11.1 Stars

Stars are spherical objects in space that radiate energy from their hot cores. They outnumber by far all other celestial bodies in the universe. Stars have a life span (like humans do, only much longer). They are formed in clouds of gas and dust. How long a star lives depends on its mass.

Words to Know

black hole
Doppler effect
fusion
interstellar matter
star
supernova

A **star** is an object in space made up of hot gases, with a core that is like a thermonuclear reactor. Astronomers estimate that 9000 billion billion stars have formed in the observable universe over its 13.7 billion year history. As Carl Sagan, an American astronomer and writer, once expressed it, there are more stars in the universe than grains of sand on all the beaches of Earth. In this section, you will learn about how stars form and change over time.

Space is not empty but filled with **interstellar matter**, which is made up of gas (mostly hydrogen) and dust. The dust accounts for only about 1 percent of the total mass of all interstellar matter. Even at such a small amount, interstellar dust makes it hard for astronomers to see the light

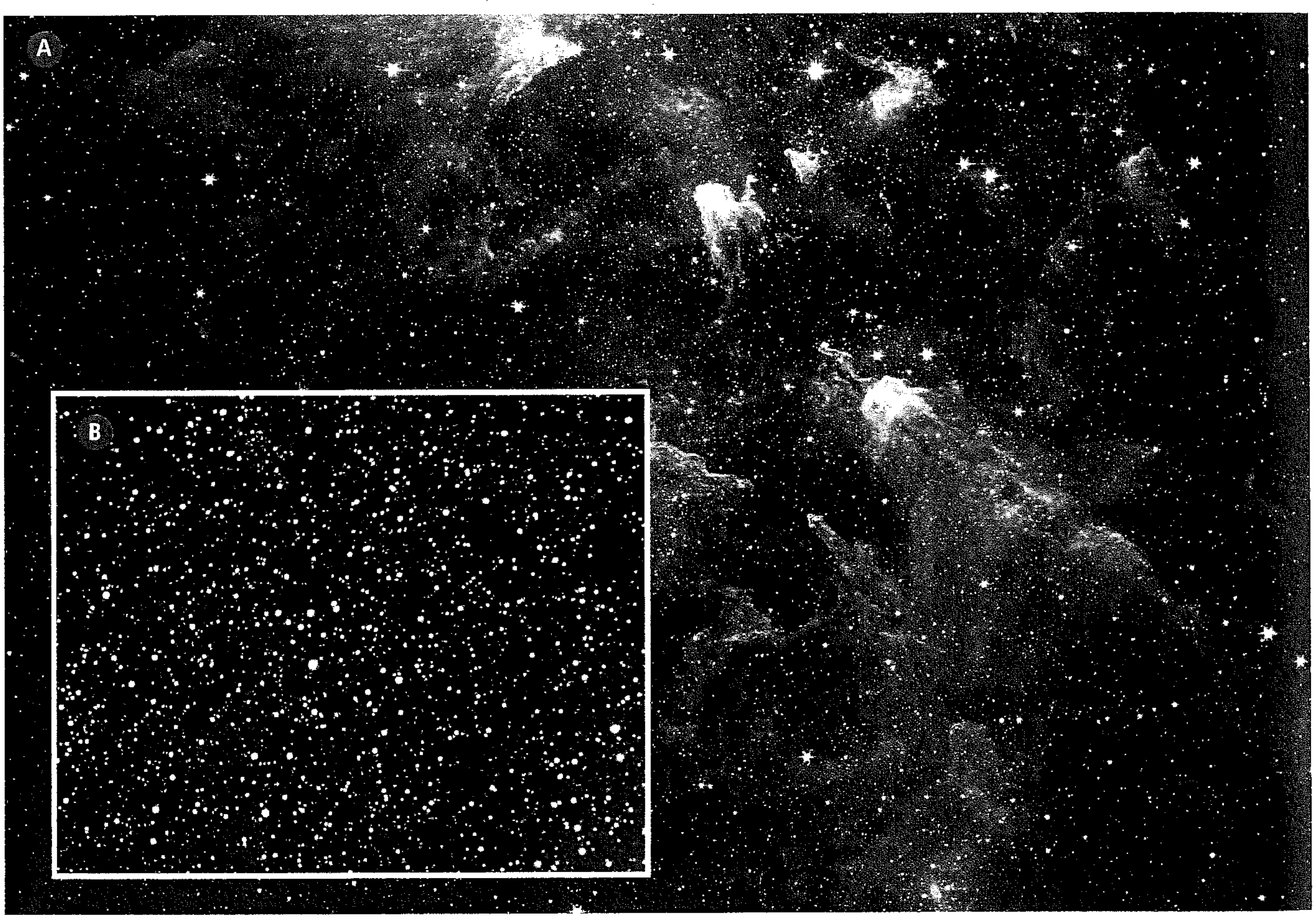

Figure 11.1 The Carina Nebula as it appears in the visible spectrum (A). A section of the same nebula, but this time as it is revealed in the infrared spectrum (B). Note the detail in (B) that was not clear in the visible spectrum.

from distant stars. If you have ever stood beside a dirt road when a vehicle has just driven by, you know how the dust that fills the air makes visibility poor for a few minutes. Fortunately, technology has enabled astronomers to "see" through the dusty curtains of interstellar matter and into what are often called stellar nurseries. Radio and infrared telescopes, for example, are able to detect and record wavelengths of electromagnetic radiation that we cannot see with our eyes. Figure 11.1 on the previous page shows this difference in images of the Carina Nebula.

Word Connect

"Interstellar" (from "inter" and "stellar") means "between stars." It describes material found in the regions of space between stars.

11-1A Light Beam Behaviour

Find Out ACTIVITY

Teacher Demonstration

Visible light is only a small part of the entire electromagnetic spectrum. A warm object will give off infrared radiation. When you turn on the element of an electric stove, for example, you will feel heat long before you see the element glow. This principle is used in astronomy. Astronomers search space for infrared radiation that comes from the dust heated by new stars. This means that stars can be detected even before they are hot enough to generate visible light. In this activity, you will model how interstellar gases and dust in space affect both infrared and visible light.

