Section 3

Terms to Learn

telescope
refracting telescope
reflecting telescope
electromagnetic spectrum

What You'll Do

- Compare and contrast refracting telescopes with reflecting telescopes.
- Explain why the atmosphere is an obstacle to astronomers and how they overcome the obstacle.
- List the types of electromagnetic radiation, other than visible light, that astronomers use to study space.

Telescopes—Then and Now

For professional astronomers and amateur stargazers, the telescope is the standard tool for observing the sky. A **telescope** is an instrument that collects *electromagnetic radiation* from the sky and concentrates it for better observation. You will learn more about electromagnetic radiation later in this section.

Optical Astronomy

An optical telescope collects visible light for closer observation. The simplest optical telescope is made with two lenses. One lens, called the *objective lens,* collects light and forms an image at the back of the telescope. The bigger the objective lens, the more light the telescope can gather. The second lens is located in the eyepiece of the telescope. This lens magnifies the image produced by the objective lens. Different eyepieces can be selected depending on the magnification desired.

Without a telescope, you can see about 6,000 stars in the night sky. With an optical telescope, you can see millions of stars and other objects. **Figure 18** shows how much more you can see with an optical telescope.

Figure 18 *The image at left shows a section of the sky as seen with the unaided eye. The image at right shows what the small clusters of stars in the left image look like when seen through a telescope.*

Refracting Telescopes Telescopes that use a set of lenses to gather and focus light are called **refracting telescopes.** The curved objective lens in a refracting telescope bends light that passes through it and focuses the light to be magnified by the eyepiece. **Figure 19** shows how refracting telescopes work. A refracting telescope's size is limited by the objective lens. If the curved lens is too large, the glass sags under its own weight, distorting images. This is why most professional astronomers use *reflecting telescopes.*

