CONCEPT 4

The properties of stars help us develop an understanding of their life cycles.

Activity

Inferring Factors That Affect Brightness

Safety

Never use a laser pointer in place of a penlight or other small flashlight in this activity. Someone could be blinded.

For this activity, your group will use three flashlights—a small one (such as a penlight) and two larger ones identical in size and type.

1. One student stands at the back of the room holding one small and one large flashlight in each hand. At the front, with the room dark, have the student at the back turn on both flashlights. Record how their brightness compares.
2. Two group members stand side by side at the back, each holding one of the large flashlights. Again, stand at the front. Darken the room and have the students turn on the flashlights. Record your observations.
3. Have one student at the back walk toward you; the other stays still. Compare the brightness of the two lights. Have the approaching students use the small flashlight. How does the brightness of the two lights compare?
4. a) What factors affect the brightness of light? What might this suggest about the nature of stars and how bright they appear to be?
   b) Imagine two stars emit the same amount of light, but one appears to be 50 times brighter than the other. What might you infer about how far each star is from Earth?

Astronomers estimate that there are about 2 trillion galaxies in the observable universe. That's about 2×10^{23} stars. Like people, each star has unique properties such as brightness, colour, temperature, composition, and mass. These properties help astronomers understand the life cycles of stars—how they form and what can happen to them over their long and, in some cases, turbulent lives.

Brightness of Stars

Astronomers refer to luminosity when describing the brightness of stars. A star's luminosity is a measure of the total amount of energy it gives off per second. The star we know best is the Sun, so it is helpful to use it to compare with other stars. Astronomers have determined that some stars are about 10 000 times less luminous than the Sun, while others are more than 30 000 times more luminous.

Extending the Connections

Comparing Magnitudes

There are two scales that astronomers and other skywatchers use to describe star brightness. One, called apparent magnitude, was developed about 2200 years ago. The other, called absolute magnitude, is a much more recent invention. How do these scales work, and how do they compare? Why are both still in use?

Another term referring to a star's luminosity is absolute magnitude—how bright a star would be if it were at a distance of 32.6 light-years from Earth. The absolute magnitude of the Sun is about 4.7. This value reveals our Sun to be an average star in terms of luminosity. Some stars would be a million times brighter if they were as close to Earth as the Sun is. Others would be much more faint.

Colour and Temperature of Stars

The colour of a star gives scientists an indication of its surface temperature. A fairly hot star appears bluish in colour, while a fairly cool star appears reddish. See **Figure 4.30** and **Table 4.2**. Rigel appears bluish-white, while Betelgeuse appears reddish-white. Our Sun, with a surface temperature of 6000°C, appears yellowish, which places it midway between bluish and reddish stars.

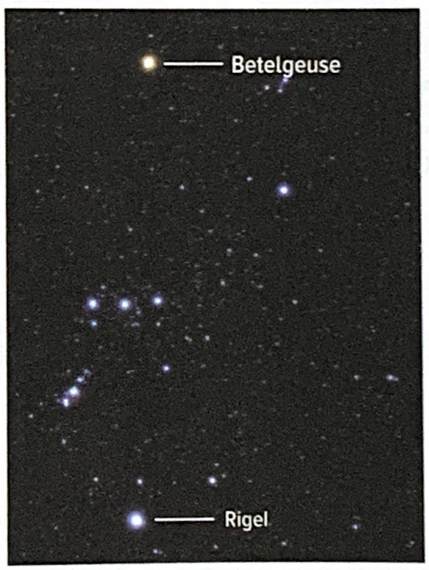


Figure 4.30 Comparing the colours and temperatures of two stars in the constellation Orion

Table 4.2 Colour and Temperature Ranges of Some Stars

Colour	Temperature Range (°C)	Examples
bluish	25 000–50 000	Zeta Orionis
bluish-white	11 000–25000	Rigel, Spica
whitish	7500–11 000	Vega, Sirius
yellowish-white	6000–7500	Polaris, Procyon
yellowish	5000–6000	Sun, Alpha Centauri
orangish	3500–5000	Arcturus, Aldebaran
reddish	2000–3500	Betelgeuse, Antares

Composition of Stars

How do astronomers know that the Sun and other stars are made of hydrogen and helium? They use a spectroscope to analyze the light from stars. A spectroscope is an instrument that produces a pattern of colours and lines, called a spectrum, from a narrow beam of light. In the 1820s, Joseph von Fraunhofer, a German optician, used a spectroscope to observe the Sun's spectrum and noticed hundreds of lines. These lines are called spectral lines. He mapped the Sun's spectrum completely, although he did not know what the spectral lines meant. Today, we know that a star's spectrum identifies the elements of which it is composed (**Figure 4.31**).

