Section 2 Characteristics of Stars

Reading Preview

Key Concepts

- How are stars classified?
- How do astronomers measure distances to the stars?
- What is an H-R diagram and how do astronomers use it?

Key Terms

- constellation
- spectrograph
- apparent brightness
- absolute brightness
- light-year
- parallax
- Hertzsprung-Russell diagram
- main sequence

Target Reading Skill

Using Prior Knowledge Before you read, write what you know about the characteristics of stars in a graphic organizer like the one below. As you read, write what you learned.

What You Know
1. Stars are bright and hot.
2.

What You Learned
1.
2.

Lab zone Discover Activity

How Does Your Thumb Move?

1. Stand facing a wall, at least an arm's length away. Stretch your arm out with your thumb up and your fingers curled.
2. Close your right eye and look at your thumb with your left eye. Line your thumb up with something on the wall.
3. Now close your left eye and open your right eye. How does your thumb appear to move along the wall?
4. Bring your thumb closer to your eye, about half the distance as before. Repeat Steps 2 and 3.

Think It Over

Observing How does your thumb appear to move in Step 4 compared to Step 3? How are these observations related to how far away your thumb is at each step? How could you use this method to estimate distances?

When ancient observers around the world looked up at the night sky, they imagined that groups of stars formed pictures of people or animals. Today, we call these imaginary patterns of stars **constellations.**

Different cultures gave different names to the constellations. For example, a large constellation in the winter sky is named Orion, the Hunter, after a Greek myth. In this constellation, Orion is seen with a sword in his belt and an upraised arm. The ancient Sumerians thought that the stars in Orion formed the outline of a sheep. In ancient China, this group of stars was called "three," probably because of the three bright stars in Orion's belt.

Astronomers use the patterns of the constellations to locate objects in the night sky. But although the stars in a constellation look as if they are close to one another, they generally are not. They just happen to lie in the same part of the sky as seen from Earth.

Illustration of Orion ▼

Classifying Stars

Like the sun, all stars are huge spheres of glowing gas. They are made up mostly of hydrogen, and they produce energy through the process of nuclear fusion. This energy makes stars shine brightly. Astronomers classify stars according to their physical characteristics. **Characteristics used to classify stars include color, temperature, size, composition, and brightness.**

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Color and Temperature If you look at the night sky, you can see slight differences in the colors of the stars. For example, Betelgeuse (BAY tul jooz), the bright star in Orion's shoulder, looks reddish. Rigel, the star in Orion's heel, is blue-white.

Like hot objects on Earth, a star's color reveals its surface temperature. If you watch a toaster heat up, you can see the wires glow red-hot. The wires inside a light bulb are even hotter and glow white. Similarly, the coolest stars—with a surface temperature of about 3,200 degrees Celsius—appear reddish in the sky. With a surface temperature of about 5,500 degrees Celsius, the sun appears yellow. The hottest stars in the sky, with surface temperatures of over 20,000 degrees Celsius, appear bluish.

Size When you look at stars in the sky, they all appear to be points of light of the same size. Many stars are actually about the size of the sun, which is a medium-sized star. However, some stars are much larger than the sun. Very large stars are called giant stars or supergiant stars. If the supergiant star Betelgeuse were located where our sun is, it would be large enough to fill the solar system as far out as Jupiter.

Most stars are much smaller than the sun. White dwarf stars are about the size of Earth. Neutron stars are even smaller, only about 20 kilometers in diameter.