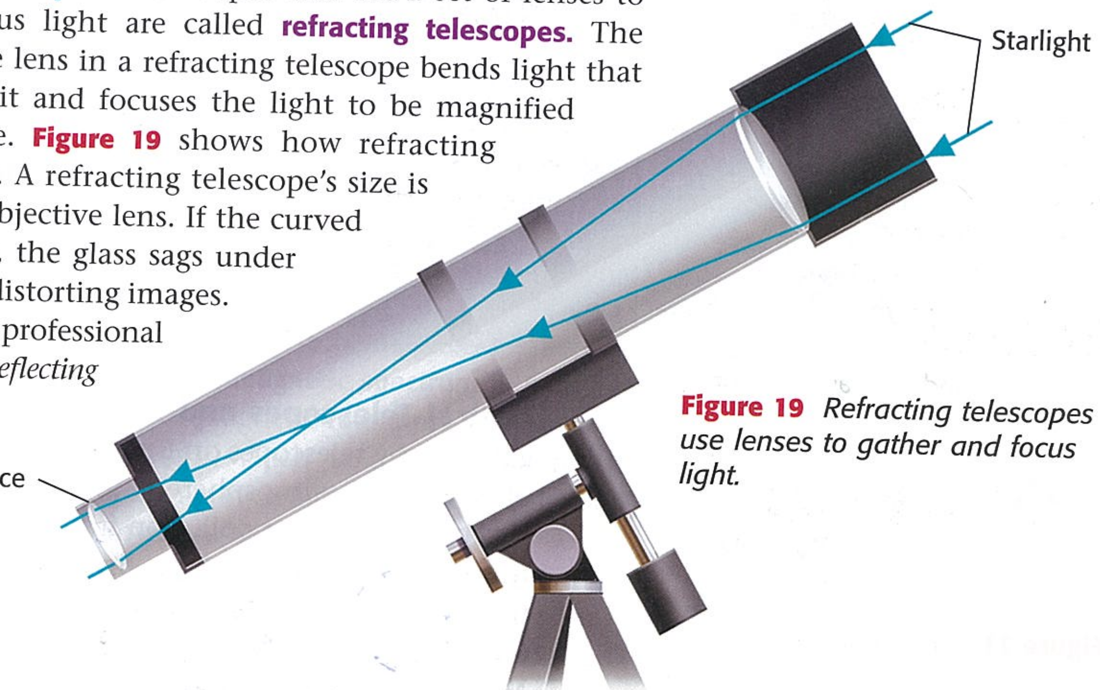


Figure 19 *Refracting telescopes use lenses to gather and focus light.*

Reflecting Telescopes Telescopes that use curved mirrors to gather and focus light are called **reflecting telescopes.** Light enters the telescope and is reflected from a large, curved mirror to a focal point above the mirror. As shown in **Figure 20,** reflecting telescopes use a second mirror in front of the focal point to reflect the light, in this case, through a hole in the side of the telescope. Here the light is collected for observation.

One advantage of reflecting telescopes over refracting telescopes is that mirrors can be made very large, which allows them to gather more light than lenses gather. Also, mirrors are polished on their curved side, preventing light from entering the glass. Therefore, any flaws in the glass do not affect the light. A third advantage is that mirrors reflect all colors of light to the same place, while lenses focus different colors of light at slightly different distances. Reflecting telescopes thus allow all colors of light from an object to be seen in focus at the same time.

LabBook

Want to make your own telescope? Turn to page 710 in the LabBook to find out how to build and use a telescope.

