CHAPTER 27

The Sun-Earth-Moon System

BIG Idea **The Sun, Earth, and the Moon form a dynamic system that influences all life on Earth.**

27.1 Tools of Astronomy

MAIN Idea Radiation emitted or reflected by distant objects allows scientists to study the universe.

27.2 The Moon

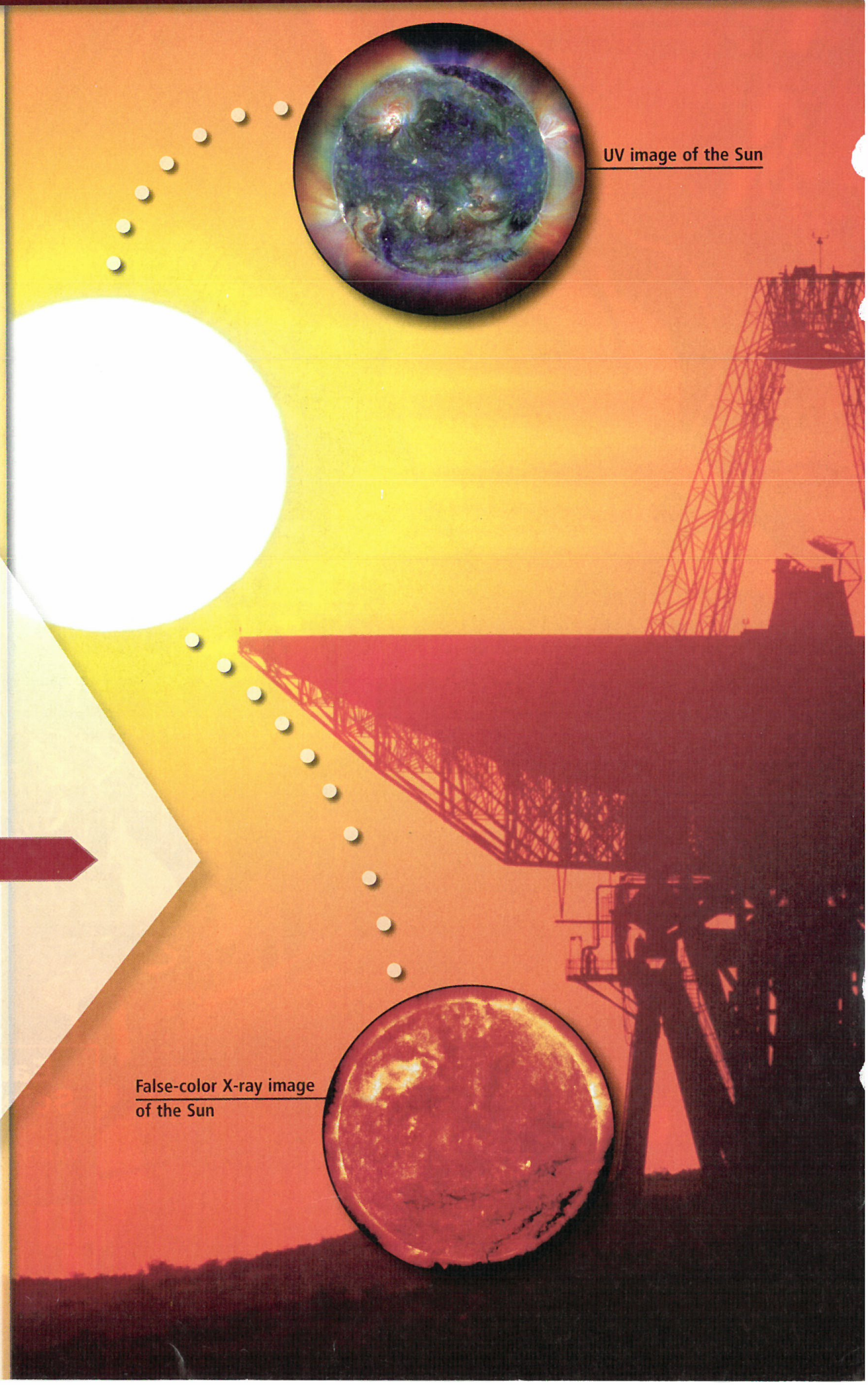
MAIN Idea The Moon, Earth's nearest neighbor in space, is unique among the moons in our solar system.