FIGURE 5
Star Size
Stars vary greatly in size. Giant stars are typically 10 to 100 times larger than the sun and more than 1,000 times the size of a white dwarf. **Calculating** *Betelgeuse has a diameter of 420 million kilometers. How many times larger is this than the sun, which has a diameter of 1.4 million kilometers?*

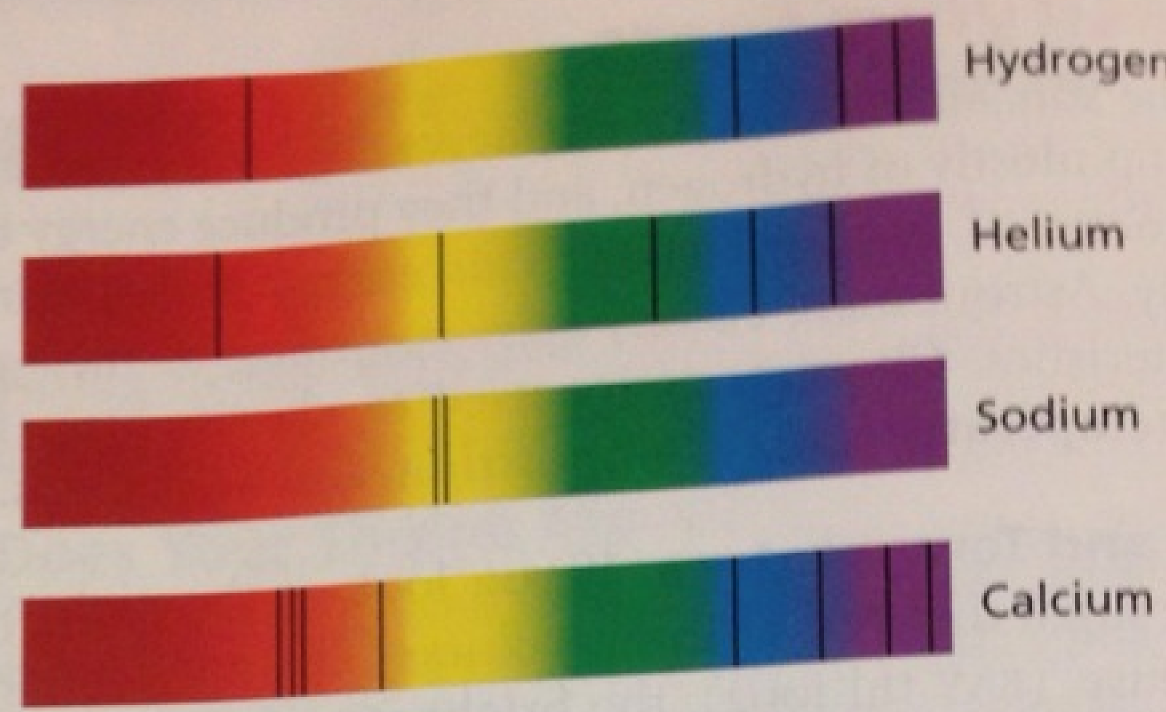


Figure 6
Spectrums of Four Stars
Astronomers can use line spectrums to identify the chemical elements in a star. Each element produces a characteristic pattern of spectral lines.

Chemical Composition Stars vary in their chemical composition. The chemical composition of most stars is about 73 percent hydrogen, 25 percent helium, and 2 percent other elements by mass. This is similar to the composition of the sun.

Astronomers use spectrographs to determine the elements found in stars. A **spectrograph** (SPEK truh graf) is a device that breaks light into colors and produces an image of the resulting spectrum. Most large telescopes have spectrographs.

The gases in a star's atmosphere absorb some wavelengths of light produced within the star. When the star's light is seen through a spectrograph, each absorbed wavelength is shown as a dark line on a spectrum. Each chemical element absorbs light at particular wavelengths. Just as each person has a unique set of fingerprints, each element has a unique set of lines for a given temperature. Figure 6 shows the spectral lines of four elements. By comparing a star's spectrum with the spectrums of known elements, astronomers can infer how much of each element is found in the star.

Reading Checkpoint What is a spectrograph?

Lab zone Skills Activity

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 Figure 6. In star A, which elements have the strongest lines? Which are the strongest in star B? In star C?