Materials

- television
- infrared remote control
- flashlight
- water glass or beaker
- fine powder (baby powder, alum, or cornstarch)
- water

What to Do

1. Copy the table below into your notebook, but make it large enough so that you can fill in your predictions and observations.
2. The teacher will shine first the flashlight and then the remote control at the television to illustrate a light beam that has no obstacles. Predict what will happen when the different beams travel through the materials. Record your predictions in the table.
3. The teacher will then aim both sources of light through the empty glass.
4. As the teacher shines the flashlight and the remote through each of the other materials, record your observations.

What Did You Find Out?

1. Did your predictions match your observations?
2. What material interfered with the light from the:
   (a) flashlight?
   (b) infrared remote?
3. (a) Refer to the electromagnetic spectrum in Figure 10.3. Which has a longer wavelength: infrared light or visible light?
   (b) How do you think the wavelength of infrared light might account for what you observed?
4. Why would infrared be useful for finding young stars hidden in dust but not useful for finding comets or asteroids?

Light Beam	Empty Glass		Glass with Water		Fine Powder	
	Predicted	Observed	Predicted	Observed	Predicted	Observed
Visible						
Infrared						

The Birth of a Star

A star begins to form from the materials in a nebula when gravity starts acting on chunks of gas and dust, pulling them together. As gravity keeps working, the mass grows and the material collapses in on itself and contracts. An early phase of star, called a "protostar," is created. "Proto" means earliest (Figure 11.2).

If its mass stays small, the protostar may just shrink away, never reaching full star status. However, if it collects enough mass of dust and gas, the protostar's core will eventually reach about 10 000 000°C. At that point, the atoms fuse together to form larger single atoms. Hydrogen atoms combine to form the heavier element helium. This process, called nuclear **fusion**, creates an enormous amount of energy.

When this stage is reached, the star begins to glow. Leftover gas and dust that surround it gradually disperse. The energy radiates from the core in every direction in the form of electromagnetic waves. This is the way the star nearest to us, the Sun, creates radiation that keeps Earth warm.

