

SECTION 1

Tools of Modern Astronomy

INTEGRATING PHYSICS



DISCOVER

ACTIVITY

Are Those Stars Really a Group?

1. Cut ten pieces of thread to different lengths between 5 cm and 25 cm. Tape a 1-cm plastic foam ball to the end of each piece of thread.
2. Obtain a piece of cardboard about 50 cm by 50 cm. Tape the free ends of the thread pieces to various points on the cardboard.
3. Turn the cardboard over so the balls hang down. While your partner holds the cardboard horizontally, look at the balls from the side.
4. Imagine that the balls are stars in a constellation. With one eye closed, sketch the pattern the balls make.



Think It Over

Observing Can you tell which balls are farther away and which are closer? Do you think you can tell how close to one another the stars in a constellation are?

GUIDE FOR READING

- What do telescopes do?
- Why do astronomers use spectrographs?

Reading Tip Before you read, rewrite the main headings of the section as *how*, *why*, or *what* questions.

Key Terms • [constellation](#) • [radio telescope](#) • [observatory](#) • [spectrograph](#)

Before the Civil War, thousands of enslaved African Americans fled north to freedom. Traveling in secret by night, they looked to the stars for direction. They told one another to “follow the drinking gourd”—the star pattern that points to the North Star. Most Americans today call this pattern the Big Dipper.

Patterns of stars in the sky are called **constellations**. Stars in a constellation can look as if they are close together, even though they are at very different distances from Earth. For example, the star at the end of the handle in the Big Dipper is about twice as far from Earth as most of the other stars in the Big Dipper. So the stars in a constellation are not, in fact, all close together. Constellations are just patterns formed by stars that happen to be in the same direction in the sky.

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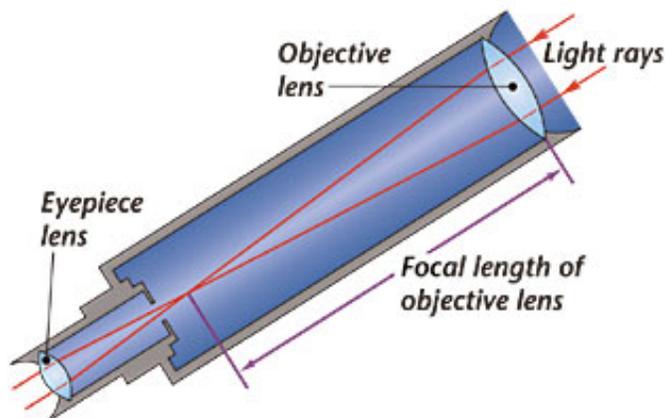
Looking at Stars

The stars in constellations appear as points of light. In fact, stars are huge spheres of hot, glowing gas, like the sun. Visible light is only one type of electromagnetic radiation given off by stars. Stars also give off radiation that you can't see. For example, some stars give off radiation in the form of radio waves. These waves are like the ones that carry signals to radios and televisions.

Astronomers use telescopes to observe stars and learn more about them. Many telescopes produce images using visible light. However, much of modern astronomy is based on detection of other types of electromagnetic radiation. **Most telescopes collect and focus different types of electromagnetic radiation from stars, including visible light.**

Visible Light Telescopes In 1609, Galileo used a simple refracting telescope to look at objects in the sky. Among the objects he saw were the moons of the planet Jupiter, sun spots, and the terrain of the moon. Recall that a refracting telescope uses convex lenses to gather a large amount of light and focus it onto a small area.

Galileo's telescope, like the refracting telescope shown below, used two lenses—an objective lens and an eyepiece lens. When light passes through the objective lens, the lens focuses the light at the focal point of the lens. The distance from the focal point to the objective lens is the focal length of the objective lens. The larger the objective lens, the more light the lens can collect. This makes it easier for astronomers to see faint objects. The eyepiece lens is also a convex lens. It has a focal point that coincides with that of the objective lens.



