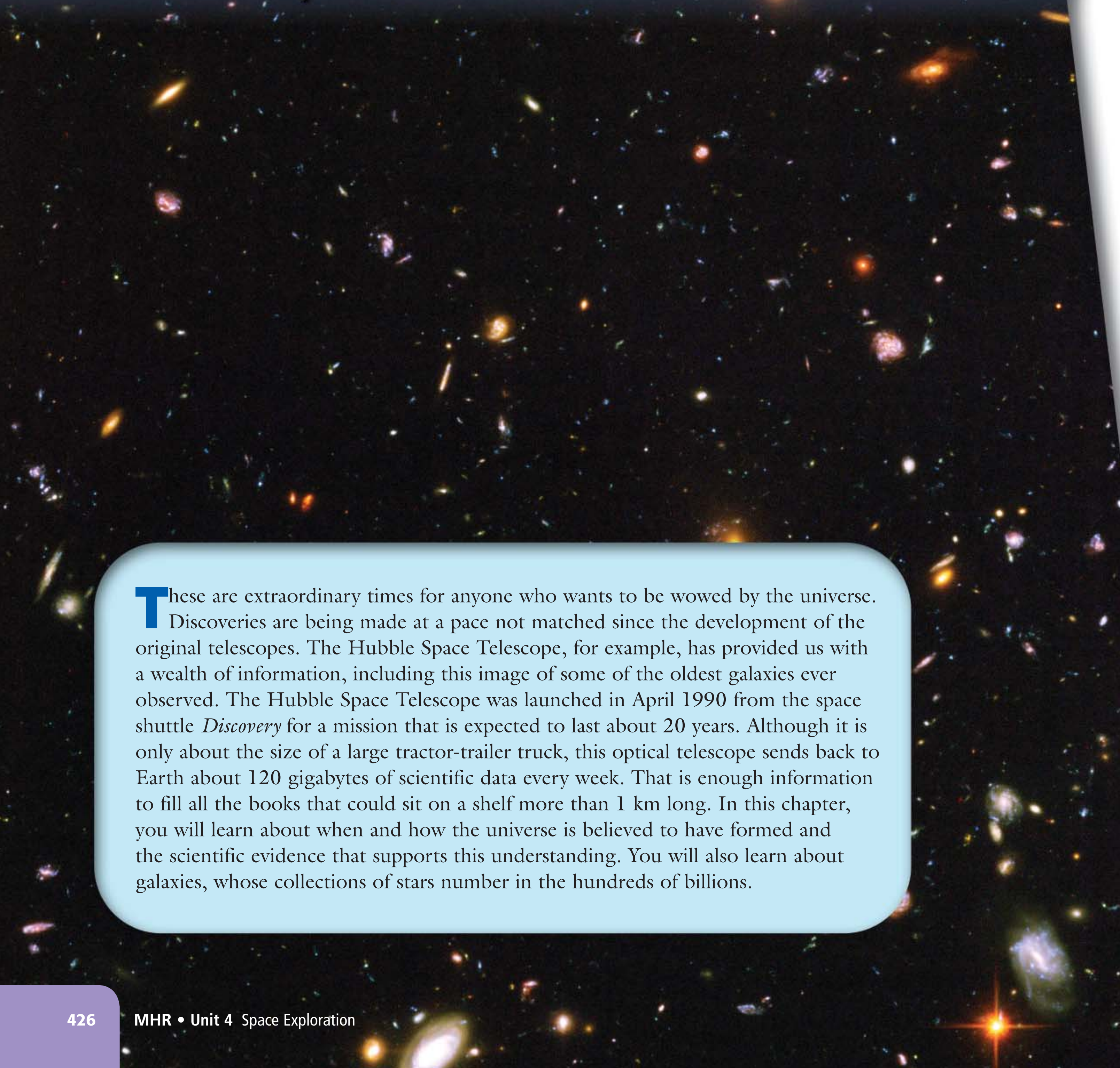
Chapter 12

We can use space exploration to learn about stars, nebulae, and galaxies outside our solar system.



These are extraordinary times for anyone who wants to be wowed by the universe. Discoveries are being made at a pace not matched since the development of the original telescopes. The Hubble Space Telescope, for example, has provided us with a wealth of information, including this image of some of the oldest galaxies ever observed. The Hubble Space Telescope was launched in April 1990 from the space shuttle *Discovery* for a mission that is expected to last about 20 years. Although it is only about the size of a large tractor-trailer truck, this optical telescope sends back to Earth about 120 gigabytes of scientific data every week. That is enough information to fill all the books that could sit on a shelf more than 1 km long. In this chapter, you will learn about when and how the universe is believed to have formed and the scientific evidence that supports this understanding. You will also learn about galaxies, whose collections of stars number in the hundreds of billions.

What You Will Learn

In this chapter, you will
- **describe** the Big Bang theory of the formation of the universe
- **identify** the characteristics of an expanding universe
- **describe** the major components of the universe
- **analyze** implications and ethical issues associated with space travel and exploration

Why It Is Important

Gaining a better understanding of the age and formation of the universe gives us better insight into the possible origin of everything around us. Improvements in technology increase our ability to see farther into the universe and, ultimately, journey farther into space ourselves.

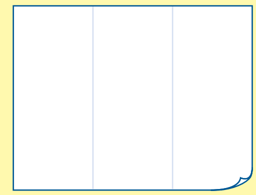
Skills You Will Use

In this chapter, you will
- **model** the expanding universe and the effects of galaxy motion
- **investigate** the properties of some stars we can see from Earth
- **examine** the distances between the stars and galaxies
- **develop** an understanding of ethical issues related to space exploration

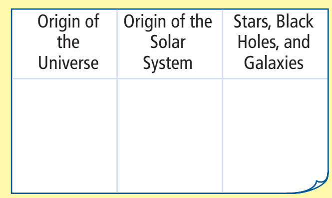
FOLDABLES™
Reading & Study Skills

Make the following Foldable and use it to take notes on what you learn in Chapter 12.

STEP 1 **Fold** a sheet of paper into thirds along the long axis to form three columns.

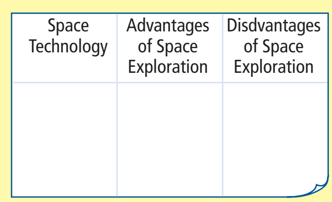


STEP 2 **Make** a 2 cm fold along one of the long sides and **label** the sections as shown.



STEP 3 **Record** information on each topic in the appropriate columns.

STEP 4 On the back, **label** the columns as shown and **record** what you learn about space technology and the advantages and disadvantages of space exploration.



Show What You Know As you read this chapter, take notes under the appropriate tabs to demonstrate what you have learned about our universe and how humans can explore it.

12.1 Explaining the Early Universe

According to the Big Bang theory, the universe is believed to have begun during an unimaginable rapid expansion of a tiny volume of space, about 13.7 billion years ago. In the 1920s, when astronomer Edwin Hubble observed the motion of several galaxies, he discovered that the galaxies were moving away from each other. Galaxies in the universe are now so far apart that it takes light millions of years to travel from some galaxies to Earth. When our Sun formed, the dust and gases surrounding its core gathered into the planets and other objects in our solar system.