Brightness of Stars

Stars also differ in brightness, the amount of light they give off. **The brightness of a star depends upon both its size and temperature.** Recall that the photosphere is the layer of a star that gives off light. Betelgeuse is fairly cool, so a square meter of its photosphere doesn't give off much light. But Betelgeuse is very large, so it shines brightly.

Rigel, on the other hand, is very hot, so each square meter of Rigel's photosphere gives off a lot of light. Even though it is smaller than Betelgeuse, Rigel shines more brightly.

How bright a star looks from Earth depends on both its distance from Earth and how bright the star truly is. Because of these two factors, the brightness of a star can be described in two ways: apparent brightness and absolute brightness.

Apparent Brightness A star's **apparent brightness** is its brightness as seen from Earth. Astronomers can measure apparent brightness fairly easily using electronic devices. However, astronomers can't tell how much light a star gives off just from the star's apparent brightness. Just as a flashlight looks brighter the closer it is to you, a star looks brighter the closer it is to Earth. For example, the sun looks very bright. This does not mean that the sun gives off more light than all other stars. The sun looks so bright simply because it is so close. In reality, the sun is a star of only average brightness.

Absolute Brightness A star's **absolute brightness** is the brightness the star would have if it were at a standard distance from Earth. Finding a star's absolute brightness is more complex than finding its apparent brightness. An astronomer must first find out both the star's apparent brightness and its distance from Earth. The astronomer can then calculate the star's absolute brightness.

Astronomers have found that the absolute brightness of stars can vary tremendously. The brightest stars are more than a billion times brighter than the dimmest stars!

Reading Checkpoint What is a star's absolute brightness?

Lab zone **Try This Activity**

Star Bright

You can compare absolute and apparent brightness.

1. Dim the lights. Put two equally bright flashlights next to each other on a table. Turn them on.
2. Look at the flashlights from the other side of the room. Think of the flashlights as two stars. Then compare them in terms of absolute and apparent brightness.
3. Move one of the flashlights closer to you and repeat Step 2.
4. Replace one of the flashlights with a brighter one. Repeat Steps 1 and 2 with the unequally bright flashlights.

Making Models How could you place the flashlights in Step 4 so that they have the same apparent brightness? Try it.

FIGURE 7
Absolute Brightness
The streetlights in this photo all give off about the same amount of light, and so have about the same absolute brightness.
Applying Concepts *Why do the closer streetlights appear brighter than the more distant lights?*