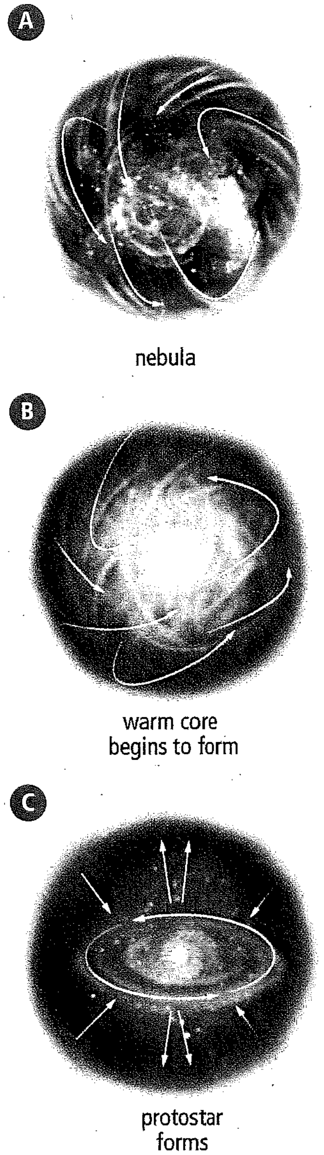

Figure 11.2 Stages in the formation of a star

The Evolution of Stars

Just as living things have a life cycle, stars go through predictable changes as they age. All stars start in a nebula, but the path of development each star takes differs depending on the mass of the newborn star. There are three main life paths for stars (Figure 11.3 on the next page).

Low mass stars

As the name implies, these stars start small and exist that way for most of their life as dim, cool red dwarfs. Red dwarfs burn their hydrogen fuel very slowly, which means that they may last for as long as 100 billion years. They eventually change into very hot, but small, dim white dwarfs and quietly burn out.

Intermediate mass stars

These are stars of similar mass to the Sun. Compared with their low mass cousins, they burn their hydrogen fuel faster, which means that the life of a typical "middle mass" star lasts only about 10 billion years. After a long period of stability, an intermediate mass star expands into a red giant. Gradually, it sheds much of its material into space and collapses in on itself, slowly shrinking into a small, dim white dwarf. As it cools even more, it turns into a black dwarf, a dense, dark body made up mostly of carbon and oxygen.

The Sun will expand to a red giant in about 5 billion years.