Key Terms

astronomical unit
axis
Big Bang theory
cosmological red shift
electromagnetic radiation
galaxy
light-year
Oscillating theory
nebula
parallax
planetesimal
red shift
revolution
rotation
spectroscope
spectral lines
triangulation

If you were studying space exploration 100 years ago, you would have been told that things in "outer space" never change. This conclusion was reached by astronomers who made observations using the best instruments available to them at the time.

Scientific theories develop and change as we learn more. New evidence can cause scientists to rethink existing theories. Between 1918 and 1929, the development of much more powerful telescopes suddenly allowed astronomers to see more celestial bodies than they had been able to see before and to see more detail in those celestial bodies.

One pioneer in space exploration during this period was American astronomer Edwin Hubble. He was the first astronomer to identify other galaxies besides the Milky Way. A **galaxy** is a collection of stars, planets, gas, and dust held together by gravity. The Sun and all the planets are in the Milky Way galaxy. By 1929, Hubble had estimated the distance from Earth to 46 galaxies. Then he made an astonishing discovery. He noticed that all the galaxies he was observing were not staying still. Rather, they were moving away from each other (Figure 12.1). Not only that, but the speed at which they were moving apart varied depending on the galaxies' distance from each other. For example, Galaxy A, located twice as far from Earth as Galaxy B, was moving away twice as fast as Galaxy B. When Hubble retraced the paths along which these galaxies would likely have moved, it appeared that they had all started moving from the same area in space.

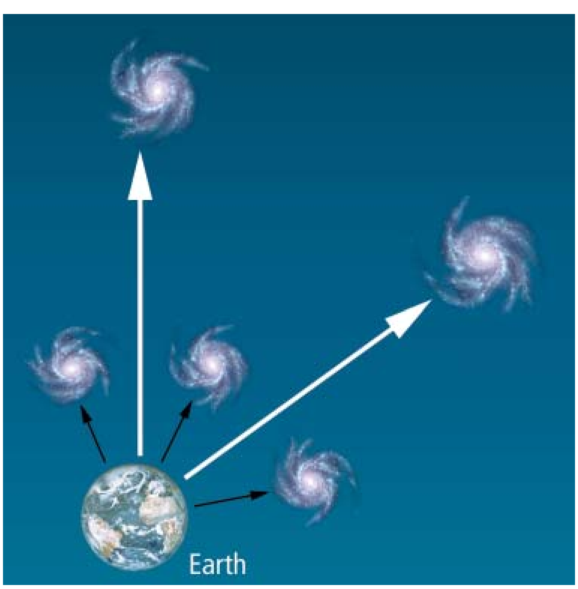


Figure 12.1 Edwin Hubble discovered that galaxies farther from our own Milky Way galaxy were moving away from each other faster than galaxies that are closer to ours. The arrows in the diagram represent the relative velocity (speed and direction) that each galaxy is moving.

Hubble's Proposal

With this information, Hubble went on to propose that the universe is expanding in all directions. He also suggested that all the galaxies have taken the same amount of time to reach their present positions from an original starting point. A good way to understand what is happening is to imagine a loaf of raisin bread baking in an oven (Figure 12.2). Think of the dough as the universe and the raisins as galaxies. As the dough (universe) expands, the distance between all the raisins (galaxies) increases.

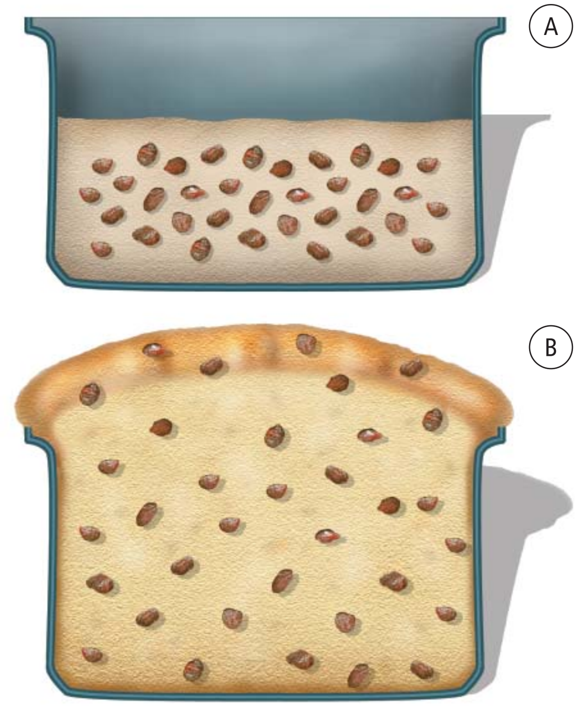


Figure 12.2 The raisins in this uncooked bread dough (A) all move away from each other as the bread bakes (B). In a similar way, galaxies in space are moving away from each other as the universe expands.

Red Shift Analysis

How did Edwin Hubble figure out that galaxies were not only moving away from Earth but also moving away at a speed that was proportional to their distance? He did so by using a tool known as **red shift** analysis. Red shift analysis is based on an understanding of electromagnetic waves and spectral patterns.

Electromagnetic radiation is energy that is carried, or radiated, in the form of waves. Electromagnetic radiation includes visible light, microwaves, radio waves, and X rays. All of these forms of electromagnetic radiation differ in their wavelengths, as shown in Figure 12.3. Many objects in space radiate various forms of energy. Stars and galaxies, for example, radiate light waves, radio waves, and X rays.

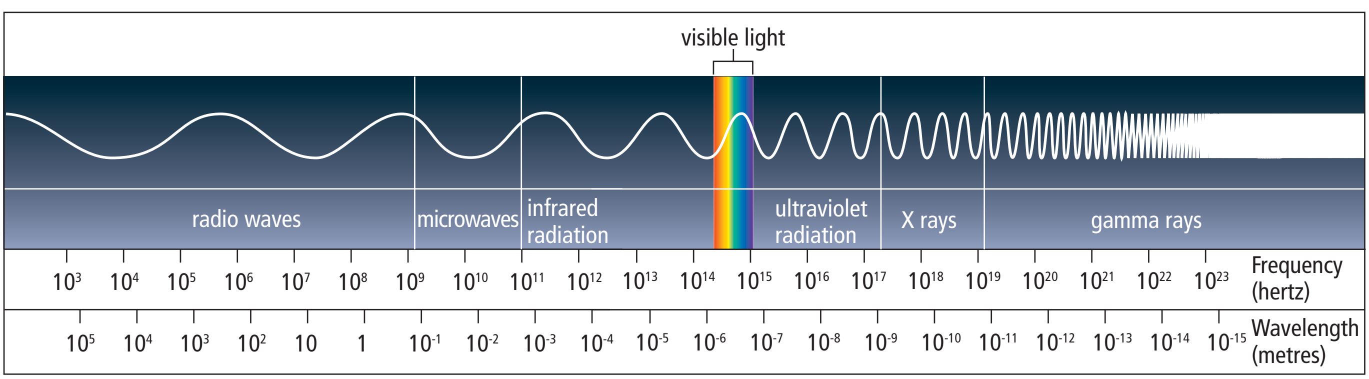


Figure 12.3 Visible light is only one small part of the electromagnetic spectrum. Waves can come in a variety of forms, from the high-energy, short wavelengths of gamma rays to the low-energy, long wavelengths of radio waves.

