and has been awarded her Private Pilot Licence. She has also helped to establish a hands-on astronomy program for schools in Nova Scotia. In her spare time, she opened a resource centre for the Canadian Space Agency in the Atlantic region.

Exploring (3A)

1. Find out if there are any introductory astronomy courses or programs in your area. Attend a stargazing party, if you can, and learn about the sky from an expert.
2. A beginner's telescope is usually priced at $350 or less. Most astronomers will tell you that it is a big mistake to buy this type of instrument to explore the sky. Why?
3. Search the Internet for astronomical societies or amateur observing groups and write a brief summary of their activities.

Other Objects in the Solar System

About 60 million years ago, the dinosaurs that had roamed on Earth for millions of years died out in a fairly short time, along with many other species. What could have caused this extinction? Scientists have found evidence that a fast-moving object from outer space crashed into Earth, sending material flying into the atmosphere. This material reduced the amount of sunlight reaching Earth's surface, causing the climate to change and numerous life forms to die out.

As scientists study more about these objects from space, they hope to find clues about how life may have formed on Earth.

Did You Know

As of 1997, astronomers had observed 15 moons orbiting Uranus. Then Canadian astronomers discovered two more moons, bringing the count to 17.

Planetary Moons

Large natural objects that revolve around planets are called **satellites**, or moons. Several planets have more than one moon, but the chunks of rock that make up the rings of the gas giants are far too small to be considered moons.

Probably the most famous satellite of any planet is Earth's Moon, which has a diameter about one-quarter that of Earth. Six visits to the surface of the Moon by humans from 1969 to 1972 provided much new information (**Figure 1**). The Moon has no atmosphere, and its surface is filled with hills and valleys as well as craters caused by the impact of large and small objects from space.

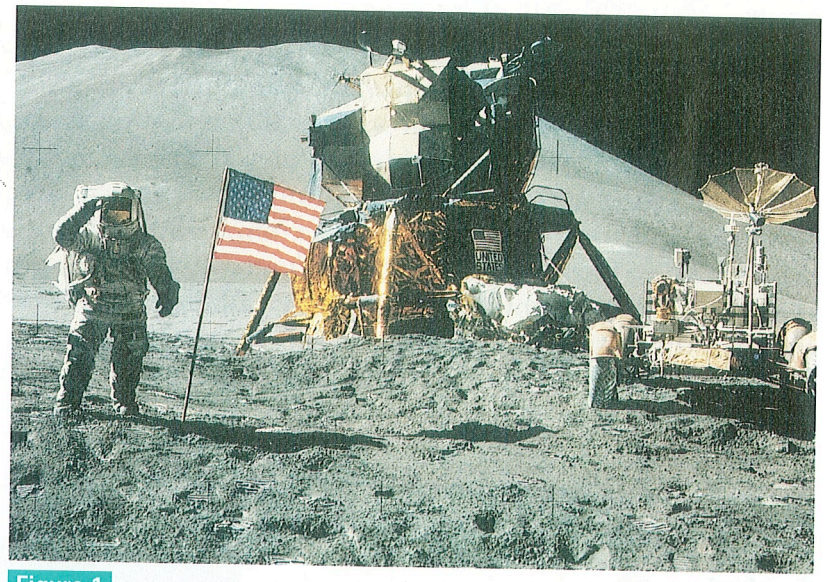


Figure 1

The *Apollo* astronauts brought moon rocks to Earth for detailed study and collected data on the moon's soil, surface conditions, and moonquakes.

The moons of the other planets were discovered after the invention of the telescope. In 1610 Galileo Galilei looked at Jupiter through his telescope and became the first person to see four of Jupiter's moons.

Although humans have not yet been to other satellite moons besides our own, space probes have investigated several at close range, including the two small moons of Mars and many of the largest moons of Jupiter and Saturn.

What has surprised astronomers most about moons is the great differences in their sizes and surfaces, as **Figure 2** shows.

Table 1 lists the number of known moons revolving around the planets of the solar system. Only the numbers of moons revolving around the four terrestrial planets are known for certain. Future space probes may reveal more moons in our solar system.

Table 1

Planetary Moon Count (1998)

Planet	Number of known moons
Mercury	0
Venus	0
Earth	1
Mars	2
Jupiter	16
Saturn	18
Uranus	17
Neptune	8
Pluto	1

be seen. For example, a regular visitor is Halley's comet, last seen in 1986. It has a period of 76 years.