27.3 The Sun-Earth-Moon System

MAIN Idea Motions of the Sun-Earth-Moon system define Earth's day, month, and year.

GeoFacts

- The volume of the Sun equals 1.3 million Earths.
- Earth is 5×10^6 km closer to the Sun in January than it is in July.
- Finding water on the Moon might make permanent lunar bases possible.



UV image of the Sun

False-color X-ray image of the Sun

Start-Up Activities

LAUNCH Lab

How can the Sun-Earth-Moon system be modeled?

The Sun is about 109 times larger in diameter than Earth, and Earth is about 3.7 times larger in diameter than the Moon. The distance between Earth and the Moon is 30 times Earth's diameter. The Sun is 390 times farther from Earth than is the Moon.

Procedure

1. Read and complete the lab safety form.
2. Calculate the diameters of Earth and the Sun using a scale in which the Moon's diameter is equal to 1 cm.
3. Using this scale, calculate the distances between Earth and the Moon and Earth and the Sun.
4. Cut out **paper** circles to represent your scaled Earth and Moon, and place them at the scaled distance apart.

Analysis

1. **Compare** the diameters of your cutout Earth and Moon to the distance between them.
2. **Infer** why your model does not have a scaled Sun placed at the scaled Sun distance.

Earth Science Online

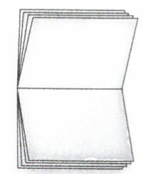
Visit glencoe.com to

- study entire chapters online;
- explore Concepts In Motion animations:
  - Interactive Time Lines
  - Interactive Figures
  - Interactive Tables
- access Web Links for more information, projects, and activities;
- review content with the Interactive Tutor and take Self-Check Quizzes.

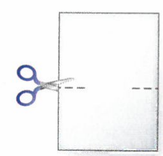
FOLDABLES™ Study Organizer

Phases of the Moon Make the following Foldable to help you learn about the major phases of the Moon.

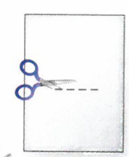
STEP 1 Fold ~~four~~ six sheets of paper in half from top to bottom.



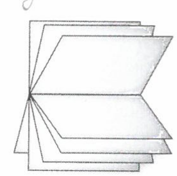
STEP 2 On ~~two~~ 3 sheets of paper, make 3-cm cuts along the fold toward the center on each side.



STEP 3 Cut a slit approximately 16 cm long along the fold line in the remaining ~~two~~ 3 sheets of paper. 2.75 cm from outer edge



STEP 4 Slip the first two sheets through the slit in the second two sheets to make a 16-page booklet.



FOLDABLES **Use this Foldable with Section 27.3.** Draw each ~~major~~ phase of the Moon in order on the bottom pages of your Foldable. Indicate the positions of the Sun, the Moon, and Earth. Include a sketch of how the Moon appears from Earth during that phase. As you turn the pages of your completed book, you will see how the Moon appears to change shape and position. Take notes on the top pages.

starting with new moon

Section 27.1

Objectives

- **Define** electromagnetic radiation.
- **Explain** how telescopes work.
- **Describe** how space exploration helps scientists learn about the universe.

Review Vocabulary

refraction: occurs when a light ray changes direction as it passes from one material into another

New Vocabulary

electromagnetic spectrum
refracting telescope
reflecting telescope
interferometry

Tools of Astronomy

MAIN Idea Radiation emitted or reflected by distant objects allows scientists to study the universe.

Real-World Reading Link Have you ever used a magnifying lens to read fine print? If so, you have used a tool that gathers and focuses light. Scientists use telescopes to gather and focus light from distant objects.