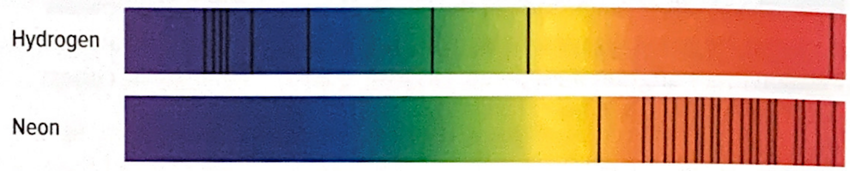
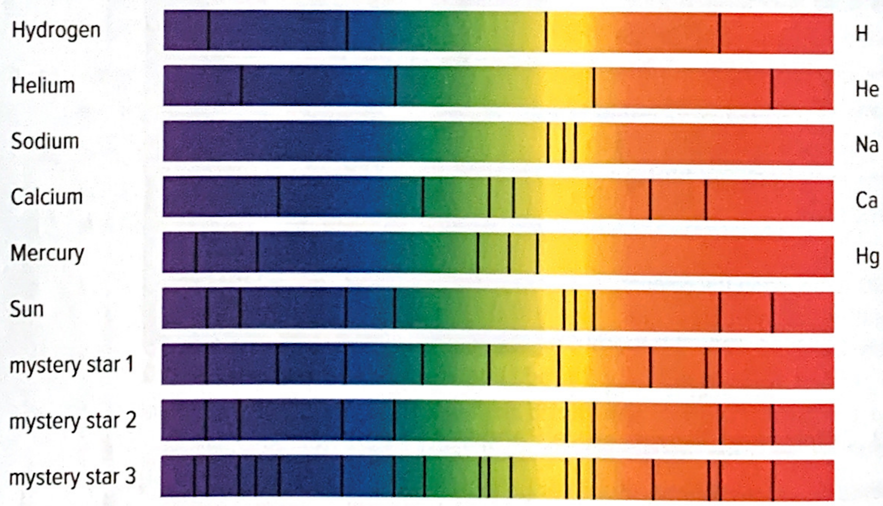


Figure 4.31 Each element is uniquely identified by its spectrum.

Activity

Identify the Composition of Three Mystery Stars

Examine the spectral lines below. Compare the patterns of the known elements to those of the Sun and the three unknown stars.



- Which elements are present in the Sun's spectrum?
- In which two mystery stars is calcium present?
- Which mystery star contains sodium?
- Only one mystery star contains mercury. Which one is it?
- Which mystery star's composition is least like that of the Sun?
- Describe, in writing or orally with a partner, how you can infer a star's composition by analyzing the pattern of its spectra.

Mass of Stars

Determining the mass of stars was not possible until astronomers discovered that most of the stars seen from Earth are binary stars. Binary stars are two stars that orbit each other. The Sun is unusual in that it is not part of a binary star system. By knowing the size of the orbit of a binary pair and the time the two stars take to complete one orbit, astronomers can calculate the mass of each star. Star mass is expressed in terms of solar mass. The mass of the Sun is 10×10^{30} kg, which is given a value of 1 solar mass. Other stars range from 0.08 solar masses to over 100 solar masses.

The Hertzsprung-Russell Diagram and Stellar Evolution

As astronomers learned more about the properties of stars, they began to look for patterns in the data. In the 1920s, two astronomers were studying data from large numbers of stars visible from Earth. Ejnar Hertzsprung in the Netherlands and Henry Norris Russell in the United States were working independently of each other. But both observed that each star type has certain properties. These relationships can be shown on a graph called the **Hertzsprung-Russell (H-R) diagram**. Their graph had star colour (ranging from blue to red) on the *x*-axis. Absolute magnitude was on the *y*-axis of their graph. Astronomers discovered from the H-R diagram that there are several different categories of stars (**Figure 4.32**).