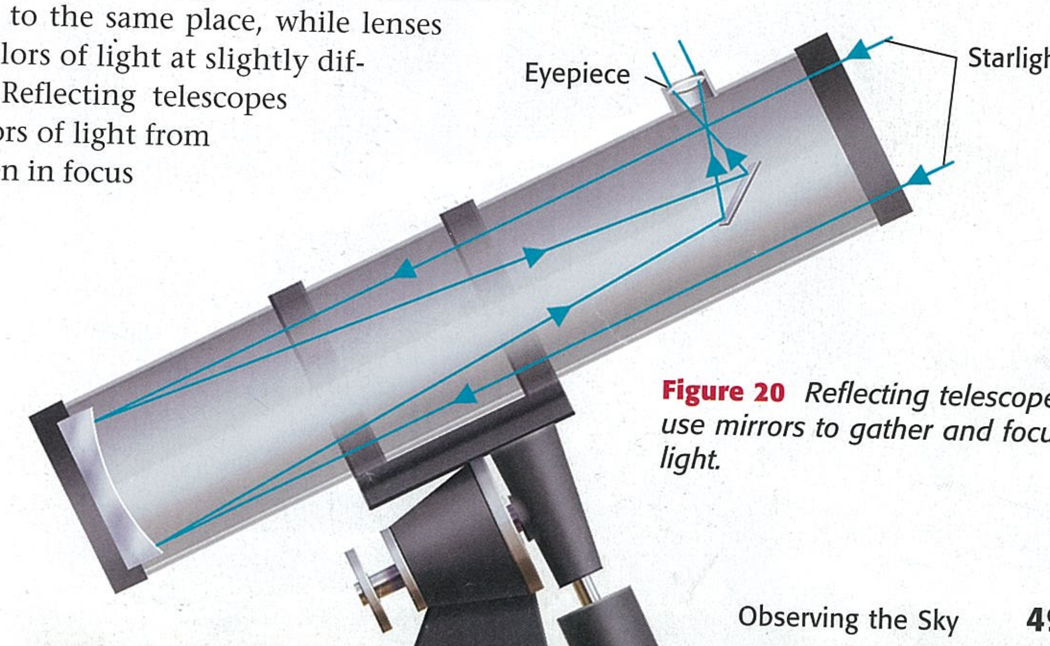


Figure 20 *Reflecting telescopes use mirrors to gather and focus light.*

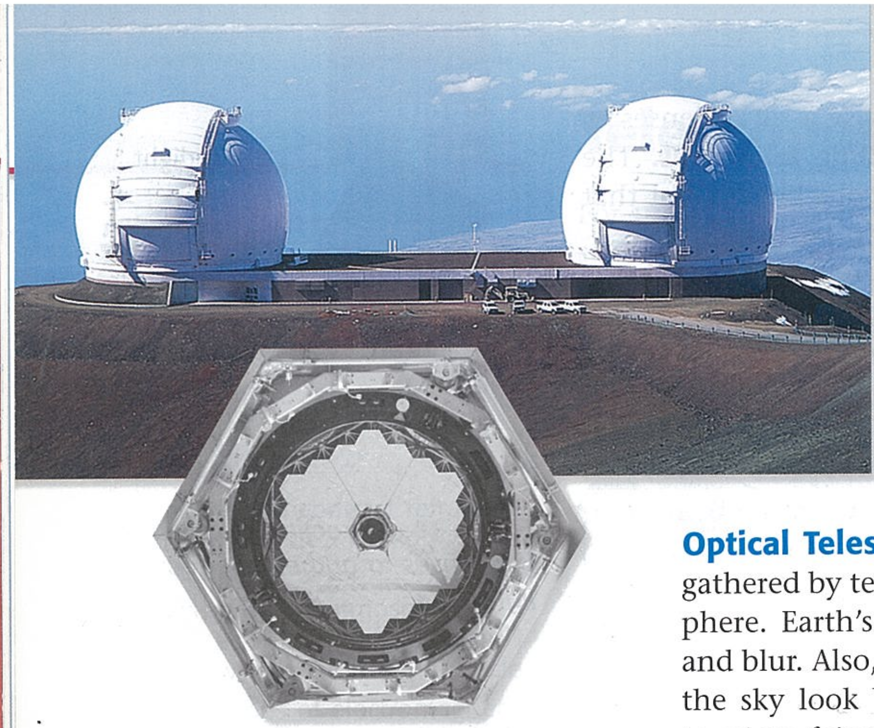


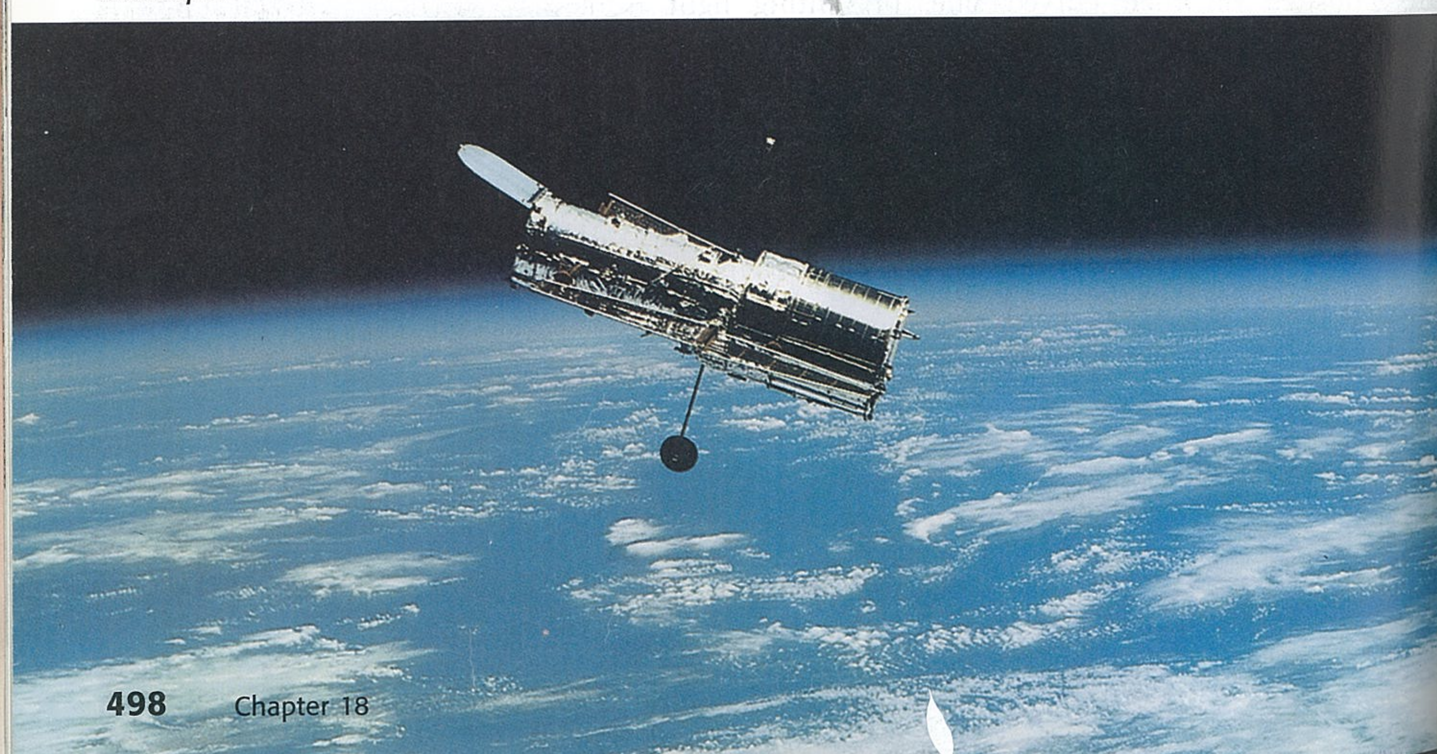
Figure 21 *The 36 hexagonal mirrors in each of the Keck Telescopes combine to form a light-reflecting surface that is 10 m across.*