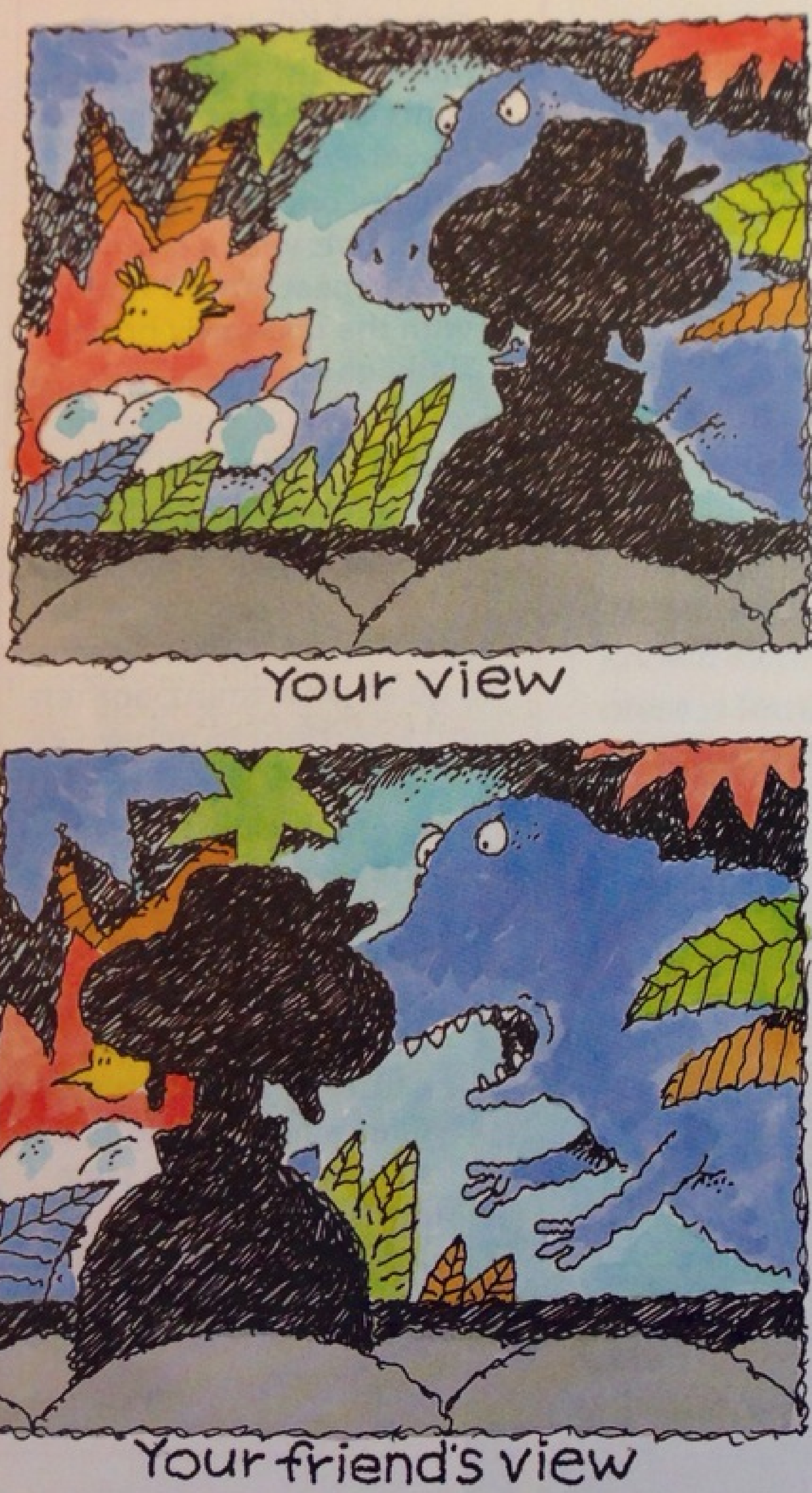
Measuring Distances to Stars

Imagine that you could travel to the stars at the speed of light. To travel from Earth to the sun would take about 8 minutes, not very much time for such a long trip. The next nearest star, Proxima Centauri, is much farther away. A trip to Proxima Centauri at the speed of light would take 4.2 years!

The Light-Year Distances on Earth's surface are often measured in kilometers. However, distances to the stars are so large that kilometers are not very practical units. **Astronomers use a unit called the light-year to measure distances between the stars.** In space, light travels at a speed of about 300,000 kilometers per second. A **light-year** is the distance that light travels in one year, about 9.5 million million kilometers.

Note that the light-year is a unit of distance, not time. To help you understand this, consider an everyday example. If you bicycle at 10 kilometers per hour, it would take you 1 hour to go to a mall 10 kilometers away. You could say that the mall is "1 bicycle-hour" away.