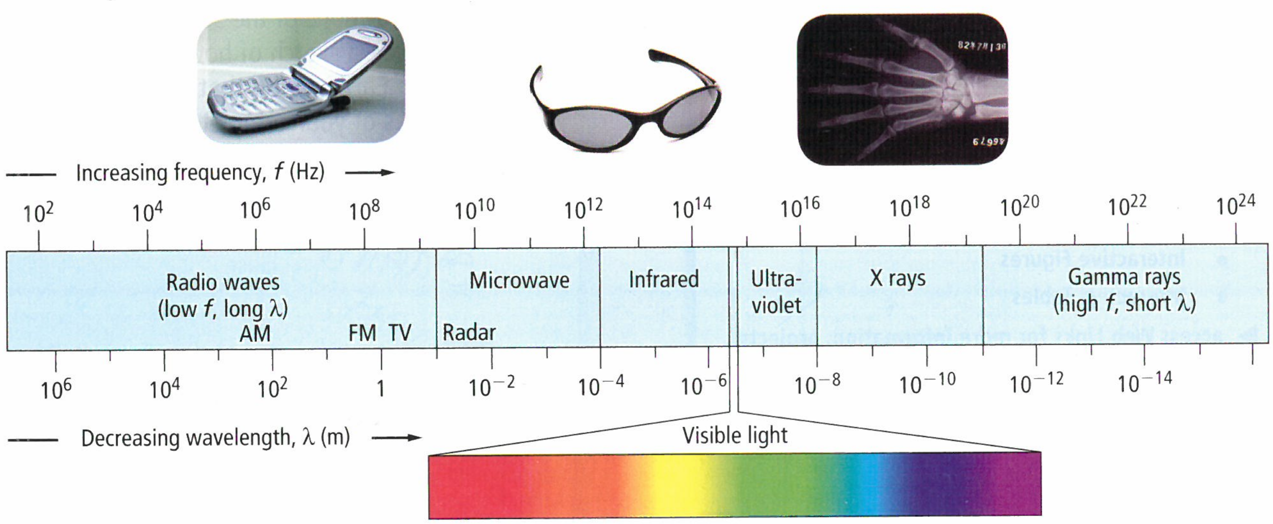
Radiation

The radiation from distant bodies throughout the universe that scientists study is called electromagnetic radiation. Electromagnetic radiation consists of electric and magnetic disturbances traveling through space as waves. Electromagnetic radiation includes visible light, infrared and ultraviolet radiation, radio waves, microwaves, X rays, and gamma rays.

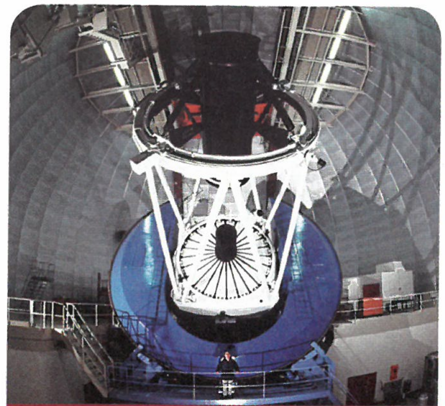
You might be familiar with some forms of electromagnetic radiation. For example, overexposure to ultraviolet waves can cause sunburn, microwaves heat your food, and X rays help doctors diagnose and treat patients. All types of electromagnetic radiation, arranged according to wavelength and frequency, form the **electromagnetic spectrum,** shown in **Figure 27.1.**

Wavelength and frequency Electromagnetic radiation is classified by wavelength—the distance between peaks on a wave. Notice in **Figure 27.1** that red light has a longer wavelength than blue light, and radio waves have a much longer wavelength than gamma rays. Electromagnetic radiation is also classified according to frequency, the number of waves or oscillations that pass a given point per second. The visible light portion of the spectrum has frequencies ranging from red to violet, or 4.3×10^{14} to 7.5×10^{14} Hertz (Hz)—a unit equal to one cycle per second.