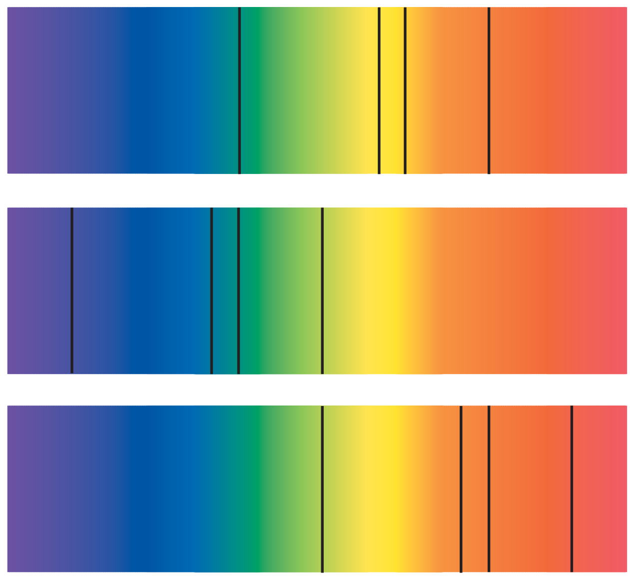
White light splits into bands of rainbow colours when it is passed through a prism. This pattern of colours is called a spectrum. Each colour of the spectrum represents a different wavelength. A **spectroscope** is an optical instrument that acts like a prism to separate light into its basic component colours. A spectroscope allows astronomers to view the spectral patterns produced by individual stars.

Standing out across the bands of colour in a star's spectrum are lines called **spectral lines** (see Figure 12.4). There are two types of spectral line patterns: emission and absorption. In an emission spectrum, the spectral lines of a star or heated gas appear as bright lines with a black background. In an absorption spectrum, the light from a star passes through a gas, and the spectral lines show up as dark lines removed from a continuous spectrum. In both types, the lines tell us about the types of atoms giving off the light. Astronomers can use both kinds of spectral patterns to determine the types of atoms present in a star.

Word Connect

The spectrum of a heated gas, such as a star, shows emission lines.

The spectrum of a hot body passing through a less dense gas shows absorption lines.



spectrum A (for all spectra in this figure: long wavelength on the right and short wavelength on the left)

spectrum B

spectrum C

Figure 12.4 Spectrum A shows the absorption spectral pattern in a star or galaxy that is stationary (not moving). Spectrum B shows the blue-shifted absorption spectral pattern that indicates the star or galaxy is moving toward Earth. Spectrum C shows the red-shifted absorption spectral pattern that indicates the star or galaxy is moving away from Earth.

Cosmological red shift

The light that leaves a distant galaxy travels an enormous distance through space before reaching the telescopes of observers on Earth. Edwin Hubble noticed that the light of the galaxies he was studying showed spectral lines that were distinctly shifted toward the red end. This red shift, as the change is called, occurs because of the light's wavelengths becoming longer (Figure 12.5 on the next page). "Red-shifting" indicates that an object is receding from us. In this case, the red-shifting indicates that the distant galaxies are moving away from us. When astronomers observed this pattern of red-shifting in so many distant galaxies, they put forward the idea that space itself must be expanding. The wavelengths of radiated light are being constantly stretched (lengthened) as the light crosses an expanding universe. Astronomers call this phenomenon the **cosmological red shift**, and it became the main evidence for a theory, called the Big Bang theory, which explained the formation of the early universe.

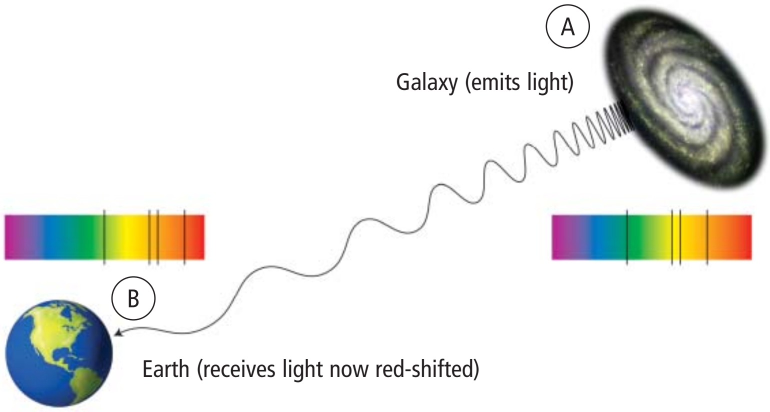


Figure 12.5 As space expands, so do the waves of radiation as they travel from the distant galaxies. When a galaxy first emitted its electromagnetic waves so long ago, the waves were not red-shifted (A). Only as space expanded did it cause the waves to expand and become red-shifted (B).

The Big Bang Theory

Hubble's observations of galaxies moving away from each other led astronomers to think about tracing the paths of the movement backward. Imagine you have a video of runners in a marathon that you decide to play backward. You would be able to see how all the runners—spread out as they near the finish line—gradually move together to where they began the race at the start line. This technique is similar to what astronomers have been doing—using supercomputers, mathematics, and logic—to study how and when these galaxies might all have been in the same place at the same time.

The search for an explanation of the universe's formation has now been going on for more than 80 years. Today, the most widely supported theory is that approximately 13.7 billion years ago, an unimaginably tiny volume of space suddenly and rapidly expanded to immense size. In a very short time, all the matter and energy in the universe was formed. That catastrophic event, first described by Belgian priest and physicist Georges Lemaître in 1927, is known as the **Big Bang theory**. The temperature of the Big Bang was over 1 billion degrees Celsius. Since then the universe has been cooling. If the Big Bang happened, we should be able to see evidence of this heat energy left over from the initial explosion.

The Oscillating Theory

There is a theory that the universe will continue to expand forever in what astronomers call an open universe. Another theory states that the universe is closed and that there is enough matter in the universe to, through gravitational force, slow and ultimately stop this expansion and even reverse it. According to this theory, all the matter will meet again in a Big Crunch. This theory is called the **Oscillating theory**. The Oscillating theory states that the universe will go through a series of Big Bangs and Big Crunches in an ongoing cycle.

As increasingly more powerful tools are developed, researchers are gaining additional evidence to determine which model is the right one. Right now, astronomers favour the single Big Bang theory, as it appears the universe is not only expanding, but the rate of expansion is increasing over time.

Did You Know?

Georges Lemaître was the first to propose the theory that the universe formed in a single, dramatic moment of expansion. At the start, his idea was ridiculed by other scientists. British astronomer Fred Hoyle sarcastically nicknamed Lemaître's theory "the Big Bang." Since then, both the theory and the nickname have endured.

Did You Know?

When Arno Penzias and Robert Wilson first detected the strange radiation signals from space, they did not understand the importance of their findings. Initially, they blamed their unexpected data on everything from faulty material in the equipment to pigeon droppings on the antenna.

Cosmic background radiation

About 35 years after Lemaître discussed his theory, two American astronomers, Arno Penzias and Robert Wilson, made a discovery that became one of the most important pieces of evidence in support of the Big Bang theory. In 1963, the two men were monitoring microwave radiation in space. To their surprise, Penzias and Wilson kept receiving background "noise," or signal interference. They thought there were problems with the antenna and other equipment they were using and made several adjustments.

However, no matter what they did or where they pointed the antenna in the sky, they continued to pick up interference. They finally concluded that what they were detecting was "cosmic background radiation."

This, as most scientists now believe, is the radiation left over from the Big Bang expansion. As particles of gas were created in the early universe, heat was produced in the form of microwave radiation.