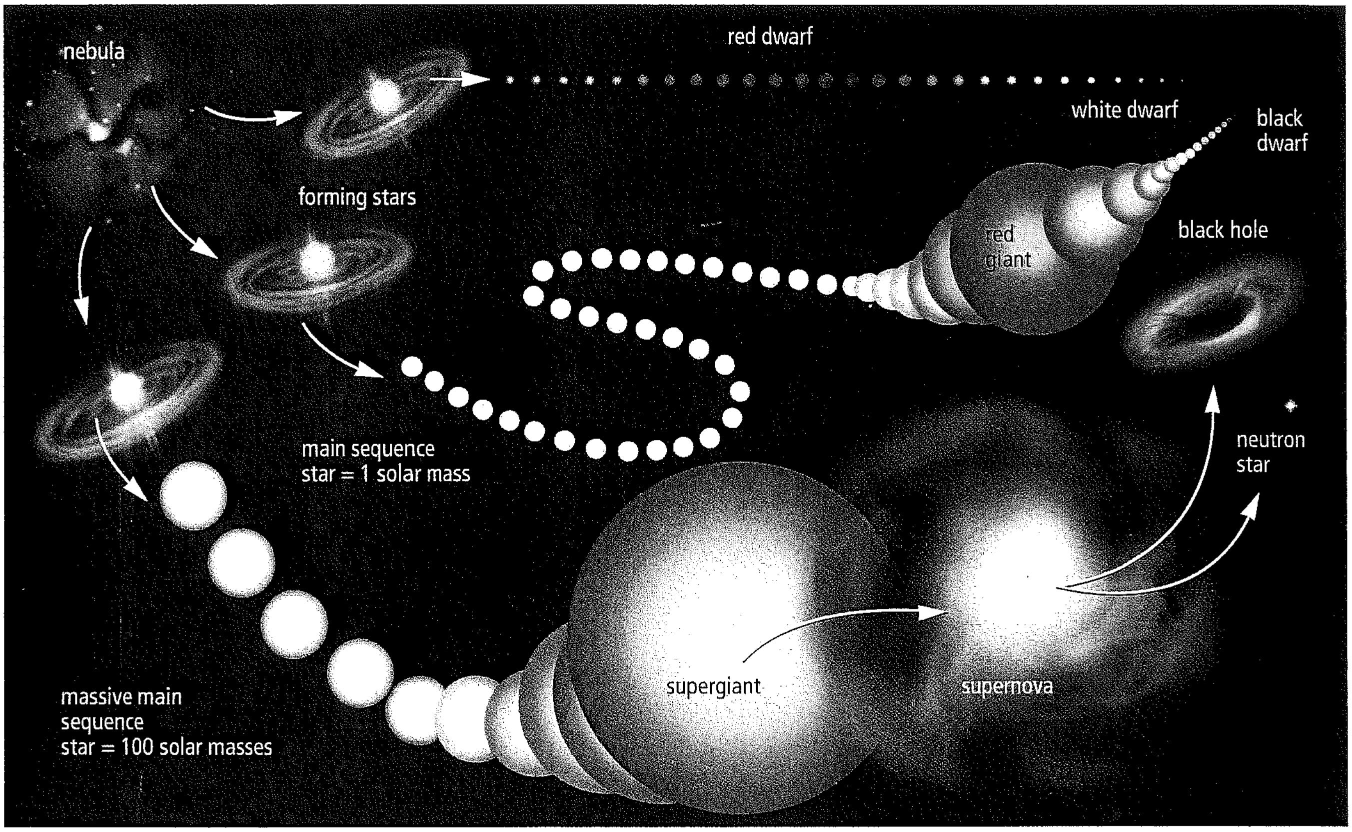

Figure 11.3 The three main life paths of stars

High mass stars

A high mass star is one that has 12 or more times the mass of the Sun. These stars consume their fuel faster than any of their smaller cousins do, becoming red giants. Because they grow rapidly and to large size, they expend much energy and burn out faster, too. The life of an average high mass star will last for only 7 billion years. In star years, that is considered a very short life.

Compared with smaller stars, high mass stars also come to a much more violent end. Massive stars that have used all their fuel become supergiants. Before long, they collapse in on themselves causing a dramatic, massive explosion called a **supernova**. Some supernovas shine so brightly that they can be seen from Earth even in daylight. Supernovas play an extremely important role in the universe. In a forest, plants die, decompose, and provide nutrients for other things to grow. In the universe, when stars die, heavy elements spread out through space. The carbon in your bones, the oxygen you breathe, and the hydrogen in the water you drink all resulted from the death of a star (Figure 11.4 on the next page).

internet connect

In 1987, a team of Canadian and Chilean astronomers reported a supernova, Supernova 1987A, that was clearly visible during the day in the southern hemisphere. To learn more about this supernova, go to **www.bcscience9.ca** and follow the links.