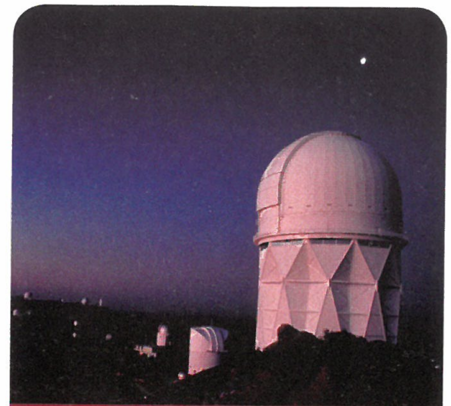
Figure 27.1 The electromagnetic spectrum identifies the different radiation frequencies and wavelengths.



Pinwheel galaxy



Mayall 4-m telescope



Mayall Observatory

Figure 27.2 This photo of the Pinwheel galaxy was taken by the Mayall 4-m telescope, shown with its observatory.

Frequency is related to wavelength by the mathematical relationship $c = \lambda f$, where c is the speed of light (3.0×10^8 m/s), λ is the wavelength, and f is the frequency. Note that all types of electromagnetic radiation travel at the speed of light in a vacuum. Astronomers choose their tools based on the type of radiation they wish to study. For example, to see stars forming in interstellar clouds, they use special telescopes that are sensitive to infrared wavelengths, and to view remnants of supernovas, they often use telescopes that are sensitive to UV, X-ray, and radio wavelengths.

Telescopes

Objects in space emit radiation in all portions of the electromagnetic spectrum. Telescopes, such as the one shown in **Figure 27.2,** give us the ability to observe wavelengths beyond what the human eye can detect. In addition, a telescope collects more electromagnetic radiation from distant objects and focuses it so that an image of the object can be recorded. The pupil of a typical human eye has a diameter of up to 7 mm when it is adapted to darkness; a telescope's opening, which is called its aperture, might be as large as 10 m in diameter. Larger apertures can collect more electromagnetic radiation, making dim objects in the sky appear much brighter.

Reading Check **Name** two benefits of using a telescope.

Another way that telescopes surpass the human eye in collecting electromagnetic radiation is with the aid of cameras, or other imaging devices, to create time exposures. The human eye responds to visible light within one-tenth of a second, so objects too dim to be perceived in that time cannot be seen. Telescopes can collect light over periods of minutes or hours. In this way telescopes can detect objects that are too faint for the human eye to see. Also, astronomers can add specialized equipment. A photometer, for example, measures the intensity of visible light and a spectrophotometer displays the different wavelengths of radiation.

CAREERS IN EARTH SCIENCE

Space Engineer Space engineers design and monitor probes used to explore space. Engineers often design probes to collect information and samples from objects in the solar system. They also study the data collected. To learn more about Earth science careers, visit glencoe.com.

NATIONAL GEOGRAPHIC To read about new telescopes scientists are using to study space, go to the **National Geographic Expedition** on page 934.