To further test the theory, astronomers also made predictions about the amount of light that would be left over from the Big Bang expansion. For the most part, observations and other evidence seem to support the predictions.

Additional supporting evidence

One of the strongest pieces of evidence in support of the theory today is the data gathered by the Cosmic Background Explorer (COBE) satellite, which was launched in 1989 by the National Aeronautics and Space Administration (NASA). It took a team of scientists four years to map the cosmic background radiation data collected by the satellite. Some astronomers have described this map as being like a "baby picture" of the universe, showing how it may have looked early in its development (Figure 12.6 on the next page). The red areas indicate the period of slightly hotter temperatures that would have occurred during the rapid expansion immediately after the Big Bang event. The blue areas indicate the period of slightly cooler temperatures that would have occurred as the universe began to cool.

Word Connect

The word "cosmology" means the study of the universe. It is derived from the Greek word *kosmos*, which means orderly arrangement. Historians think that Pythagoras, the Greek mathematician, was the first person to use the word in connection with the universe.

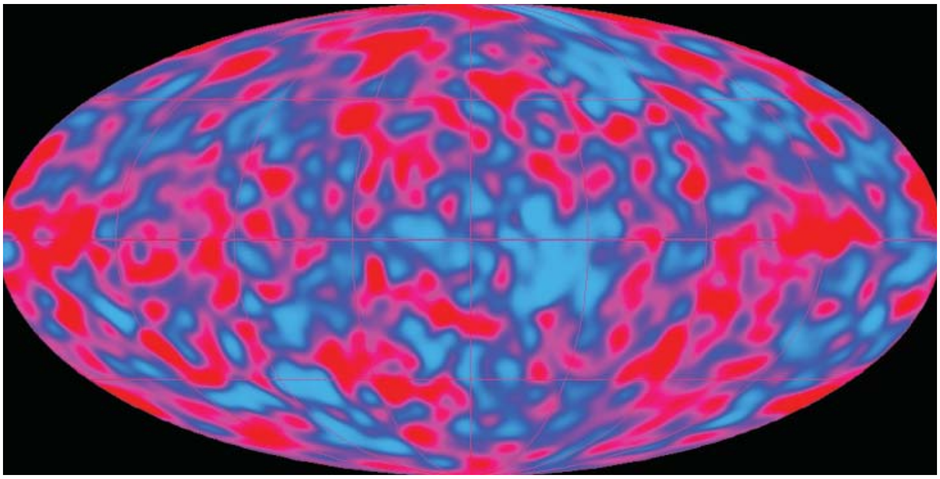


Figure 12.6 The COBE map of cosmic background radiation in the universe. This is the radiation that scientists believe is left over from the Big Bang expansion.

In 2001, NASA sent another spacecraft out to gather more information about cosmic background radiation. This one is called the Wilkinson Microwave Anistropy Probe (WMAP), and it is able to make more precise measurements than have ever been made before. The microwave radiation data collected by the probe have been mapped, as shown in Figure 12.7. Blue shows the slightly denser regions of the early universe. These areas, many scientists believe, are where galaxies formed as a result of gravity. Red shows the less dense regions that became emptier and emptier as the universe expanded. These WMAP results have confirmed the data gathered by the COBE satellite, giving scientists greater understanding about the universe's early moments.

Explore More

The average temperature of the universe is about –270°C, or 3° above absolute zero. This higher-than-expected temperature is thought to be the result of heat left over from the original formation of the universe. This is sometimes referred to as "fossil glow." Find out more about this topic. Start your search at **www.discoveringscience9.ca**.

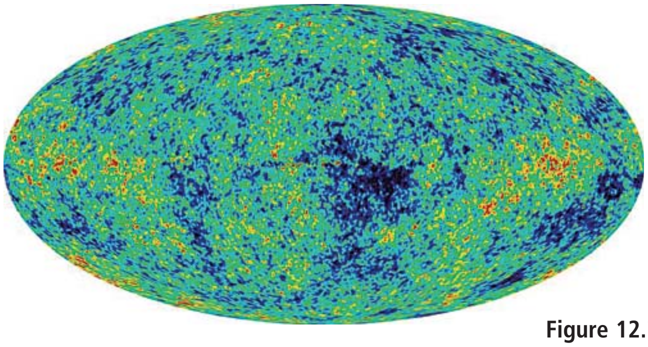


Figure 12.7 The WMAP microwave radiation map of the universe

Reading Check

1. What did Edwin Hubble notice about the direction of movement of galaxies in space?
2. Give two main concepts related to Hubble's proposal.
3. (a) What is a spectrum?
   (b) What is indicated by a shift of a galaxy's spectral lines toward the red part of its spectrum?
4. Explain the Oscillating theory.
5. What events led to the formation of cosmic background radiation? Explain.

The Origin of Our Solar System

In between the stars in a galaxy, there are clouds of hydrogen gas and dust called **nebulae** (singular: nebula). If the material in these clouds can somehow be pulled together, stars can form. Our Sun and solar system were probably formed from one of these clouds. Although one theory suggests that our Sun and the planets were spun off from collisions between stars—the Stellar Collision theory—it is believed to be more likely, from our observations of other star systems, that the Sun and planets formed when a large nebula condensed and collected together by gravity (Figure 12.8). This theory is the nebular hypothesis of solar system formation. It is possible that a nearby exploding star created a shock wave, which caused the nebula to start condensing.

Figure 12.8 The Great Nebula in Orion is an example of an area where new stars and solar systems are being formed.

When a star forms in a nebula, its hot core remains surrounded by gas and dust that have not been pulled into the centre. Sometimes this leftover material just drifts off into space. In other cases, however, it remains in the nebula. Gravity causes the cloud to collapse. Just as a figure skater spins faster as he pulls in his arms, the cloud begins to rotate as it collapses (Figure 12.9A on the next page). The gas and dust begin to gather in the centre of the spinning cloud. We call this ring-like cloud a protoplanetary disc. In the spinning particle cloud, tiny grains begin to collect, building up into bigger, rocky lumps called **planetesimals** (Figure 12.9B on the next page). If these planetesimals can survive collisions with each other, they may build up further and eventually develop into full-fledged planets (Figure 12.9C on the next page).

Our solar system formed more than 4.5 billion years ago. As the Sun became an active star, the leftover material combined to form eight planets and numerous other smaller bodies: moons, asteroids, and comets. Not all the planets formed at the same time or in the same way. In the first 100 million years or so, the material closest to the young Sun developed into the planets Mercury, Venus, Earth, and Mars. These planets are called the inner planets or terrestrial (Earth-like) planets. They are relatively small and have solid cores and rocky crusts. It is too hot near the Sun for the lighter elements of hydrogen and helium to form into planets. Farther away from the Sun, where it is colder, large clumps of gas, ice, and dust formed what are called the outer (or Jovian) planets: Jupiter, Saturn, Uranus, and Neptune. These planets are known for their large gaseous bands and cold temperatures.