Very Large Reflecting Telescopes In some very large reflecting telescopes, several mirrors work together to collect light and deliver it to the same focus. The Keck Telescopes, in Hawaii, shown in **Figure 21,** are twin telescopes that each have 36 hexagonal mirrors working together. Linking several mirrors allows more light to be collected and focused in one spot.

Optical Telescopes and the Atmosphere The light gathered by telescopes on Earth is affected by the atmosphere. Earth's atmosphere causes starlight to shimmer and blur. Also, light pollution from large cities can make the sky look bright, which limits an observer's ability to view faint objects. Astronomers often place telescopes in dry areas to avoid water vapor in the air. Mountaintops are also good places to use a telescope because the air is thinner at higher elevations. The fact that air pollution and light pollution are generally lower on mountaintops also increases the visibility of stars.

Optical Telescopes in Space! To avoid interference by the atmosphere altogether, scientists have put telescopes in space. Although the mirror in the Hubble Space Telescope, shown below in **Figure 22,** is only 2.4 m across, the optical telescope produces images that are as good or better than any images produced by optical telescopes on Earth.

Figure 22 *The Hubble Space Telescope has provided clearer images of objects in deep space than any ground-based optical telescope.*



Non-Optical Astronomy

For thousands of years, humans have observed the universe with their eyes. But scientists eventually discovered that there are more forms of radiation than the kind we can see—*visible light.* In 1800, William Herschel discovered an invisible form of radiation called *infrared radiation.* We sense infrared radiation as heat.

In 1852, James Clerk Maxwell showed that visible light is a form of *electromagnetic radiation.* Each color of visible light represents a different wavelength of electromagnetic radiation. Visible light is just a small part of the electromagnetic spectrum, as shown in **Figure 23.** The **electromagnetic spectrum** is made of all of the wavelengths of electromagnetic radiation. Humans can see radiation only from blue light, which has a short wavelength, to red light, which has a longer wavelength. The rest of the electromagnetic spectrum is invisible to us!