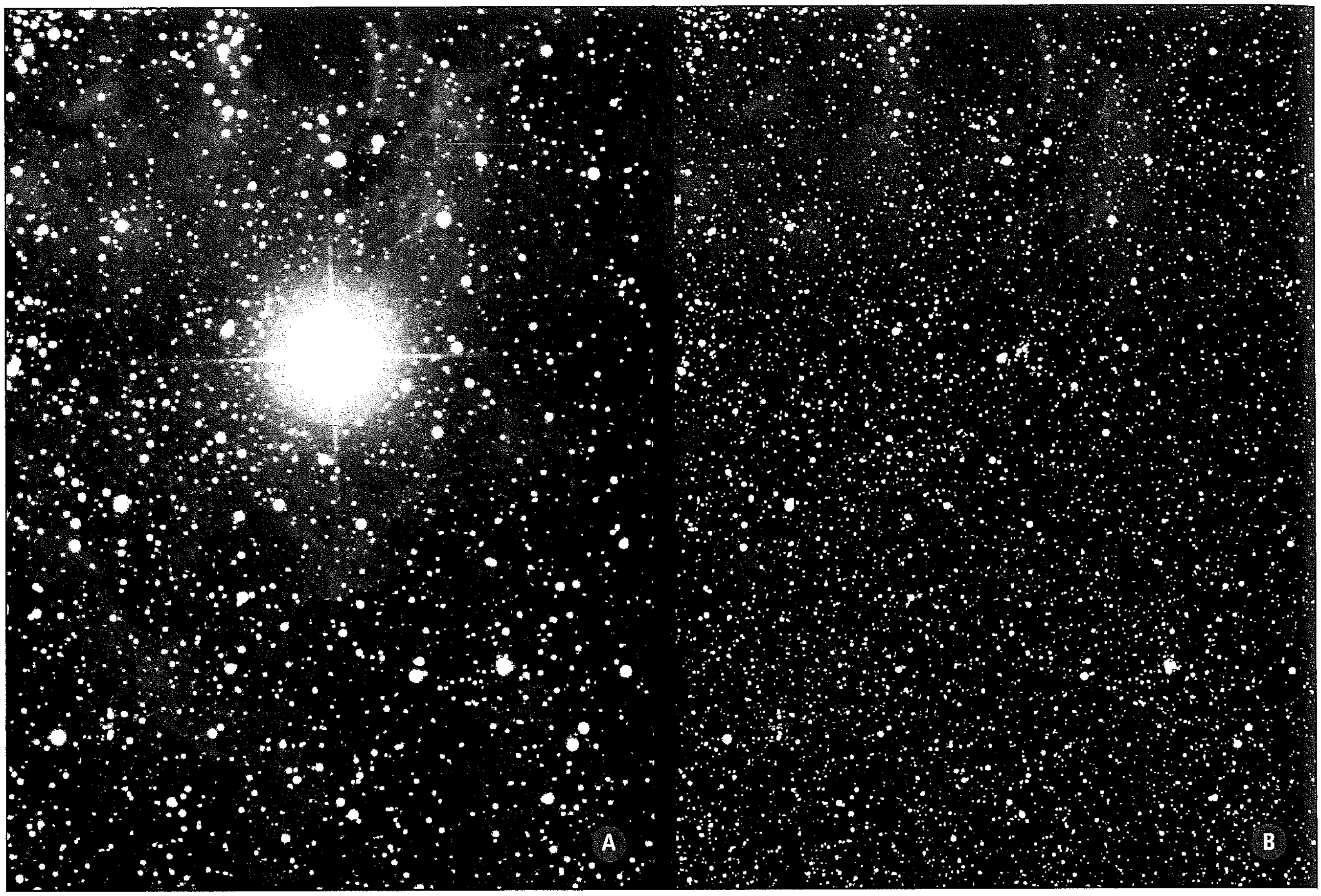

Figure 11.4 The elements created in stars and scattered with each supernova explosion are the building blocks of all matter in the universe, including Earth and every atom in your body.

ore More

e mass of a typical black
'e is 10 times the mass
:he Sun, but black holes
ı a million times the
:s of the Sun have been
cted in the centres of
emely large galaxies,
ding our Milky Way.
out more about black
and how they affect
:s around them. Begin
your research at
www.bcscience9.ca.

If the star began with a mass about 12 to 15 times that of the Sun, the remaining core of the supernova will eventually collapse back in on itself and form a neutron star. The average neutron star starts out being more than 1 million km wide but collapses into a sphere only 10 km wide. This would be like collapsing the mass of your school into the size of the head of a pin. The cores of neutron stars are thought to be as hot as 100 000 000°C and may take trillions of years to cool.

Black holes

A star more than 25 times as massive as the Sun faces a different end. After exploding as a supernova, it becomes a **black hole** and collapses into itself. Because the material is so dense, it has an extraordinary amount of gravitational pull. Black holes are called "black" because nothing, not even light, can escape their powerful gravitational force.