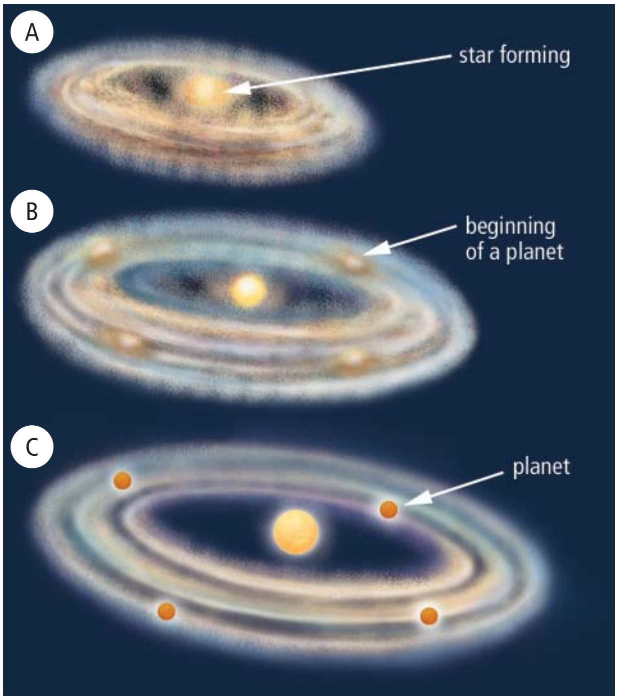


Figure 12.9 This model of planet formation is called the protoplanet hypothesis.

Each galaxy spins like an enormous merry-go-round around its central nucleus. Within the spinning Milky Way galaxy, our solar system is also rotating, moving at a speed of about 250 km/s. Within the solar system, all the planets are in motion too, spinning like toy tops while orbiting the Sun. Earth spins on its **axis** (an imaginary line from the North Pole to the South Pole) at a speed of 1670 km/h, or 0.5 km/s. This process of spinning is called its **rotation**. At the same time, it orbits the Sun at 30 km/s. This process of orbiting the Sun is called its **revolution**. The paths that Earth and the other planets take as they revolve around the Sun are elliptical, resembling long, slightly flattened circles.

The rotation of stars in the Milky Way galaxy will affect the way these constellations look from Earth. Although the patterns of stars we see in the sky do not change from night to night, or even from year to year, they change over very long periods of time. Studies of the red shift pattern of individual stars have enabled scientists to predict the direction and speed of their motion. Scientists predict, for example, that in 50 000 years the pattern of stars we call the Big Dipper will look different from Earth than it does today (Figure 12.10).

Explore More

A group of three stars makes the head of the scorpion in the constellation Scorpius. In 2000, the middle star in this group of stars suddenly became brighter. what changes have occurred in other constellations? Begin your research at **www.discoveringscience9.ca.**

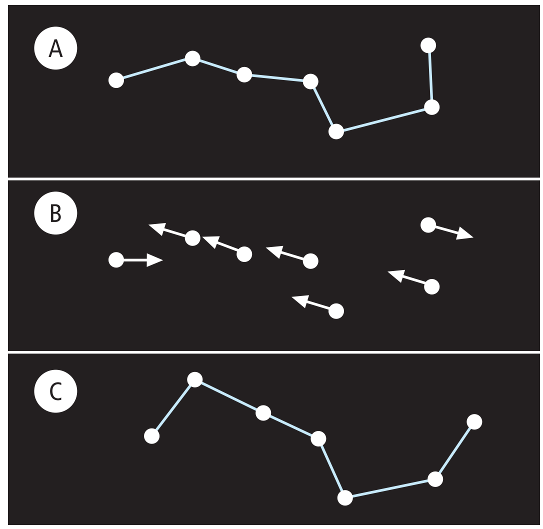


Figure 12.10 A: The Big Dipper as it looks today. B: The motions of stars in the Big Dipper. C: The Big Dipper as scientists predict it will look from Earth in 50 000 years.

The distances from Earth to other planets in our solar system and to stars in the universe are much greater than any other distances we know. If asked to measure the distance from home to school, a student would probably answer by stating the number of blocks or kilometres. These units are appropriate because millimetres and centimetres would be meaningless for distances greater than a few metres. Within the solar system, scientists often use **astronomical units** (AU) to measure distances. One astronomical unit is equal to the distance from Earth to the Sun, or approximately 150 million km.

Even astronomical units become meaningless for the really great distances that separate stars and galaxies throughout the universe. For example, the distance from Earth to the area at the edge of the solar system where comets are thought to originate is estimated to be between 50 000 and 100 000 AUs.

As the distances to most stars from Earth are in the millions of AUs, astronomers have devised a different unit to talk about the enormous distances outside our solar system. That unit is called a **light-year**. Although it sounds like it describes time, a light-year is actually a measure of distance. It is the distance that light, which moves at 300 000 km/s, travels in a year. It is equal to about 9.5 trillion km.

The light from the Moon takes about 1.3 s to reach us, so you are seeing the Moon as it was 1.3 s ago. The light from the Sun takes 8 min to reach us, the light from Jupiter takes 41 min, and so on. The nearest star to us, apart from the Sun, is Alpha Centauri. Its light takes 4.3 years to reach us. When you look at the Andromeda galaxy in Figure 12.11, you are seeing a distance of 2.5 million light-years from Earth. Said another way, it took the light from the galaxy 2.5 million years to travel through space and into the camera's lens. You are seeing the galaxy not as it is, but as it was. When you look at objects far away in space, you are actually looking back in time.

Suggested Activity

Find Out Activity 12-1A on page 439

Figure 12.11 The Andromeda galaxy can be seen from Earth even with binoculars. It is one of the Milky Way's nearest neighbours, yet it lies 2.5 million light-years away.

Word Connect

The Andromeda galaxy is part of the Andromeda constellation, which is named after Princess Andromeda in Greek mythology.

Technique for Indirectly Measuring Distance

Try this: extend your arm and hold up your thumb. Close your right eye. As you look with your left eye only, line your thumb up against an object on the far wall, such as a light switch or the corner of a window. Without moving your thumb, now close your left eye and look with your right eye only. The apparent shift of your thumb against the unmoving background is called **parallax**. Parallax is caused by the change in position of observation. This same principle applies to stars that are viewed from Earth. When a nearby star is viewed from different locations on Earth, it appears to shift against the background of the much more distant and seemingly stationary stars. Observers at two different locations on Earth can measure the angles of sight from a baseline and then calculate the distance to the star using a process called triangulation (Figure 12.12).

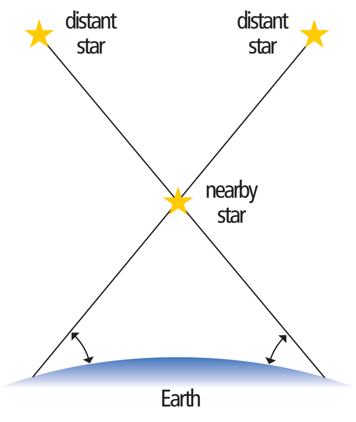


Figure 12.12 The effect of parallax can be used to triangulate a star's distance from Earth.

Triangulation uses simple geometry to find the distance to an object by drawing a triangle. By measuring two angles and the length of a baseline, the distance to any object that is visible can be determined (Figure 12.13).