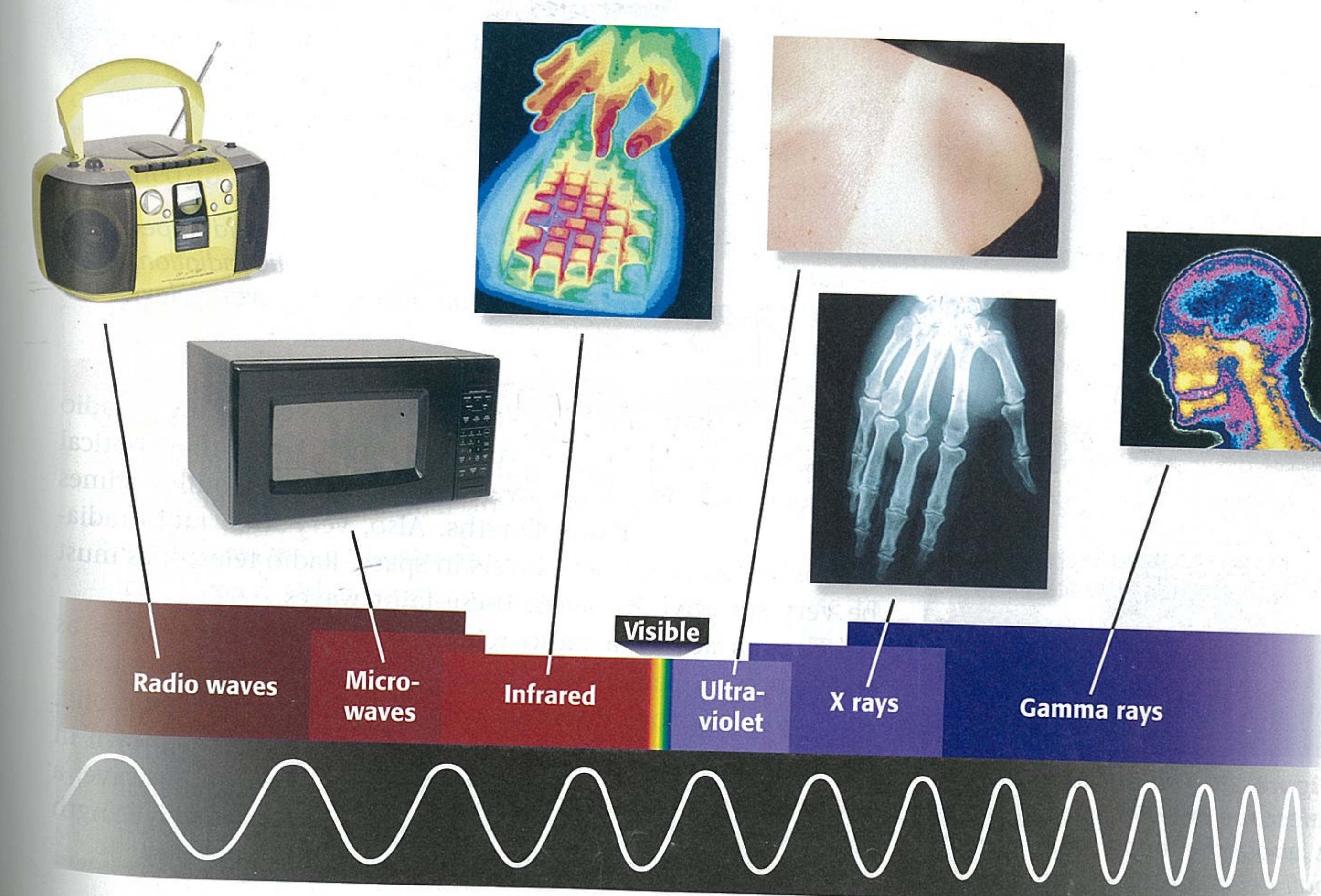
Most electromagnetic radiation is blocked by the Earth's atmosphere. Think of the atmosphere as a screen that lets only certain wavelengths of radiation in. These wavelengths include infrared, visible light, some ultraviolet, and radio. All other wavelengths are blocked.

Activity

Artificial light at night is often needed for safety and security. But it also causes light pollution that interferes with stargazing. Do some research on this problem, and list some possible solutions. What compromises can be made so that people feel safe and stargazers can see objects in the night sky?