Exploring the Minor Bodies

Think of a chocolate bar that has many mixed ingredients covered with chocolate. In order to figure out how the bar was made, you would start by finding out the ingredients. Scientists go through a similar process when they try to figure out what formed Earth and other planets. Scientists think that the ingredients of the planets and moons were objects similar to asteroids and comets—the minor bodies of the solar system. Unlike Earth, many of the minor bodies have changed little since the birth of the solar system. This is why scientists send probes to the minor bodies to learn more about them, and perhaps learn more about the origin of the solar system.

A probe called *Deep Space 1*, launched in 1998, is the first of a new type of probe, sent to explore minor bodies. This light-weight probe was sent to study an asteroid about 1.9×10^8 km away. The probe is unique because its main source of energy uses ions (charged particles) of xenon and mercury gases. These ions escape at extremely high speeds from the rear of the vehicle, causing a forward thrust on the vehicle. The amount of fuel needed is only about 10% of what a conventional rocket uses. Another feature of this probe is that, when it gets closer to the asteroid it is chasing, it will use an on-board computer to decide on its final approach. This form of artificial intelligence is being used more and more for space exploration (**Figure 6**).

Figure 6
Deep Space 1

Understanding Concepts

1. **(a)** What is an asteroid?
   (b) Where is the asteroid belt?
2. **(a)** Explain the difference between a meteoroid and a meteorite.
   (b) Why are meteorites less common than meteors?
3. Using a labelled diagram, describe what causes the glowing tails of comets.
4. Both comets and planets orbit the Sun. How do their orbits differ?
5. When will Halley's comet next be close enough to the Sun to be seen?

Making Connections

6. Describe what might happen if a giant meteorite crashed into Earth's surface (a) on land (b) on water. On a map of the world, mark the spots where a meterorite would have the least impact on human life.

Exploring

7. The names of many astronomical objects may sound romantic or old-fashioned to us: many of them were named thousands of years ago. However, some recently discovered objects are given exotic names, too.
   (a) What are the planets of our solar system named after?
   (b) Find out what the features on the surface of Venus are named after.
8. One theory suggests that the extinction of dinosaurs may have been caused by the collision of a small asteroid or comet. Investigate this theory. Do you agree or disagree?
9. Of all the planetary moons in our solar system, which one would you be most interested in visiting on a scientific expedition? Research and describe the special features of this moon, and explain what you would try to discover about it while you were there.
10. Chart the names and dates of meteor showers, as well as the point in the sky from which the meteor appears to orginate.

Reflecting

11. Space exploration is costly. Do you think sending probes to explore the minor bodies is justified? Give reasons to support your opinion.

Chapter 13 Review

Key Expectations

Throughout the chapter, you have had opportunities to do the following things:

- Describe and compare constellations. (13.1, 13.3, 13.4, 13.7, 13.8)
- Investigate the motions and characteristics of objects visible in the sky and organize, record, and communicate your results. (13.2, 13.4, 13.5, 13.7, 13.8, 13.11, 13.13)
- Analyze data and use them to predict future observations, such as when to see a seasonal constellation or the return of a comet. (13.2, 13.7, 13.8, 13.13)
- Plan ways to model answers to questions about the motion of objects in the sky, and communicate results. (13.2, 13.8, 13.11, 13.13)
- Describe and compare the properties and motions of the objects in the solar system. (13.1, 13.2, 13.7, 13.8, 13.11, 13.13, 13.14, 13.15)
- Formulate and research questions related to sky-watching and the solar system, and communicate results. (all sections)
- Describe and explain how data from space probes contribute to our knowledge of the solar system. (13.12, 13.15)
- Describe different ways in which various cultures have understood the universe (13.6)
- Evaluate the impact of light pollution on the work of astronomers. (13.9)
- Identify careers related to the exploration of space. (Career Profile)

KEY TERMS

asteroid
asteroid belt
astronomical unit
astronomy
axis
comet
constellation
gas giant
inner planet
light pollution
meteorite
meteoroid
nonluminous
orbit
orbital period
outer planet
planet
revolution
rotation
satellite
solar system
star
Sun
terrestrial planet
universe
zodiac constellation

Reflecting

- "Observation of the stars has affected many human beliefs and activities, including navigation, calendar-making, and the creation of myths." Reflect on this idea. How does it connect with what you've done in this chapter? (To review, check the sections indicated above.)
- Revise your answers to the questions raised in Getting Started. How has your thinking changed?
- What new questions do you have? How will you answer them?