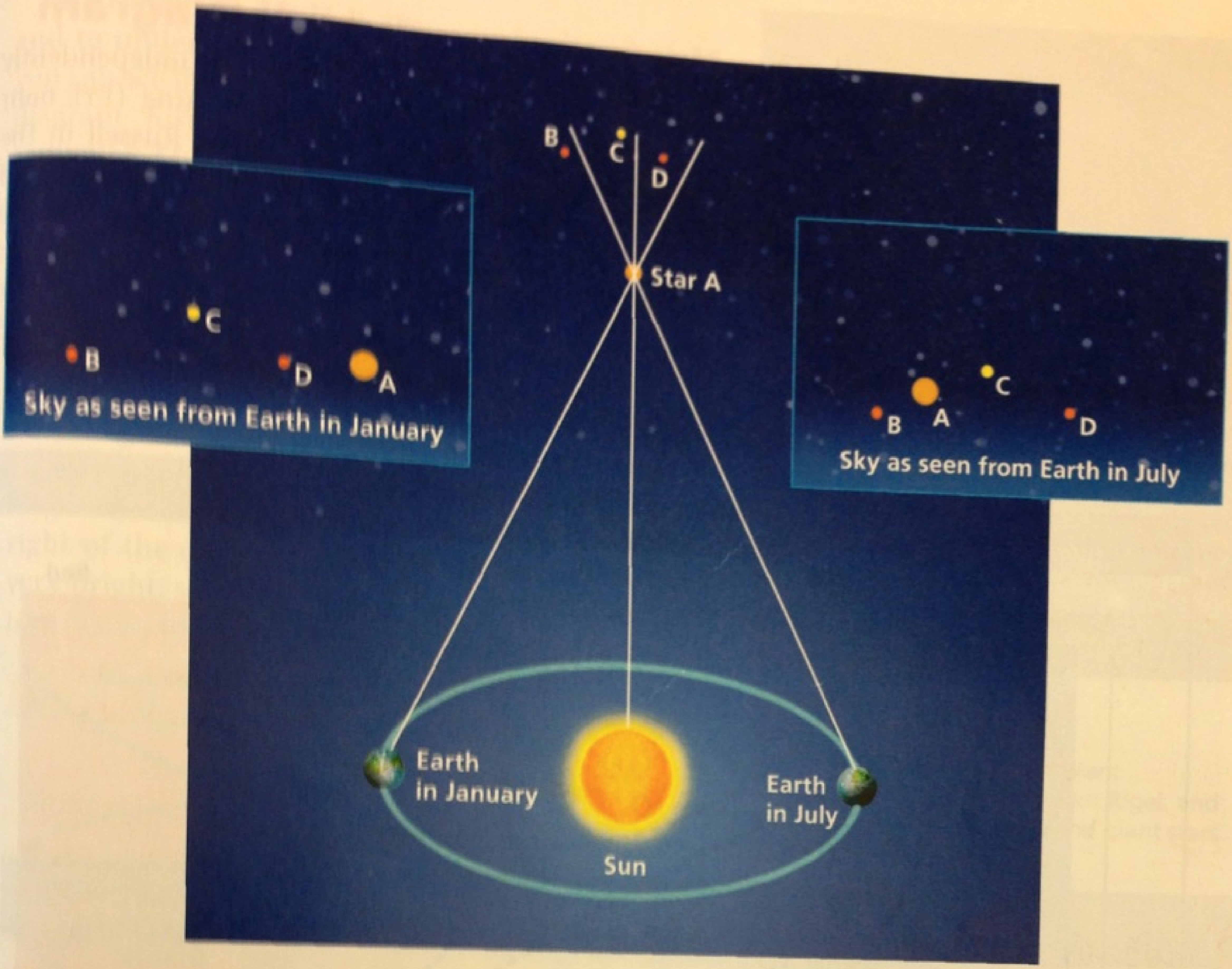
FIGURE 8
Parallax at the Movies
You and your friend are sitting behind a woman with a large hat. **Applying Concepts** *Why is your view of the screen different from your friend's view?*



Parallax Standing on Earth looking up at the sky, it may seem as if there is no way to tell how far away the stars are. However, astronomers have found ways to measure those distances. **Astronomers often use parallax to measure distances to nearby stars.**

Parallax is the apparent change in position of an object when you look at it from different places. For example, imagine that you and a friend have gone to a movie. A woman with a large hat sits down in front of you, as shown in Figure 8. Because you and your friend are sitting in different places, the woman's hat blocks different parts of the screen. If you are sitting on her left, the woman's hat appears to be in front of the large dinosaur. But to your friend on the right, she appears to be in front of the bird.