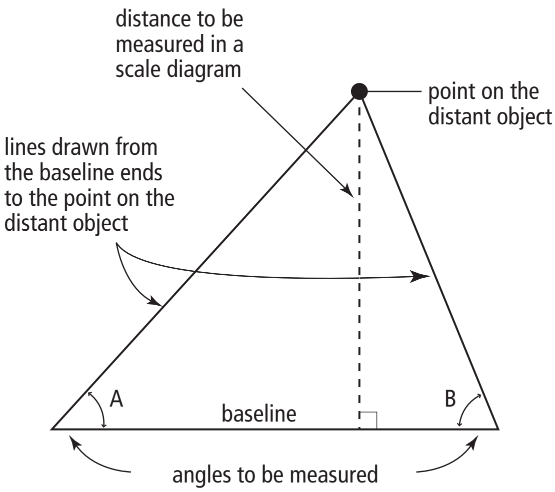


Figure 12.13 Triangulation: By measuring two angles and the length of the side in between them, you can calculate any other measurement in the triangle.

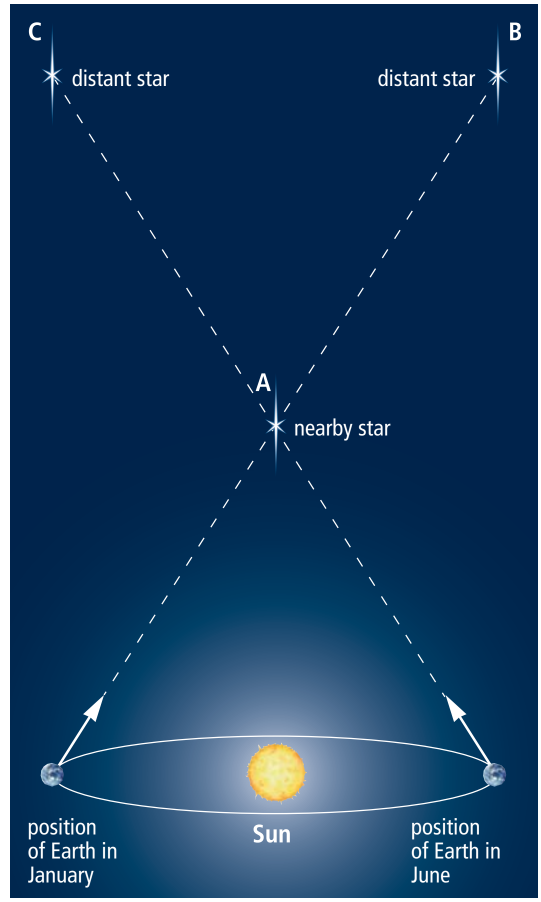


Figure 12.14 Calculating a star's distance from Earth using parallax and triangulation. In January, the nearby star (A) appears to line up with the distant star B. In June, it seems to line up with the distant star C. The distance that star A appears to move in the sky (the apparent distance between stars B and C) is its parallax. The parallax provides the angles needed for using triangulation.

Did You Know?

Triangulation is also used by geologists to determine an earthquake's location and by surveyors to create land maps and boundaries.

The longer the baseline is, the more accurate a triangulation calculation will be. Therefore, to achieve the most accurate distance measurements to objects in space, astronomers use the width of Earth's orbit to create the largest baseline possible (Figure 12.14). Because it takes Earth a year to fully orbit the Sun, measurements from each end of the baseline must be taken six months apart, when Earth reaches its farthest points on opposite sides of the Sun (Figure 12.15 on the next page).

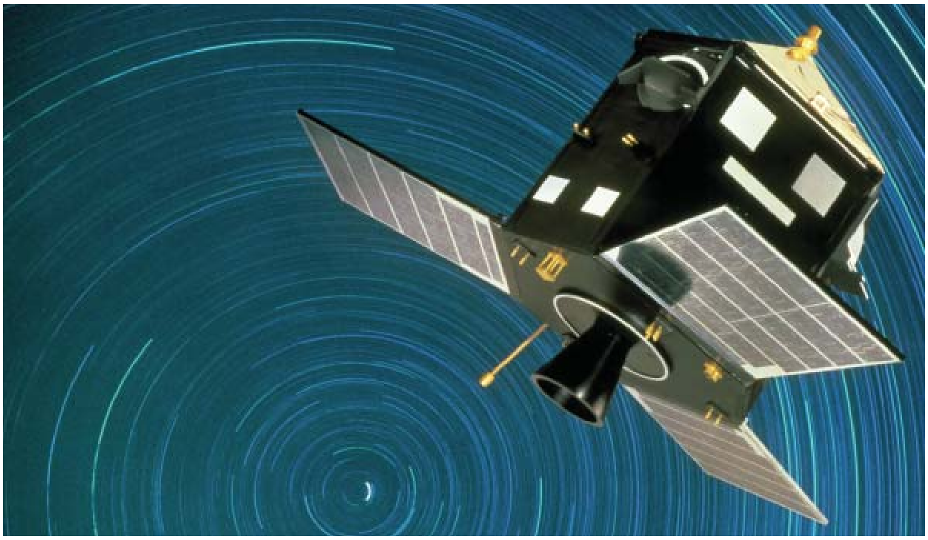


Figure 12.15 The *Hipparcos* space probe was able to precisely measure the parallax of 1 million stars from Earth orbit. As the Earth travelled around the Sun, *Hipparcos* took multiple observations, obtaining accurate brightness and distance measurements.

Reading Check

1. What is the nebular hypothesis of solar system formation?
2. How long ago did our solar system form?
3. What are the two groups into which we divide planets?
4. Why do astronomers use light-years and not astronomical units (AU) to measure distances outside our solar system?

12-1A The Light-Year

Find Out ACTIVITY

In this activity, you will determine the length of a light-year and how long light takes (and therefore how long radio waves take) to travel from the planets and nearby stars to Earth.

What to Do

1. Light travels 300 000 km per second. How far does it travel in an hour? in a day? in a year?
2. Polaris is 430 light-years away. How far is this distance in kilometres?
3. The Sun is 150 000 000 km away (1 AU). How long does it take for light from the Sun to reach the Earth?
4. At its closest, Mars is about 100 million km from Earth. At its farthest it is about 380 million km away. When the Sun's light reflects off Mars, what is the shortest time that it takes to reach Earth? What is the longest time?
5. Cell phones transmit radio waves, which travel at the speed of light. If you had a friend on Pluto (39 AUs from Earth) and you said "Hello," how long would it take for your friend to hear you?
6. The *New Horizons* space probe is on its way to Pluto, travelling at a speed of 60 000 km/h. Alpha Centauri is 4.3 light-years away from Earth. How long would the *New Horizons* probe take to get to Alpha Centauri?

What Did You Find Out?

1. What did you notice about the size of the values as you measured the distance light travels in a day or year?
2. What is the problem when trying to talk to someone on Pluto using a cell phone (aside from the problems a person would encounter trying to survive on Pluto)?
3. What is the major problem people would face on a trip to the nearest star?

12-1B Investigating the Relative Motion of Galaxies in the Expanding Universe

Find Out ACTIVITY

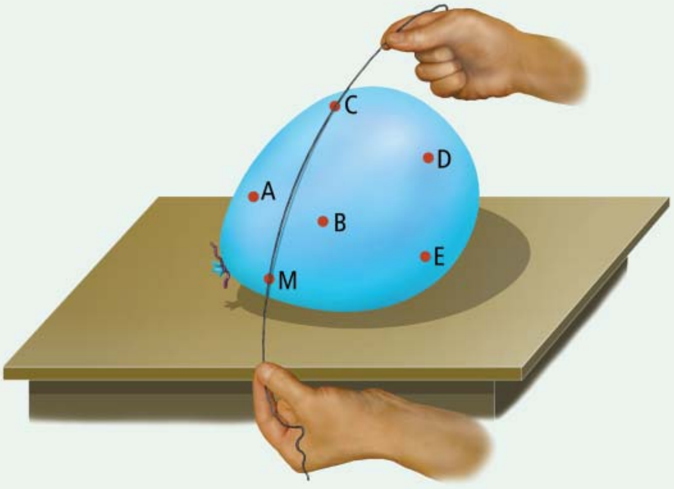
In this activity, you will use a model of the expanding universe to determine the apparent movement of galaxies relative to each other.

