

■ **Figure 29.14** As Earth orbits the Sun, nearby stars appear to change position in the sky compared to faraway stars. Earth reaches its maximum change in position at six months, so the angle measured to the star from these two positions is also at the maximum. This shift in observation position is called parallax and can be used to estimate the distance to the star being observed.

**Predict** the position of the star in September.

Concepts in Motion

**Interactive Figure** To see an animation of parallax, visit [glencoe.com](http://glencoe.com).

**Parallax** Precise position measurements are important for determining distances to stars. When estimating the distance of stars from Earth, astronomers must account for the fact that nearby stars shift in position as observed from Earth. This apparent shift in position caused by the motion of the observer is called **parallax**. In this case, the motion of the observer is the change in position of Earth as it orbits the Sun. As Earth moves from one side of its orbit to the opposite side, a nearby star appears to be shifting back and forth, as illustrated in **Figure 29.14**. The closer the star, the larger the shift. The distance to a star can be estimated from its parallax shift by measuring the angle of the change. A pc is defined as the distance at which an object has a parallax of 1 arcsecond. Using the parallax technique, astronomers could find accurate distances to stars up to only 100 pc, or approximately 300 ly, until recently. With advancements in technology, such as the *Hipparcos* satellite, astronomers can find accurate distances up to 500 pc by using parallax.



**Reading Check** Identify the motion of the observer in the diagram.

## Basic Properties of Stars

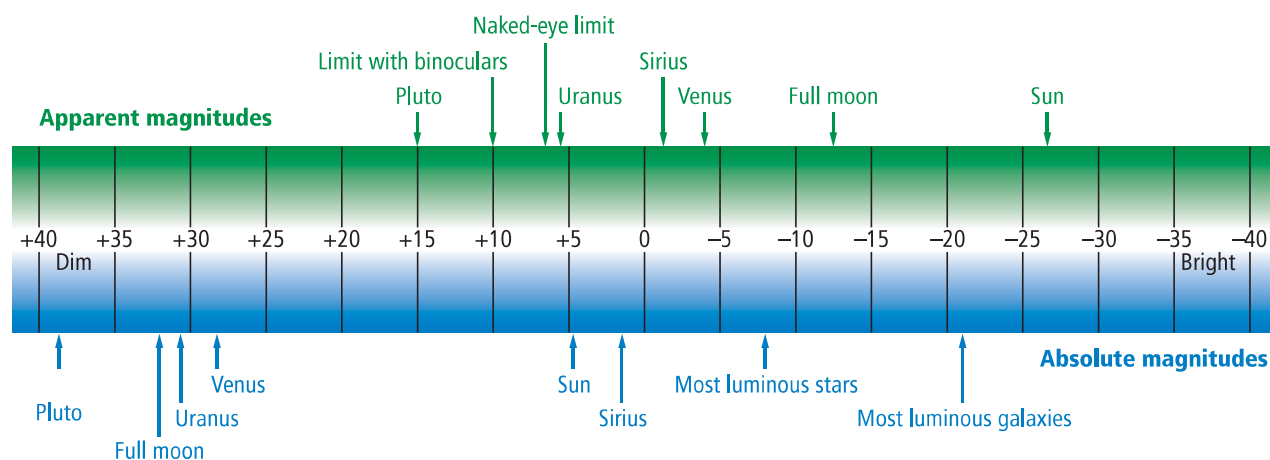
The basic properties of a star are mass, diameter, and luminosity, which are all related to each other. Temperature is another property and is estimated by finding the spectral type of a star. Temperature controls the nuclear reaction rate and governs the luminosity, or apparent magnitude. The absolute magnitude compared to the apparent magnitude is used to find the distance to a star.

## VOCABULARY

### ACADEMIC VOCABULARY

#### Precise

exactly or sharply defined or stated  
The builder's accurate measurements ensured that all of the boards were cut to the same, precise length.



■ **Figure 29.15** Apparent magnitude is how bright the stars and planets appear in the sky from Earth. Absolute magnitude takes into account the distance to that star or planet and makes adjustments for distance.