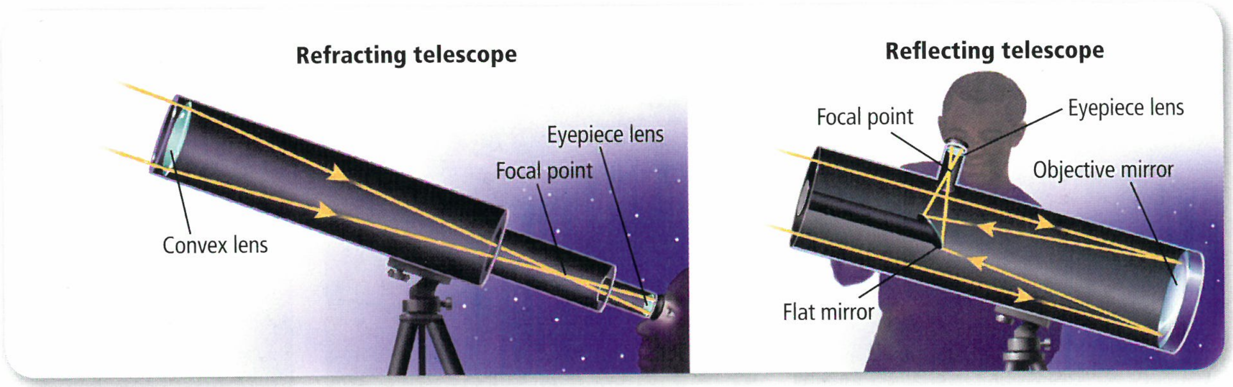


Figure 27.3 Refracting telescopes use a lens to collect light. Reflecting telescopes use a mirror to collect light.

Refracting and reflecting telescopes Two different types of telescopes are used to focus visible light. The first telescopes, invented around 1600, used lenses to bring visible light to a focus and are called **refracting telescopes,** or refractors. The largest lens on such telescopes is called the objective lens. In 1668, a new telescope that used mirrors to focus light was designed. Telescopes that bring visible light to a focus with mirrors are called **reflecting telescopes,** or reflectors. **Figure 27.3** illustrates how simple refracting and reflecting telescopes work. Telescope technology has changed over time, as shown in **Figure 27.4.**

Although both refracting and reflecting telescopes are still in use today, most astronomers use reflectors because mirrors can be made larger than lenses and can collect more light.

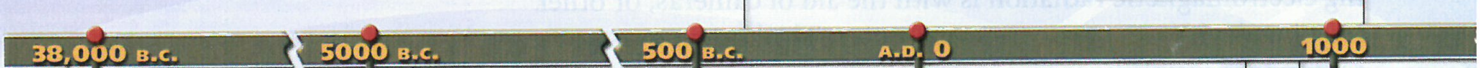
Reading Check **Compare** refracting and reflecting telescopes.

Most telescopes used for scientific study are located in observatories far from city lights, usually at high elevations where there is less atmosphere overhead to blur images. Some of the best observatory sites in the world are located high atop mountains in the southwestern United States, along the peaks of the Andes mountain range in Chile, and on the summit of Mauna Kea, a volcano on the island of Hawaii.

Figure 27.4

Development of Astronomy

Humanity's curiosity about the night sky was limited to Earth-bound explorations until the first probe was sent into space in 1957.



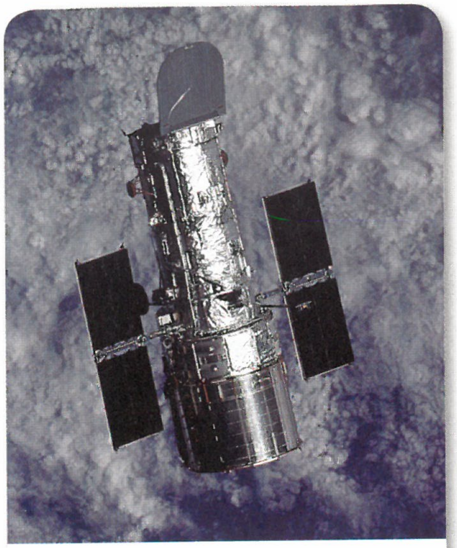
38,000 B.C. Cro-Magnon people sketch moon phases on tools made out of bones.

4236 B.C. After lunar and solar calendars predict agricultural seasons, Egyptians adopt a 365-day calendar based on the movement of the star Sirius.

410 B.C. The first prophecies based on the positions of the five visible planets, the Moon, and the Sun were written for individuals in Mesopotamia.

A.D. 900s Arab astronomers greatly improve the accuracy of the Greek astrolabe—a tool for celestial navigation that determines time and location.

1054 Chinese astronomers document the explosion of the supernova that creates the Crab nebula, believing it foretells the arrival of a wealthy visitor to the emperor.



■ **Figure 27.6** The *Hubble Space Telescope* has been used to observe a comet crashing into Jupiter as well as to detect the farthest known galaxy.