Electromagnetic Waves



Development of Modern Telescopes

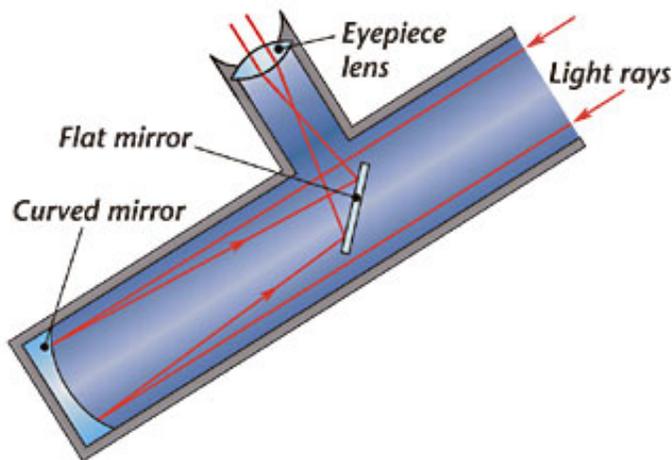


Optical Telescopes



Refracting Telescope A refracting telescope uses an objective lens to focus the light rays from an image, which can be seen with the eyepiece lens. Both lenses are convex lenses.

Isaac Newton built the first reflecting telescope in 1668. As you can see in the diagram below, a reflecting telescope uses a mirror instead of an objective lens. Like the lenses in a refracting telescope, the mirror in a reflecting telescope focuses a large amount of light onto a small area. The larger the mirror, the more light the telescope can collect. The largest visible light telescopes are now all reflecting telescopes.



Reflecting Telescope In a reflecting telescope, a mirror focuses a large amount of light onto a small area.

Radio Telescopes Devices used to detect radio waves from objects in space are called [radio telescopes](#). Most radio telescopes have curved, reflecting surfaces. These surfaces can be several hundred meters in diameter. They focus radio waves the way the mirror in a reflecting telescope focuses light waves. Radio telescopes concentrate the faint radio waves from outer space onto an antenna like that on a radio. As with visible light telescopes, the larger a radio telescope is, the more radio waves it can collect.



TRY THIS

Locating Radio Waves

You can use an umbrella to focus radio waves.

1. Line the inside of an umbrella with aluminum foil.
2. Turn on a small radio and tune it to a station.
3. Move the radio up and down along the umbrella handle. Find the position where the station is clearest. Radio waves reflecting off the foil focus at this point. Tape the radio to the handle.
4. Hold the umbrella at different angles. At which angle is the station the clearest?



Inferring In which direction do you think the radio station is located? Explain.

Other Telescopes Some telescopes detect infrared radiation, which has longer wavelengths than visible light. There are also telescopes that detect the shortest wavelengths—ultraviolet radiation, X-rays, and gamma rays.

Sharpen your Skills

Observing

Use a telescope to look at the night sky. Make a list of your answers to these questions.

1. Can you distinguish a planet from a star using a telescope? If so, how?
2. How do the objects you view in the night sky differ? How are they the same? Record their colors, their brightnesses, and anything else you observe.
3. If the moon is visible, what do you see when you look at the moon's surface?
4. Can you locate an object that scientists have placed in the sky? How can you tell that it is not natural?

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Observatories

A building that contains one or more telescopes is called an [observatory](#). Most large observatories are located on mountaintops. Why have astronomers built the largest visible light telescopes on the tops of mountains? Earth's atmosphere makes objects in space look blurry. The sky on some mountaintops is clearer and is not brightened by city lights.

The best observatory site on Earth is probably the top of Mauna Kea, an ancient volcano on the Island of Hawaii in the Pacific Ocean. Mauna Kea is so tall—4,200 meters above sea level—that it is above 40 percent of Earth's atmosphere. The sky there is very dark at night, and many nights are free of clouds.

The McDonald Observatory in the Davis Mountains of southwest Texas has four operating telescopes. The largest is the Hobby-Eberly reflecting telescope. It sits on Mount Fowlkes, about 2 kilometers above sea level. It collects light on a mirror that is over 9 meters in diameter!

To collect data from visible light telescopes on Earth, astronomers must sometimes stay awake all night. Radio telescopes, however, can be used 24 hours a day and do not have to be on mountaintops.





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Satellites

Most ultraviolet radiation, X-rays, and gamma rays are blocked by Earth's atmosphere. To detect these wavelengths, astronomers have placed telescopes on satellites.