## VOCABULARY

### SCIENCE USAGE V. COMMON USAGE

#### Magnitude

**Science usage:** a number representing the apparent brightness of a celestial body

**Common usage:** the importance, quality, or caliber of something

**Magnitude** One of the most basic observable properties of a star is how bright it appears, or the **apparent magnitude**. The ancient Greeks established a classification system based on the brightness of stars. The brightest stars were given a ranking of +1, the next brightest +2, and so on. Today's astronomers still use this system, but they have refined it. In this system, a difference of 5 magnitudes corresponds to a factor of 100 in brightness. Thus, a magnitude +1 star is 100 times brighter than a magnitude +6 star.

**Absolute magnitude** Apparent magnitude does not indicate the actual brightness of a star because it does not account for distance. A faint star can appear to be very bright because it is relatively close to Earth, while a bright star can appear to be faint because it is far away. To account for these phenomena, astronomers have developed another classification system for brightness. **Absolute magnitude** is how bright a star would appear if it were placed at a distance of 10 pc. The classification of stars by absolute magnitude allows comparisons that are based on how bright the stars would appear at equal distances from an observer. The disadvantage of absolute magnitude is that it can be calculated only when the actual distance to a star is known. The apparent and absolute magnitudes for several objects are shown in **Figure 29.15**.

**Luminosity** Apparent magnitudes do not give an actual measure of energy output. To measure the energy output from the surface of a star per second, called its power or **luminosity**, an astronomer must know both the star's apparent magnitude and how far away it is. The brightness observed depends on both a star's luminosity and distance from Earth, and because brightness diminishes with the square of the distance, a correction must be made for distance. Luminosity is measured in units of energy emitted per second, or watts. The Sun's luminosity is about  $3.85 \times 10^{26}$  W. This is equivalent to  $3.85 \times 10^{24}$  100-W lightbulbs. The values for other stars vary widely, from about 0.0001 to more than 1 million times the Sun's luminosity. No other stellar property varies as much.

## Classification of Stars

You have learned that the Sun has dark absorption lines at specific wavelengths in its spectrum. Other stars also have dark absorption lines in their spectra and are classified according to their patterns of absorption lines. Spectral lines provide information about a star's composition and temperature.

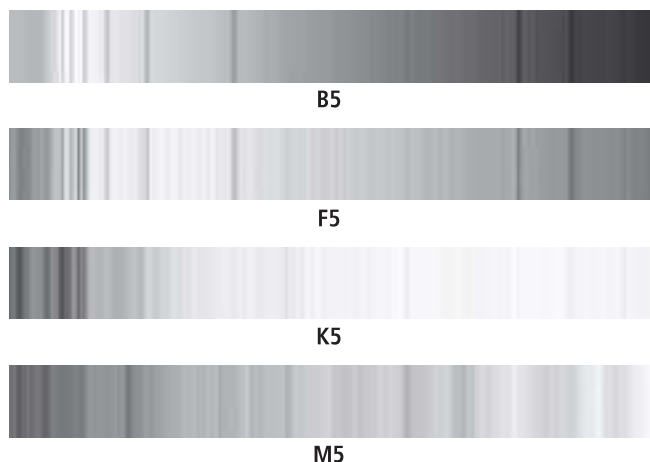
**Temperature** Stars are assigned spectral types in the following order: O, B, A, F, G, K, and M. Each class is subdivided into more specific divisions with numbers from 0 to 9. For example, a star can be classified as being a type A4 or A5.

The classes were originally based only on the pattern of spectral lines, but astronomers later discovered that the classes also correspond to stellar temperatures, with the O stars being the hottest and the M stars being the coolest. Thus, by examination of a star's spectra, it is possible to estimate its temperature.

The Sun is a type G2 star, which corresponds to a surface temperature of about 5800 K. Surface temperatures range from about 50,000 K for the hottest O stars to as low as 2000 K for the coolest M stars.

**Figure 29.16** shows how spectra from some different star classes appear.

Temperature is also related to luminosity and absolute magnitude. Hotter stars put out more light than stars with lower temperatures. In most normal stars, the temperature corresponds to the luminosity. Since the temperature is not affected by its distance, by measuring the temperature and luminosity, distance is known.