How do astronomers know black holes exist if they cannot see them? There are several pieces of evidence. One is that the material pulled toward the black hole emits electromagnetic radiation, and this can be measured. Another is the effect that the gravity of black holes has on passing stars and galaxies (Figure 11.5 on the next page). Third is from the results suggested by computer models that show how super-dense objects would distort light from distant stars. The computer simulations match the observations astronomers have been making.

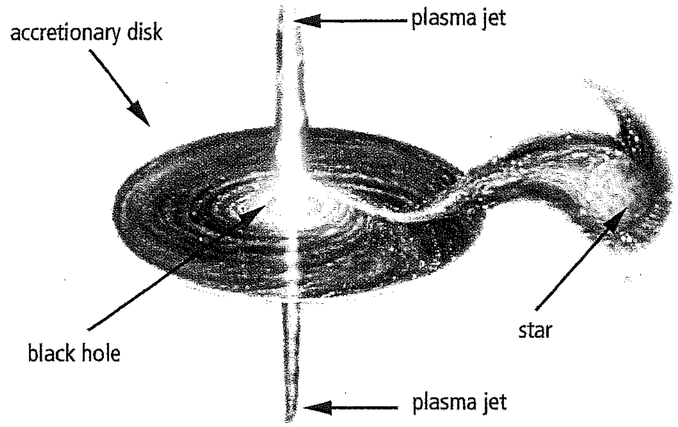

Figure 11.5 A black hole's effects on its surroundings. A star is being drawn into the black hole, and jets of material are shooting out of the centre.

Star Sizes

Many stars visible from Earth are much larger than our Sun. Some of these are shown in Figure 11.6. Imagine the Sun being the size of a volleyball, which has a diameter of about 26 cm. By comparison, the giant star Arcturus would be about 6.5 m in diameter and the red supergiant Betelgeuse would be nearly 170.0 m in diameter. The largest star discovered so far might be VY Canis Majoris. Astronomers are still debating its full size, but some observations suggest it could have a diameter 3000 times larger than that of the Sun.

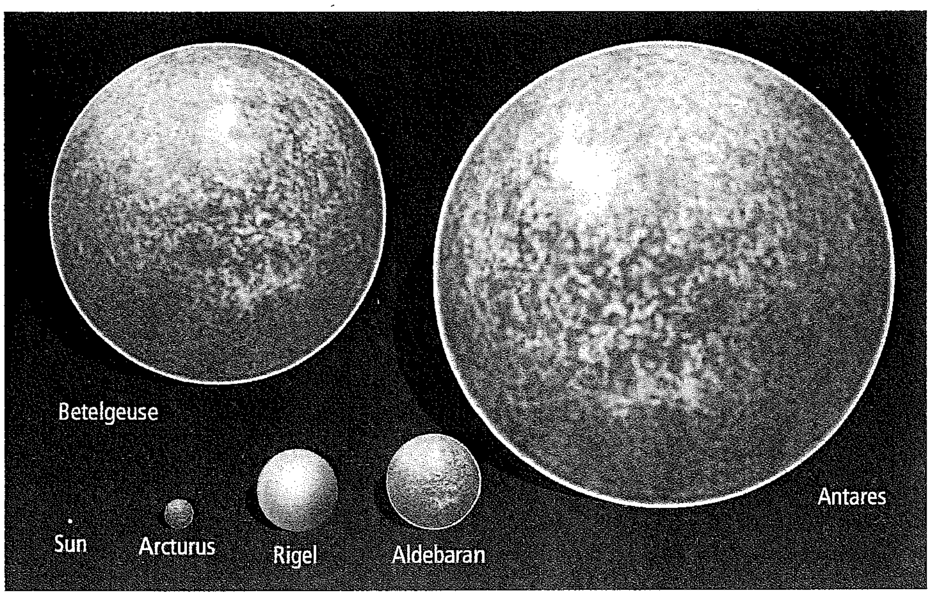

Figure 11.6 The size of the Sun compared with five other stars

Reading Check

1. What nuclear process combines two atomic nuclei to form one heavier element?
2. What are the three basic classifications of stars?
3. How is our star, the Sun, classified?
4. What is the explosion of a very large star called?
5. Why do astronomers call a black hole "black"?