TRY at HOME

Figure 23 *Radio waves have the longest wavelengths and gamma rays have the shortest. Visible light is only a small band of the electromagnetic spectrum.*



The Night Sky Through Different Eyes Astronomers are interested in all forms of electromagnetic radiation because different objects radiate at different wavelengths. For each type of radiation, a different type of telescope or detector is needed. For example, infrared telescopes have polished mirrors similar to those of reflecting telescopes, but the detectors are more sensitive to infrared waves than to visible light waves. As you can see in **Figure 24,** the universe looks much different when observed at other wavelengths.

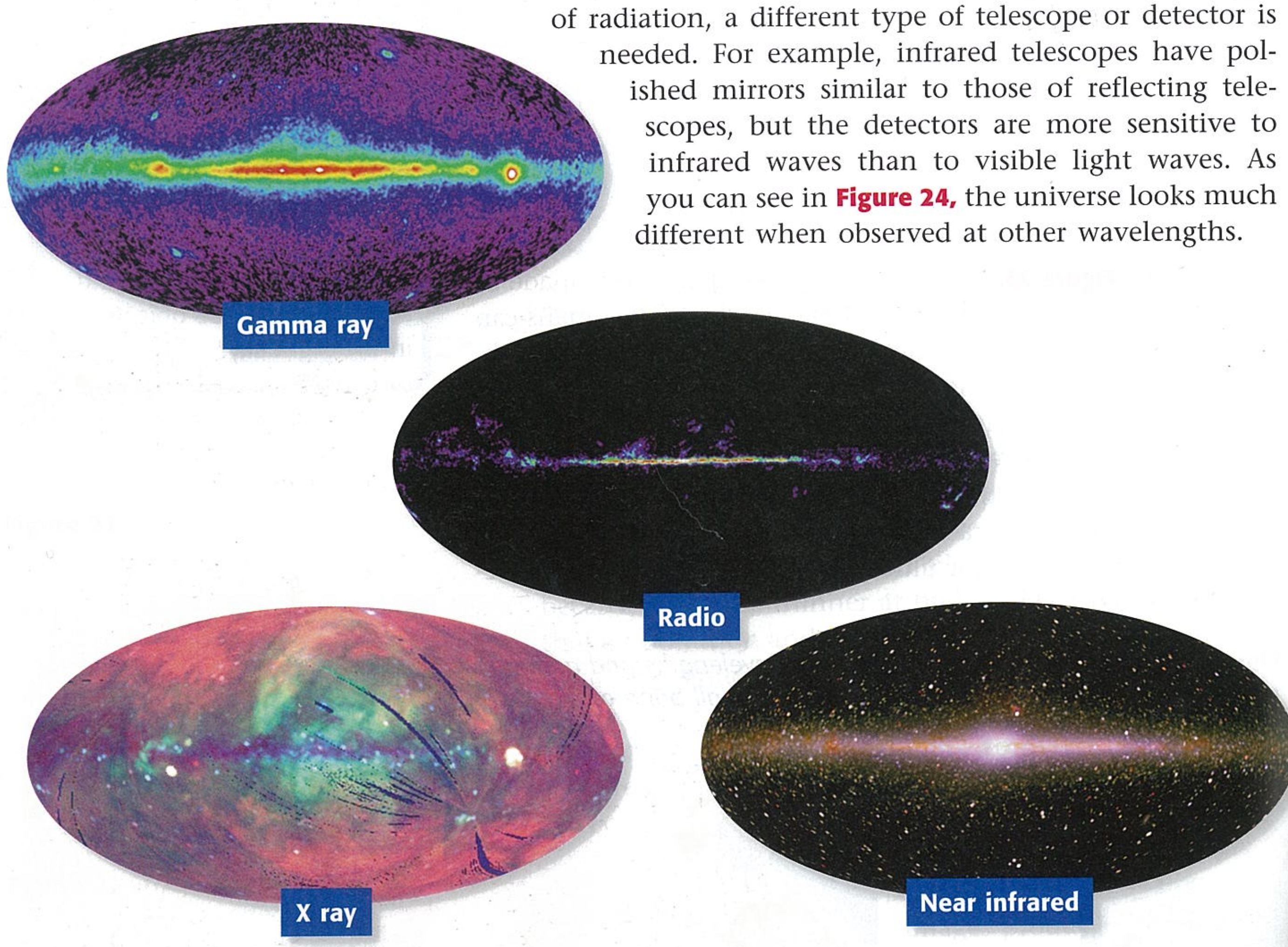


Figure 24 *Each image shows the night sky as it would appear if we could see other wavelengths of electromagnetic radiation. The "cloud" that goes across each picture is the Milky Way galaxy.*