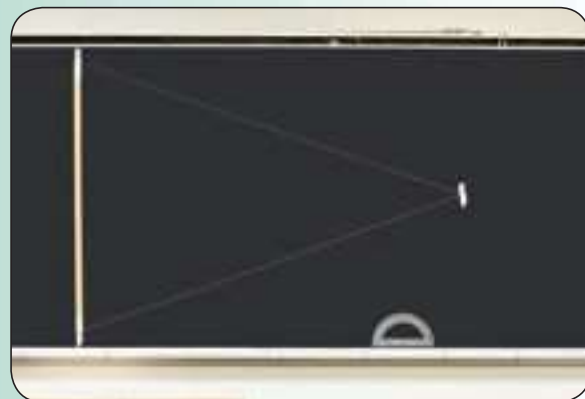


■ **Figure 29.16** These are typical absorption spectra of a class B5 star, class F5 star, class K5 star, and a class M5 star. The black stripes are absorption lines telling us each star's element composition.

## MiniLab

### Model Parallax

**How does parallax angle change with distance?** If a star is observed at six-month intervals in its orbit, it will appear to have moved because Earth is 300 million km away from the location of the first observation. The angle to the star is different and the apparent change in position of the star is called parallax.



### Procedure

1. Read and complete the lab safety form.
2. Place a **meterstick** at a fixed position and attach a **4-m piece of string** to each end.
3. Stand away from the meterstick and hold the two strings together to form a triangle. Be sure to hold the strings taut. Measure your distance from the meterstick. Record your measurement.
4. Measure the angle between the two pieces of string with a **protractor**. Record your measurement of the angle.
5. Repeat Steps 3 and 4 for different distances from the meterstick by shortening or lengthening the string.
6. Make a graph of the angles versus their distance from the meterstick.

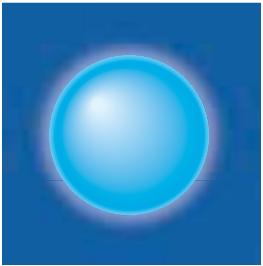
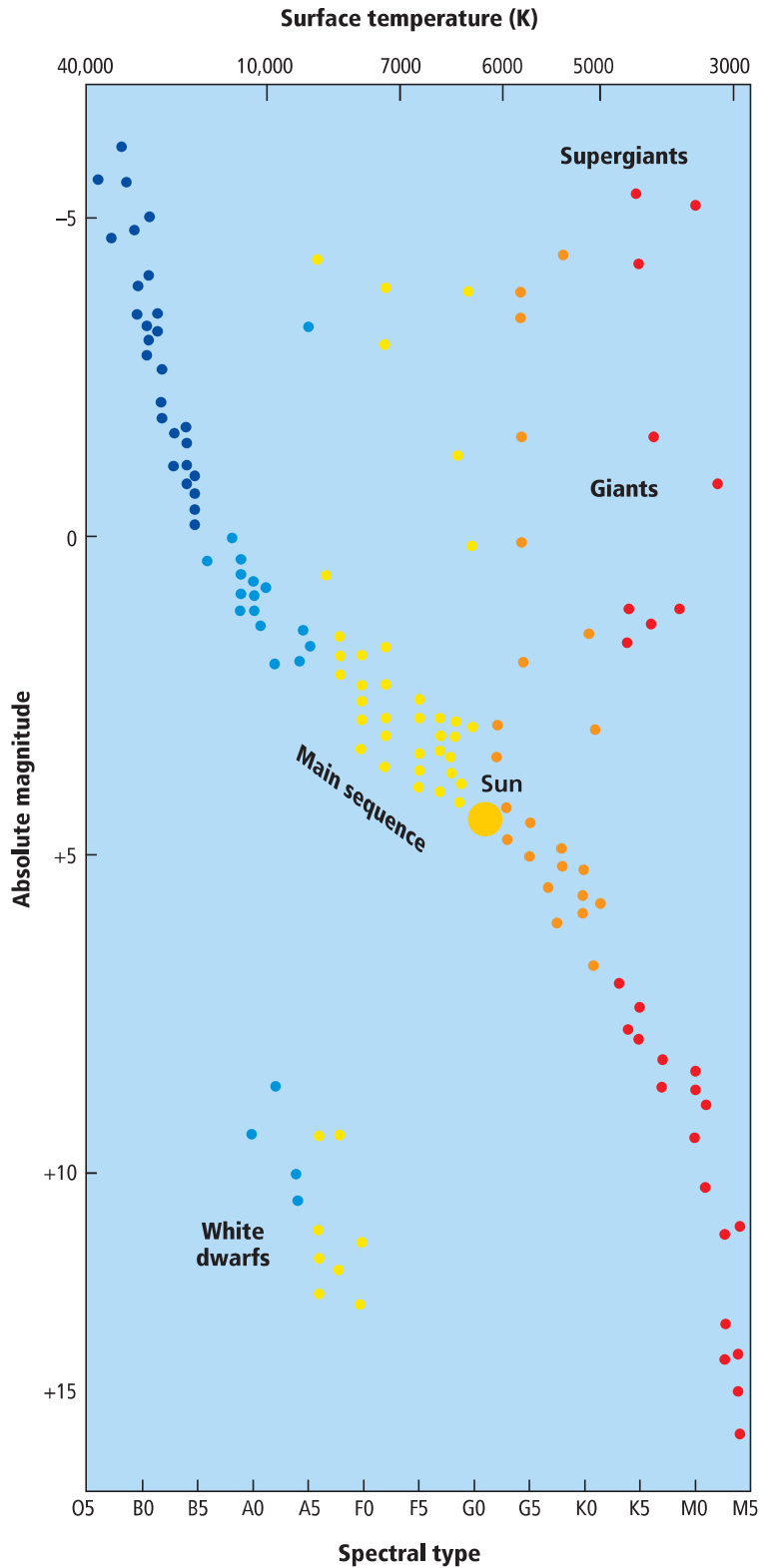