Connect to Investigation 4-C on page 348

Hertzsprung-Russell (H-R) diagram a graph that compares the properties of stars

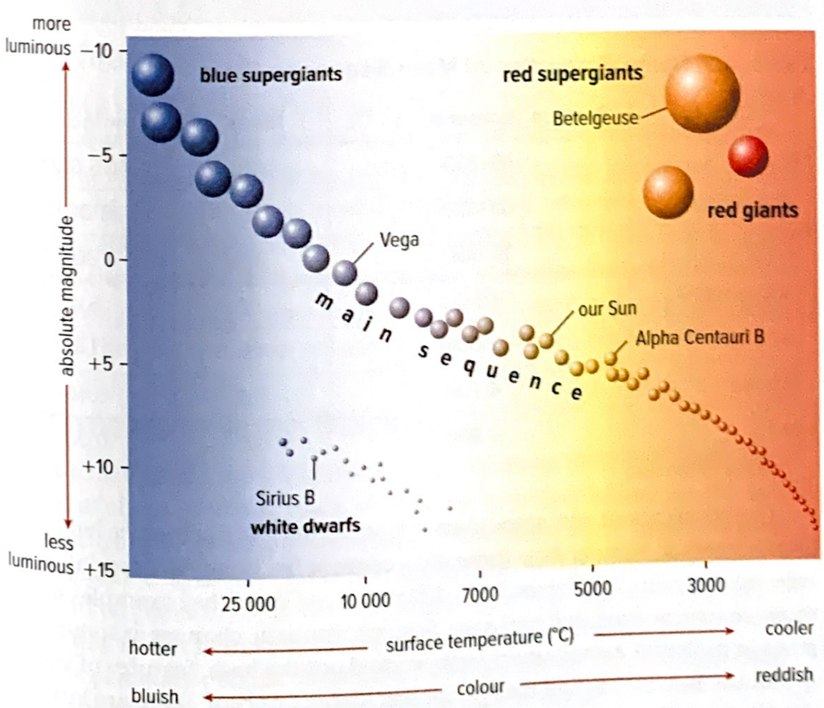


Figure 4.32 This simplified Herzsprung-Russell (H-R) diagram is based on data from thousands of stars. It shows that there is a relationship among the colour, temperature, luminosity, and mass of stars. **Inferring: Before deducing the patterns that led to the H-R diagram, most astronomers assumed that stars were unchanging and eternal. What can you see in the H-R diagram that challenges this assumption? What other assumptions could you make?**

The Main Sequence

main sequence a narrow band of stars on the H-R diagram that runs diagonally from the upper left (bright hot stars) to the lower right (dim cool stars)

The central band of stars stretching from the upper left to the lower right of the H-R diagram in Figure 4.32 is called the **main sequence**. The main sequence accounts for about 90% of the stars that you can see from Earth. What about the 10% of known stars *not* in the main sequence? Hertzsprung and Russell found that some stars were cooler but very luminous. The star Antares, for example, shown in Figure 4.33, has a surface temperature of only 3500°C, but it is the 15th brightest star in the night sky.

When placed on the H-R diagram, the cool, bright stars are far above the main sequence. Find these red giant and supergiant stars on the H-R diagram in Figure 4.32 and note their sizes. Table 4.3 summarizes some properties of main-sequence stars.

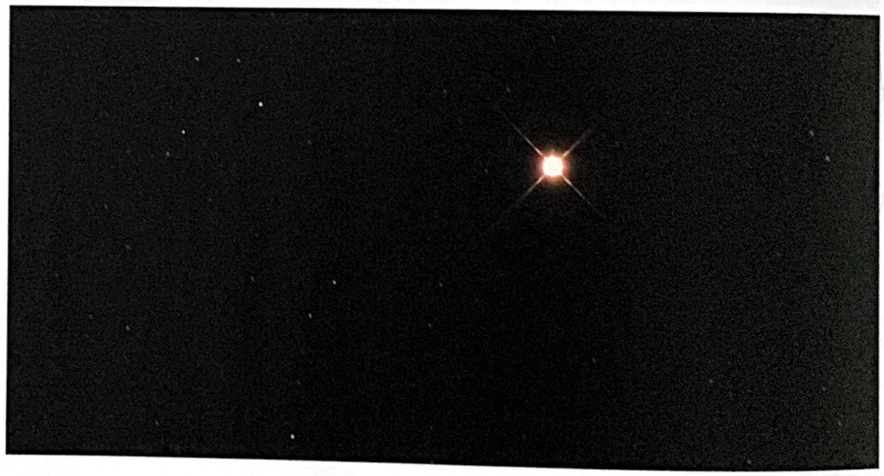


Figure 4.33 Antares is a bright supergiant located about 600 light-years from Earth. Its surface temperature is fairly cool, but it is extremely luminous.

Table 4.3 Some Properties of Main-Sequence Stars

Colour	Surface Temperature (°C)	Mass*	Luminosity*
blue	35 000	40	405 000
blue-white	21 000	15	13 000
white	10 000	3.5	80
yellow-white	7 500	1.7	6.4
yellow	6 000	1.1	1.4
orange	4 700	0.8	0.46
red	3 300	0.5	0.08

* relative to the Sun

Questions about why some stars are not in the main sequence led astronomers to wonder how these stars came to be. Were they special, rare types of stars that formed in a different way? Were they examples of main-sequence stars that had gone through dramatic changes at some stage in their life? Astronomers have worked out the basic features of stellar evolution. But, as you will read in the rest of this Concept, there are lots of details missing, and many puzzles still remain.