Figure 25 *The Arecibo radio telescope is 305 m across. That is about the length of three football fields arranged end to end!*

Radio Telescopes Radio telescopes receive and focus radio waves. Radio telescopes have to be much larger than optical telescopes because radio wavelengths are about 1 million times longer than optical wavelengths. Also, very little radio radiation reaches Earth from objects in space. Radio telescopes must be very sensitive to detect these faint waves.

The surface of a radio telescope does not have to be as flawless as the lens of an optical telescope. In fact, the surface of a radio telescope does not even have to be completely solid. When it was first built, the Arecibo radio telescope, shown in **Figure 25,** was covered with chicken wire! To a radio wave, a surface made of chicken wire is solid because the wavelength is so much longer than the diameter of the holes.

Linking Radio Telescopes Together Astronomers can get clearer images of radio waves by using two or more radio telescopes at the same time. When radio telescopes are linked together, they work like a single giant telescope. For example, the Very Large Array (VLA), shown in **Figure 26,** consists of 27 separate telescopes that can be spread out 30 km. When the dishes are spread out to the maximum distance, they work as a single telescope that is 30 km across! The larger the area that linked telescopes cover, the more detailed the collected data are.

Figure 26 *The radio telescopes of the Very Large Array near Socorro, New Mexico, work together as one giant telescope.*

X-ray Vision Most electromagnetic waves are blocked by the Earth's atmosphere. To detect these blocked waves, scientists have put special telescopes in space. These telescopes include ultraviolet telescopes, infrared telescopes, gamma-ray telescopes, and X-ray telescopes. Each type of telescope is made to receive one type of radiation. For example, **Figure 27** shows a telescope that is designed to detect X rays.

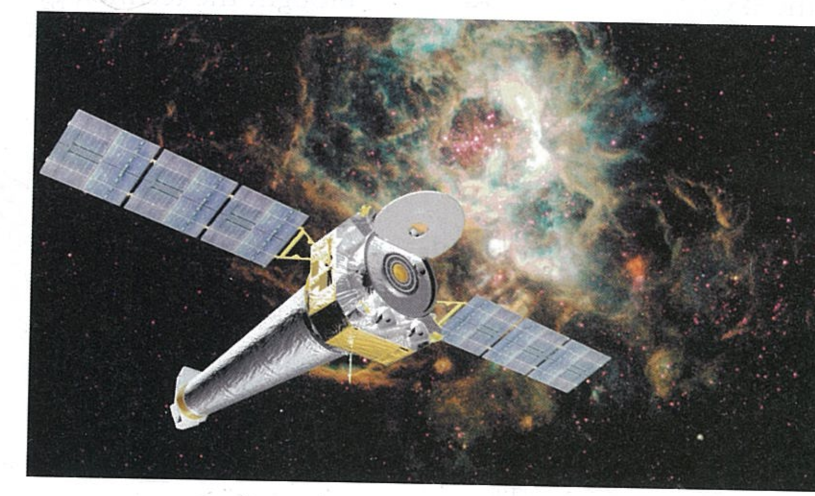


Figure 27 *Launched in 1999, the Chandra X-ray Observatory is the most powerful X-ray telescope ever built.*

REVIEW

1. Name one way in which refracting telescopes and reflecting telescopes are similar and one way they are different.
2. Name two ways the atmosphere limits what astronomers can detect. What single method do astronomers use to solve both problems?
3. **Summarizing Data** Make two lists—one for electromagnetic wavelengths that commonly penetrate Earth's atmosphere and one for other wavelengths. Which wavelengths can astronomers detect from Earth? How do they detect each wavelength?

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