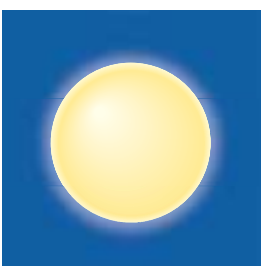

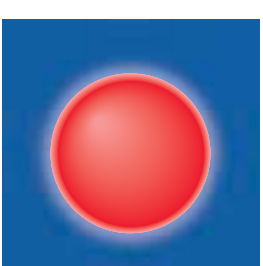
### Analysis

1. **Interpret** what the length of the meterstick represents. What does the angle represent?
2. **Analyze** what the graph shows. How does parallax angle depend on distance?
3. **Explain** how the angles that you measured are similar to actual stellar parallax angles.

**Interactive Table** To explore more about main-sequence stars, visit [glencoe.com](http://glencoe.com).

**Table 29.2**

**Relationships of Spectral Types of Stars**

Color of Star	Spectral Type	H-R diagram
	O5	 <p>The H-R diagram plots Absolute magnitude (y-axis, from -5 to +15) against Surface temperature in Kelvin (top x-axis, from 40,000 to 3,000) and Spectral type (bottom x-axis, from O5 to M5). The Main sequence is a diagonal band of stars. Supergiants are located at the top right, Giants in the middle right, and White dwarfs at the bottom left. The Sun is a yellow dot on the Main sequence at spectral type G2.</p>
	B5	
	F5	
	G5	
	M5	

**Composition** All stars, including the Sun, have nearly identical compositions, despite the differences in their spectra, shown in **Table 29.2**. The differences in the appearance of their spectra are almost entirely a result of temperature differences. Hotter stars have fairly simple visible spectra, while cooler stars have spectra with more lines. The coolest stars have bands in their spectra due to molecules such as titanium oxide in their atmospheres. Typically, about 73 percent of a star's mass is hydrogen (H), about 25 percent is helium (He), and the remaining 2 percent is composed of all the other elements. While there are some variations in the composition of stars, particularly in the final 2 percent, all stars have this general composition.

**H-R diagrams** The properties of mass, luminosity, temperature, and diameter are closely related. Each class of star has a specific mass, luminosity, magnitude, temperature, and diameter. These relationships can be demonstrated on a graph called the **Hertzsprung-Russell diagram** (H-R diagram) on which absolute magnitude is plotted on the vertical axis and temperature or spectral type is plotted on the horizontal axis, as shown in **Table 29.2**. Spectroscopists first plotted this graph in the early twentieth century. An H-R diagram with luminosity plotted on the vertical axis looks similar to the one in **Table 29.2** and is used to calculate the evolution of stars.