Materials

- large round balloon
- twist-tie
- felt pen
- 25 cm of string
- ruler

What to Do

1. Inflate the balloon to the point that it just begins to become round. (Do not inflate it all the way yet.) Wrap the twist-tie tightly around the balloon's neck to keep it inflated.
2. Using the felt pen, draw six dots on one side of the balloon at least 2 cm away from each other. Label the dot on the bottom "M." This will represent the galaxy we live in, the Milky Way. Label the other dots "A" through "E," which will represent other galaxies in space.



3. Copy a table like the one below into your notebook. Give your table a title.

Galaxy	Distance to M (mm)		
	Trial 1	Trial 2	Trial 3
A			
B			
C			
D			
E			

Trial 1

4. Measure the distance between M and the other dots using the string and ruler. Record the measurement in the table.

Trial 2

5. Loosen the twist-tie and inflate the balloon a little bit more. Measure the new distances between the dots and record the numbers in your notebook.

Trial 3

6. Repeat step 5.

What Did You Find Out?

1. When measured from M, what galaxy distances increased the most?
2. Which distances did not increase as much?
3. (a) How is this activity similar to what you would expect from an expanding universe?
   (b) How is this model different from what you would expect?
4. Write a brief statement relating how each point increases its distance from the Milky Way galaxy (dot M).

Science Watch

Trying to Simulate the Big Bang

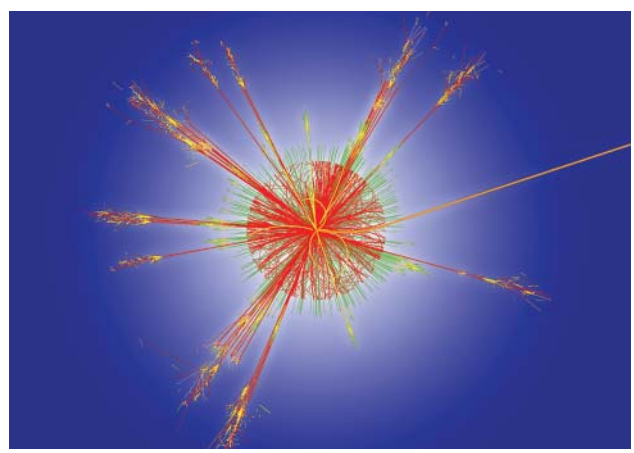
To answer questions such as "How did the universe form the way it did?" scientists have to try to re-create an event that happened billions of years ago. The challenges in doing this are obvious, since no one was there to record or witness it. The next best thing is to simulate small aspects of it.

Physicists who study subatomic particles (particles that are smaller than atoms) are searching for a thing so small that 10 trillion (meaning 10 million million) of them would fit inside a single grain of salt! As described in Chapter 1, all matter in the universe (even you) is made up of atoms. Atoms are composed of protons, neutrons, and electrons. Physicists now hypothesize that protons and neutrons are made of smaller particles called quarks. Physicists want to know how the building blocks of everything in the universe are put together. Learning this is the first step in understanding how everything in our universe formed in the instant of the Big Bang.

What is the most effective way to get inside protons? The usual technique is to smash them apart. This is a lot more difficult (and expensive) than it sounds. The particles must be generated in a special piece of equipment called a particle accelerator. The most sophisticated accelerator is located at CERN, in Switzerland, pictured to the right. Known as a super-collider, it looks like a very large, thin concrete doughnut. The thickness of the shell is only 3 m, but it measures 27 km around. Two beams of protons are fired off in opposite directions so that individual protons will crash into each other and break into their smaller component particles. An image of the result of such a collision is shown here.

Scientists believe that finding out more about the particles that make up protons will reveal how protons were first created when the universe began. Determining how basic particles are made will be like looking back in time to the very beginning of the universe.

The quest for reproducing the effects of the Big Bang is a massive undertaking. More than 2000 scientists in 34 countries are involved, including physicists at the TRIUMF facility in Vancouver. Data are being generated so quickly that computers worldwide are networked to act as a single computer. The equivalent of a DVD full of data is generated every 5 s. It is hoped these efforts will provide a better understanding of how the basic ingredients of matter are formed.