Have the woman and her hat moved? No. But because you changed your position, she appears to have moved. This apparent movement when you look from two different directions is parallax.



Parallax in Astronomy Astronomers are able to measure the parallax of nearby stars to determine their distances. As shown in Figure 9, astronomers look at a nearby star when Earth is on one side of the sun. Then they look at the same star again six months later, when Earth is on the opposite side of the sun. Astronomers measure how much the nearby star appears to move against a background of stars that are much farther away. They can then use this measurement to calculate the distance to the nearby star. The less the nearby star appears to move, the farther away it is.

Astronomers can use parallax to measure distances up to a few hundred light-years from Earth. The parallax of any star that is farther away is too small to measure accurately.

Reading Checkpoint **How is parallax useful in astronomy?**

FIGURE 9
Parallax of Stars
The apparent movement of a star when seen from a different position is called parallax. Astronomers use parallax to calculate the distance to nearby stars. Note that the diagram is not to scale.
Interpreting Diagrams *Why do nearby stars appear to change position between January and July?*

The Hertzsprung-Russell Diagram

About 100 years ago, two scientists working independently made the same discovery. Both Ejnar Hertzsprung (EYE nahr HURT sprung) in Denmark and Henry Norris Russell in the United States made graphs to find out if the temperature and the absolute brightness of stars are related. They plotted the surface temperatures of stars on the *x*-axis and their absolute brightness on the *y*-axis. The points formed a pattern. The graph they made is still used by astronomers today. It is called the **Hertzsprung-Russell diagram,** or H-R diagram.