Most stars occupy the region in the diagram called the **main sequence**, which runs diagonally from the upper-left corner, where hot, luminous stars are represented, to the lower-right corner, where cool, dim stars are represented. **Table 29.3** shows some properties of main-sequence stars.

#### CAREERS IN EARTH SCIENCE

**Spectroscopist** The main job of an astronomer is to select the stars and objects to observe, but there are other scientists who are affiliated with an observatory. Scientists who make and analyze the spectra from stars are called spectroscopists. To learn more about Earth science careers, visit [glencoe.com](http://glencoe.com).

<div> <div>Table 29.3</div> <div> <b>Properties of Main-Sequence Stars</b> <div> <b>Interactive Table</b> To explore more about main-sequence star properties, visit <a href="http://glencoe.com">glencoe.com</a>. </div> </div> </div>				
Spectral Type	Mass*	Surface Temperature (K)	Luminosity*	Radius*
O5	40.0	40,000	$5 \times 10^5$	18.0
B5	6.5	15,500	800	3.8
A5	2.1	8500	20	1.7
F5	1.3	6580	2.5	1.2
G5	0.9	5520	0.8	0.9
K5	0.7	4130	0.2	0.7
M5	0.2	2800	0.008	0.3

\* These properties are relative to the Sun.



**Main sequence** About 90 percent of stars, including the Sun, fall along a broad strip of the H-R diagram called the main sequence. While stars are in the main sequence, they are fusing hydrogen in their cores. The interrelatedness of the properties of these stars indicates that all these stars have similar internal structures and functions. As stars evolve off the main sequence, they begin to fuse helium in their cores and burn hydrogen around the core edges.

The Sun lies near the center of the main sequence, being of average temperature and luminosity. A star's mass determines almost all its other properties, including its main-sequence lifetime. The more massive a star is, the higher its central temperature and the more rapidly it burns its hydrogen fuel. This is due primarily to the ratio of radiation pressure to gravitational pressure. Higher pressures cause the fuels to burn faster. As a consequence, the star runs out of hydrogen faster than a lower-mass star.

**Red giants and white dwarfs** The stars plotted at the upper right of the H-R diagram in **Table 29.2** are cool, yet luminous. Because cool surfaces emit much less radiation per square meter than hot surfaces do, these cool stars must have large surface areas to be so bright. For this reason, these larger, cool, luminous stars are called red giants. Red giants are so large—more than 100 times the size of the Sun in some cases—that Earth would be swallowed up if the Sun were to become a red giant! Conversely, the dim, hot stars plotted in the lower-left corner of the H-R diagram must be small, or they would be more luminous. These small, dim, hot stars are called white dwarfs. A white dwarf is about the size of Earth but has a mass about as large as the Sun's. You will learn how all the different stars are formed in Section 29.3.

## Section 29.2 Assessment

### Section Summary

- ▶ Stars exist in clusters held together by their gravity.
- ▶ The simplest cluster is a binary.
- ▶ Parallax is used to measure distances to stars.
- ▶ The brightness of stars is related to their temperature.
- ▶ Stars are classified by their spectra.
- ▶ The H-R diagram relates the basic properties of stars: class, temperature, and luminosity.

### Understand Main Ideas

1. **MAIN Idea** **Relate** the stellar temperature to the classification of a star.
2. **Explain** the difference between apparent and absolute magnitudes.
3. **Explain** how parallax is used to measure the distance to stars.
4. **Compare and contrast** luminosity and magnitude.
5. **Contrast** the apparent magnitude and the absolute magnitude of a star.
6. **Compare** a light-year and a parsec.

### Think Critically

7. **Design** a model to explain parallax.
8. **Explain** the relationship between radius and mass using **Table 29.3**.

### MATH in Earth Science

9. Compare Orion's brightest stars, Rigel (O class) and Betelgeuse (M class), by mass, temperature, luminosity, and radius, using **Table 29.3** as a reference.