The Hubble Space Telescope is a reflecting telescope with a mirror 2.4 meters in diameter. Because it is above the atmosphere, its images of stars in visible light are about seven times more detailed than the best images from telescopes on Earth. The Hubble Space Telescope can also collect ultraviolet and infrared radiation. The Chandra X-ray Observatory, similar in size to Hubble, makes images in the X-ray portion of the spectrum.



The Hubble Telescope





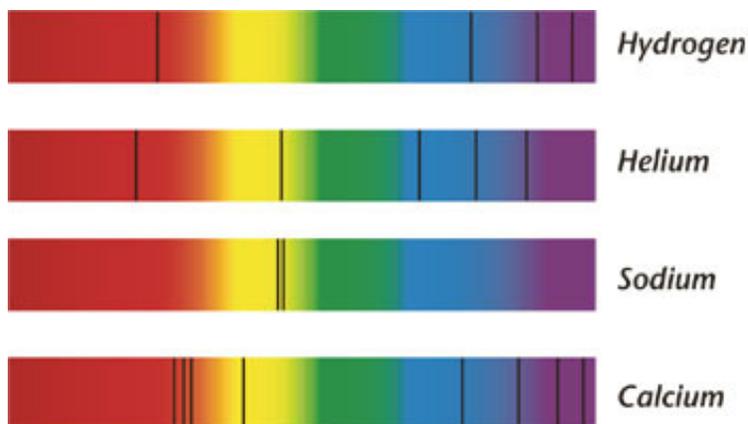
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Spectrographs

Most large telescopes today have spectrographs. A [spectrograph](#) (spek truh graf) breaks the light from an object into colors and photographs the resulting spectrum. **Astronomers use spectrographs to get information about stars, including their chemical compositions and temperatures.**

Chemical Compositions Chemical elements in a star's atmosphere absorb light from the star. Each element absorbs light at different wavelengths, and each absorbed wavelength appears as a dark line on a spectrum. Just as each person has a unique set of fingerprints, each chemical element has a unique set of such lines. By comparing a star's spectrum with the known spectra of different elements, such as those shown below, astronomers can infer which elements are found in a star.

Spectral Fingerprints



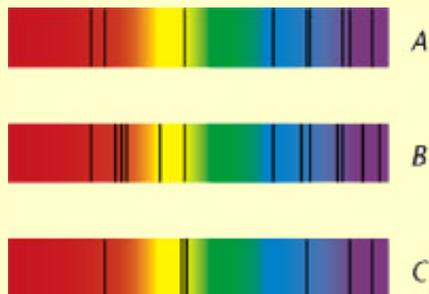
Line Spectrums Astronomers can use line spectrums to find the temperatures of stars.

Temperatures Most stars have a chemical composition similar to the sun, about 73% hydrogen, 25% helium, and 2% other elements. The amount of energy each of these elements absorbs depends on the temperature of the star. Because of this, stars at different temperatures produce different line spectrums. By comparing a star's spectrum with the known spectra of elements at different temperatures, astronomers can infer how hot the star is. Hydrogen, for example, produces very strong spectral lines when it is at about 10,000 degrees Celsius. If astronomers do not see a strong hydrogen line on a spectrum, this does not mean there is no hydrogen in the star. It just means that the star is either cooler or hotter than 10,000 degrees Celsius.

Sharpen your Skills

Inferring

The lines on the spectrums below are from three different stars. Each of these star spectrums is made up of an overlap of spectrums from the individual elements shown in *Line Spectrums*. In Star A, which elements have the strongest lines? Which are the strongest in Star B? In Star C?

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Section 1 Review

Checkpoint

1. For what purpose are most telescopes designed? [hint](#)
2. What can astronomers tell from looking at a star's spectrum? [hint](#)
3. What does a spectrum without strong hydrogen lines tell you about a star's temperature? [hint](#)
4. **Thinking Critically Applying Concepts** Why are images from the Hubble Space Telescope clearer than images from telescopes on Earth? [hint](#)



Check Your Progress

Using the star charts in [Appendix G](#), try to locate constellations in the night sky. (*Hint:* Remember that you may be looking at a constellation upside down. Also, light conditions may affect how many stars you can see.) Sketch the constellations you can locate and compare them with the ones your classmates saw. Now choose one constellation and research the myths or legends that gave it its name. Find as many stories as you can about your constellation and make notes about them.

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