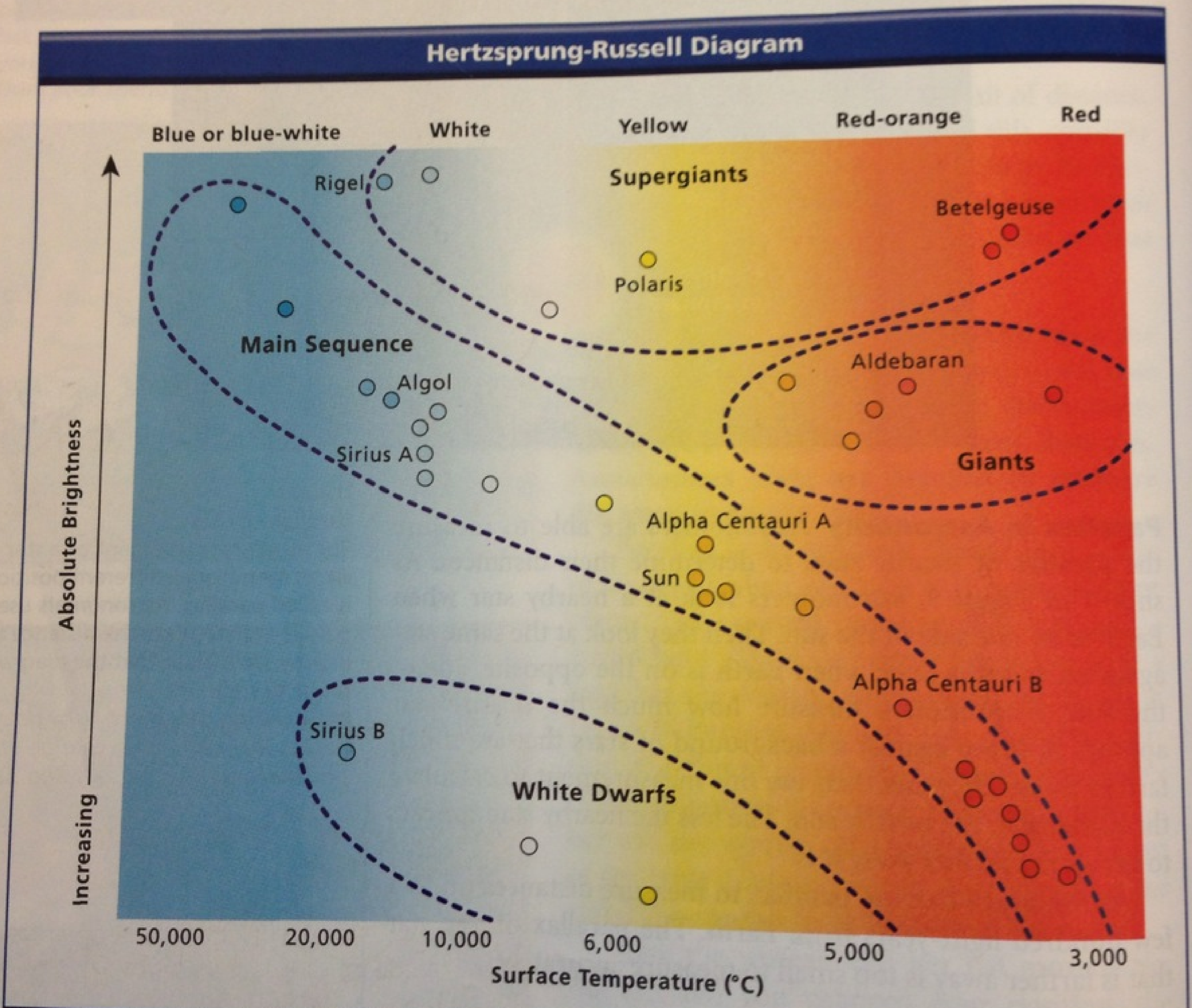


FIGURE 10
The Hertzsprung-Russell diagram shows the relationship between the surface temperature and absolute brightness of stars.
Interpreting Diagrams *Which star has a hotter surface: Rigel or Aldebaran?*

Astronomers use H-R diagrams to classify stars and to understand how stars change over time. As you can see in Figure 10, most of the stars in the H-R diagram form a diagonal area called the **main sequence.** More than 90 percent of all stars, including the sun, are main-sequence stars. Within the main sequence, surface temperature increases as absolute brightness increases. Thus, hot bluish stars are located at the left of an H-R diagram and cooler reddish stars are located at the right of the diagram.

The brightest stars are located near the top of an H-R diagram, while the dimmest stars are located at the bottom. Giant and supergiant stars are very bright. They can be found near the top center and right of the diagram. White dwarfs are hot, but not very bright, so they appear at the bottom left or bottom center of the diagram.

Reading Checkpoint What is the main sequence?

FIGURE 11
Orion
Orion includes the red supergiant Betelgeuse, the blue supergiant Rigel, and many other main-sequence and giant stars.

Section 2 Assessment

Target Reading Skill Using Prior Knowledge Review your graphic organizer and revise it based on what you just learned in the section.

Reviewing Key Concepts

1. a. **Listing** Name three characteristics used to classify stars.
   b. **Comparing and Contrasting** What is the difference between apparent brightness and absolute brightness?
   c. **Applying Concepts** Stars A and B have about the same apparent brightness, but Star A is about twice as far from Earth as Star B. Which star has the greater absolute brightness? Explain your answer.
2. a. **Measuring** What is a light-year?
   b. **Defining** What is parallax?
   c. **Predicting** Vega is 25.3 light-years from Earth and Arcturus is 36.7 light-years away. Which star would have a greater parallax? Explain.
3. a. **Summarizing** What two characteristics of stars are shown in an H-R diagram?
   b. **Identifying** Identify two ways in which astronomers can use an H-R diagram.
   c. **Classifying** The star Procyon B has a surface temperature of 6,600° Celsius and an absolute brightness that is much less than the sun's. What type of star is Procyon B? (*Hint:* Refer to the H-R diagram.)

Lab zone At-Home Activity

Observing Orion With adult family members, go outside on a clear, dark night. Determine which way is south. Using the star charts in the appendix, look for the constellation Orion, which is visible in the evening during winter and spring. Find the stars Betelgeuse and Rigel in Orion and explain to your family why they are different colors.