Understanding Concepts

1. Make a concept map to summarize the material that you have studied in this chapter. Start with the word "Sun."
2. Each of the following descriptions fits one of the planets in the solar system. Name the planet described by each sentence.
   (a) It was discovered in 1846 after careful observations.
   (b) It has more mass than all the other planets combined.
   (c) It has surface temperatures ranging from –180°C to 400°C.
   (d) It has an atmosphere containing oxygen.
   (e) It is neither a gas giant nor a terrestrial planet.
   (f) It has over 1000 rings around it.
   (g) It appears reddish in colour.
   (h) It has a very warm surface caused by its thick atmosphere.
   (i) It rotates on its side.
3. Why does a meteor appear as a streak of light in the sky?

4. (a) Describe Earth's position among the nine planets of the solar system.
   (b) Describe several features of Earth that make it unique in the solar system.

5. Choose one planet and name three similarities and three differences between it and Earth.

6. Why are some comets seen much more often than others?

7. (a) State one constellation that you can see best during each of the four seasons.
   (b) Why can you see some constellations only during certain seasons?

8. Mercury is much closer to the Sun than Earth is, yet at night its surface temperature can fall much lower than the lowest surface temperature on Earth. Why do you think this happens?

9. (a) Why do you think craters caused by meteorites are rare on Earth?
   (b) Why do you think there are many meteorite craters on a planet such as Mercury?

10. Would the asteroid belt be dangerous to travel through in a spacecraft? Explain why or why not.

11. Describe a demonstration you could perform with other students to illustrate both revolution and rotation. Try your ideas.

12. Look back to Table 1 on page 418. On which planets would you weigh more than you do on Earth? On which would you weigh less?

Applying Skills

13. If you wanted to see the planets, where would you look in the night sky? Explain your answer.

14. (a) Use your hands to measure the angular sizes of at least five different objects outdoors. Create a table for your measurements, and draw conclusions about the relative sizes of the objects.
   (b) If the objects you investigated had been constellations, would you have been able to draw similar conclusions about their relative sizes?

15. Why do the planets all have different surface temperatures? Interpret the information in Table 1 on page 418 to find reasons for the differences.

16. Describe how you would use "pointer stars" to locate each of the following stars or constellations in the night sky:
   (a) Polaris
   (b) Cassiopeia
   (c) Sirius
   (d) Arcturus
   (e) Regulus

17. Many books are available on how to build your own telescope. Obtain one or two such references and write plans to build such an instrument. If possible, begin your project soon so you can use the telescope to view the planets.

Making Connections

18. What are some benefits that scientists would achieve by sending space probes to objects in outer space?

19. Before humans are sent to explore other planets, robots are sent to study areas of the planet.
   (a) Describe two advantages of using robots rather than humans for such exploration.
   (b) Describe two advantages of sending humans rather than robots.

20. The table below shows a total of 63 known planetary moons in the solar system in 1998. If you checked other reference books published in earlier years, you would find the number of moons listed as follows:

Year of publication	Number of known moons
1969	28
1984	44
1987	53
1991	60
1998	63

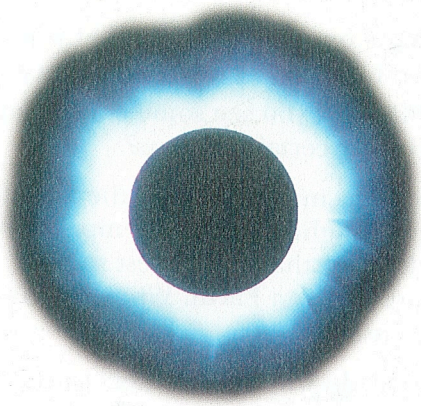
   (a) Why has the number of known moons changed so greatly in such a short period of time?
   (b) Do you think the number of moons will change as much in the next 25 years or so? Explain why or why not.

21. (a) Describe some of the problems that humans might face as they try to set up a settlement on Mars.
   (b) Suggest ways to overcome each of the major problems you listed in (a). Explain your answer in each case.

CHAPTER

14 The Nature of the Universe

Getting Started



1 Darkness in the middle of the day is an eerie sensation. Before people understood solar eclipses, this phenomenon was associated with bad luck, a message from the gods, or even a warning of the end of the world. Although we now know that a solar eclipse is caused by the Moon passing between Earth and the Sun, it is still an exciting and fascinating event. Observing a solar eclipse also helps astronomers learn about properties of the Sun, and stars in general. What do you notice when you look at this image of a solar eclipse? Do all the stars, including our Sun, have the same properties?

2 Every 10 or 11 years Earth's communication systems may be disrupted. This happens just after violent storms occur on the surface of the Sun. We know that the Sun gives us light and heat, but how else does it affect Earth? We can learn a lot about the Sun, and other stars, by observing effects of the Sun on Earth's atmosphere. Is there a change in the environmental impact of the Sun on Earth? What can you judge by looking at the photo shown here?