Hubble Space Telescope Orbiting Earth every 97 minutes, one of the best-known space-based observatories—the *Hubble Space Telescope (HST)*—shown in **Figure 27.6,** was launched in 1990. *HST* was designed to obtain sharp visible-light images without atmospheric interference, and also to make observations in infrared and ultraviolet wavelengths. The *James Webb Space Telescope* is planned for 2013. It will only observe in the infrared range and is not a replacement for *HST*. Some other space-based telescopes that observe in wavelengths that are blocked by Earth's atmosphere are shown in **Table 27.1.**

Spacecraft In addition to making observations from above Earth's atmosphere, spacecraft can be sent directly to the bodies being observed. Robotic probes are spacecraft that can make close-up observations and sometimes land to collect information directly. Probes are practical only for objects within our solar system, because other stars are too far away. In 2005, the *Cassini* spacecraft arrived at Saturn, where it went into orbit for a detailed look at its moons and rings; the *Mars Reconnaissance Orbiter* reached Mars in 2006 and began orbiting the red planet to use its high-resolution cameras to search for places where life might have evolved; and *New Horizons* was launched in 2006, on its way to Pluto and the region beyond. *New Horizons* is armed with visible, infrared, and ultraviolet cameras, as well as equipment to measure magnetic fields.

Table 27.1 Orbiting Telescopes

Name	Launch	Wavelengths	Studies	Host
Chandra	1999	X ray	wide ranging	NASA
Newton	1999	X ray	wide ranging, black holes	ESA
MAP	2001	microwave	early universe	NASA
Integral	2002	X ray, gamma ray	wide ranging, neutron stars	ESA, Russia, NASA
CHIPSat	2003	X ray	interstellar plasma	NASA
Galex	2003	UV	survey	JPL, NASA
MOST	2003	visible	observe stars	Canada
Spitzer	2003	IR	wide range	NASA
Swift	2004	X ray, UV, visible	back holes	NASA
Suzaku	2005	X ray	star-forming regions	Japan
Akari	2006	IR	survey	Japan

Telescopes using non-visible wavelengths For all telescopes, the goal is to bring as much electromagnetic radiation as possible into focus. Infrared and ultraviolet radiation can be focused by mirrors in a way similar to that used for visible light. X rays cannot be focused by normal mirrors, and thus special designs must be used. Gamma rays cannot be focused, so telescopes designed to detect this type of radiation can determine only the direction from which the rays come.

A radio telescope collects the longer wavelengths of radio waves with a large dish antenna, which resembles a satellite TV dish. The dish plays the same role as the primary mirror in a reflecting telescope by reflecting radio waves to a point above the dish. There, a receiver converts the radio waves into electric signals that can be stored in a computer for analysis.

The data are converted into visual images by a computer. The resolution of the images produced can be improved using a process called **interferometry,** which is a technique that uses the images from several telescopes to produce a single image. By combining the images from several telescopes, astronomers can create a highly detailed image that has the same resolution of one large telescope with a dish diameter as large as the distance between the two telescopes. One example of this is the moveable telescopes shown in **Figure 27.5.** Both radio and optical telescopes can be linked this way.

Figure 27.5 The Very Large Array is situated near Socorro, New Mexico. The dish antennae of this radio telescope are mounted on tracks so they can be moved to improve resolution.

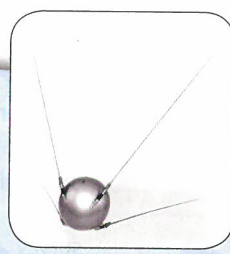
Space-Based Astronomy

Astronomers often send instruments into space to collect information because Earth's atmosphere interferes with most radiation. It blurs visual images and absorbs infrared and ultraviolet radiation, X rays, and gamma rays. Space-based telescopes allow astronomers to study radiation that would be blurred by our atmosphere. American, European, Soviet, Russian, and Japanese space programs have launched many space-based observatories to collect data.

1608 The telescope is invented allowing astronomers to discover planets, such as Uranus and Neptune, moons, and stars that are invisible to the naked eye.

1860s The invention of spectroscopy suggests that the celestial bodies are composed of some of the same elements that make up Earth's atmosphere.

1957 Russia launches the first two satellites into orbit around Earth, marking the beginning of space exploration.



1969 The U.S. astronauts become the first humans to walk on the Moon.

2004 A Mars rover discovers rock formations and sulfate salts indicating that the planet once had flowing water.

Concepts In Motion

Interactive Time Line To learn more about these discoveries and others, visit glencoe.com. Earth Science Online

Human spaceflight Before humans can safely explore space, scientists must learn about the effects of space, such as weightlessness and radiation. The most recent human studies have been accomplished with the space shuttle program, which began in 1981. Shuttles are used to place and service satellites, such as the *HST* and the *Chandra X-ray Telescope*. The space shuttle provides an environment for scientists to study the effects of weightlessness on humans, plants, the growth of crystals, and other phenomena. However, because shuttle missions last a maximum of just 17 days, long-term effects must be studied in space stations. A multicountry space station called the *International Space Station*, shown in **Figure 27.7**, is the ideal environment for studying the effects of space on humans. Crews have lived aboard the *International Space Station* since 2000. The crew members conduct many different experiments in this weightless environment.

Spinoff technology Space-exploration programs not only benefit astronomers and space exploration, but they also benefit society. Many technologies that were originally developed for use in space programs are now used by people throughout the world. Did you know that the technology for the space shuttle's fuel pumps led to the development of pumps used in artificial hearts? Or that the Apollo program that put humans on the Moon led to the development of cordless tools? In fact, more than 1400 different NASA technologies have been passed on to commercial industries for common use; these are called spinoffs.

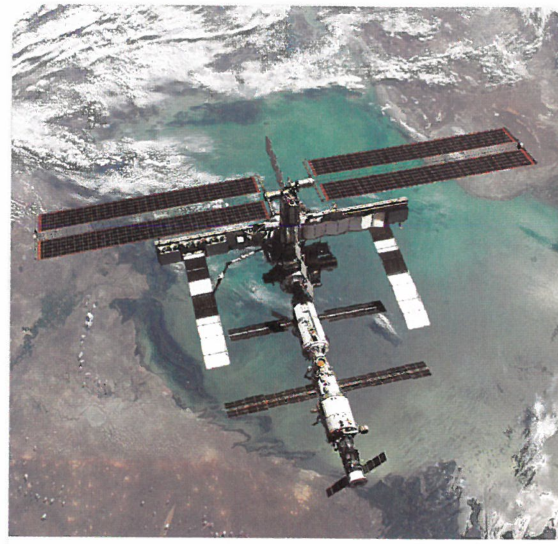


Figure 27.7 This view of the *International Space Station* was taken from the Space Shuttle *Discovery*. The Caspian Sea is visible in the background.

Review ***What types of studies can be carried out in the space station?***

Section 27.1 Assessment

Section Summary

- Telescopes collect and focus electromagnetic radiation emitted or reflected from distant objects.
- Electromagnetic radiation is classified by wavelength and frequency.
- The two main types of optical telescopes are refractors and reflectors.
- Space-based astronomy includes the study of orbiting telescopes, satellites, and probes.
- Technology originally developed to explore space is now used by people on Earth.

Understand Main Ideas

1. MAIN Idea **Explain** how electromagnetic radiation helps scientists study the universe.
2. **Distinguish** between refracting and reflecting telescopes and how they work.
3. **Report** on how interferometry affects the images that are produced by telescopes.
4. **Examine** the reasons why astronomers send telescopes and probes into space.

Think Critically

5. **Assess** the benefits of technology spinoffs to society.
6. **Consider** the advantages and disadvantages of using robotic probes to study distant objects in space.

MATH in Earth Science

7. Calculate the wavelength of radiation with a frequency of 10^{12} Hz. [*Hint: Use the equation* $c = \lambda f$.]