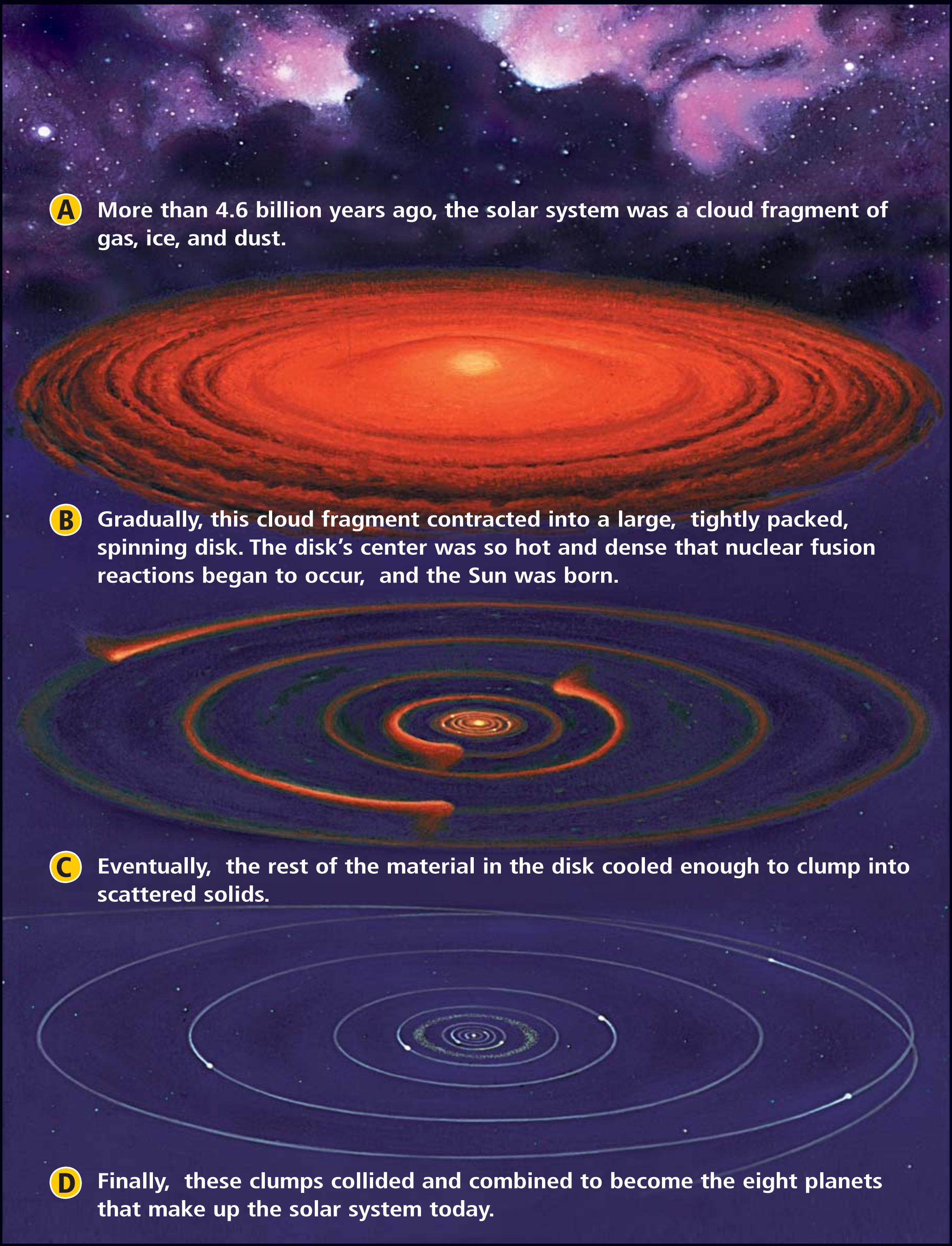
Questions

1. What is a quark?
2. How does using a particle accelerator help scientists learn about quarks?
3. Why is understanding quarks important to physicists studying the formation of the universe?

NATIONAL GEOGRAPHIC

VISUALIZING THE SOLAR SYSTEM'S FORMATION

Through careful observations, astronomers have found clues that help explain how the solar system may have formed.



A More than 4.6 billion years ago, the solar system was a cloud fragment of gas, ice, and dust.

B Gradually, this cloud fragment contracted into a large, tightly packed, spinning disk. The disk's center was so hot and dense that nuclear fusion reactions began to occur, and the Sun was born.

C Eventually, the rest of the material in the disk cooled enough to clump into scattered solids.

D Finally, these clumps collided and combined to become the eight planets that make up the solar system today.

Check Your Understanding

Checking Concepts

1. What are some of the contributions Edwin Hubble made to the study of astronomy?
2. What do we call energy that is carried in the form of waves?
3. What is the purpose of a spectroscope?
4. What does the cosmological red shift suggest about the motion of galaxies?
5. State the main idea of the Big Bang theory.
6. Give one piece of evidence that supports the Big Bang theory.
7. According to the Big Bang theory, how did the temperature of the universe change as the universe expanded?
8. What is a nebula?
9. How do planets form?
10. Describe two differences between inner and outer planets.
11. Define a light-year.
12. From each of the following, give the amount of time it takes light to reach Earth.
    (a) the Moon
    (b) the Sun
    (c) Jupiter
    (d) Alpha Centauri
    (e) Andromeda galaxy
13. Describe what parallax means.
14. Explain how you would use parallax and triangulation to determine the distance of a star from Earth.

Understanding Key Ideas

15. What evidence did Edwin Hubble use to suggest the universe was expanding?
16. Explain how a loaf of raisin bread baking in the oven can be used to illustrate Hubble's view of an expanding universe.
17. Astronomers have developed differing theories about how the universe formed. Describe the theory related to each of the following:
    (a) open universe
    (b) closed universe
18. Both the COBE satellite and WMAP were designed to measure temperatures only a few degrees above absolute zero. Why was it necessary to take these measurements in space rather than on Earth?
19. What do the blue and red zones found in the WMAP map indicate?
20. (a) How does cosmic background radiation provide evidence for the Big Bang theory of the origin of the universe?
    (b) What results from the WMAP were important to the study of the formation of galaxies?
21. Parallax and triangulation are considered to be indirect measurement techniques. Why are such techniques used to measure distances in space?
22. The galaxy below is the Andromeda galaxy. Explain why this image represents the past and not the present.

Pause and Reflect

New technologies like the COBE satellite and the WMAP have advanced our scientific understanding of space. How have advances in technology further improved our understanding of the structure and formation of the universe?

12.2 Galaxies and 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 dust and gas, and go through predictable changes as they age. A galaxy is a collection of stars, gas, and dust held together by gravity. Scientists estimate that at least 125 billion galaxies exist in the universe.

Key Terms

black hole
elliptical galaxy
fusion
interstellar matter
irregular galaxy
quasar
spiral galaxy
star
supernova

Space is not empty but filled with **interstellar matter**, which is made up of gas (mostly hydrogen) and a small amount of dust. Clouds of gas and dust in galaxies are called nebulae. The dust accounts for only about 1 percent of the total mass of interstellar matter. Even at such a small amount, interstellar dust makes it hard for astronomers to see the light 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, new 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 12.16 shows this difference in images of the Andromeda galaxy.

Word Connect

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

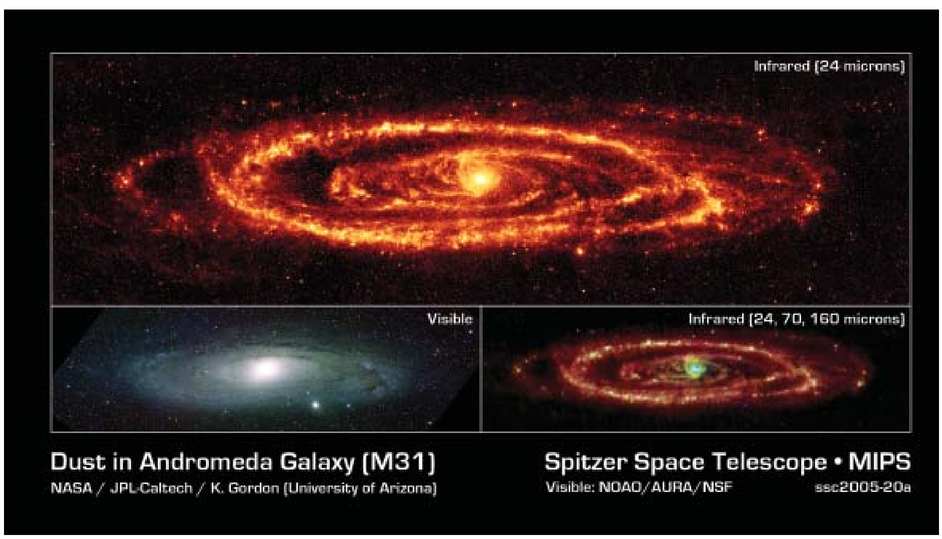


Figure 12.16 The Andromeda galaxy as it appears in the visible spectrum (bottom left). The same galaxy as it appears in different frequencies of infrared light (bottom right and top). The infrared views clearly show the dusty spiral arms more clearly than the view in visible light.

The Number of Galaxies

Every star you see in the sky on a clear night is part of the Milky Way. Our Sun is one of the estimated 100 billion stars in this galaxy. A galaxy forms when gravity causes a large, slowly spinning cloud of gases, dust, and stars to contract. All the stars in the universe were formed in galaxies.

To get a better idea of just how many stars 100 billion is, imagine a star being the size of a grain of sand. The number of stars you can see with your unaided eye on a clear winter night would be about the same as the number of grains of sand that would fit into the lid of a toothpaste tube. The number of stars in the entire Milky Way would be about the same as the number of grains of sand that would fill a dump truck. 100 billion is a huge number. How huge? If you count to 100 billion at one number per second, it would take you 3170 years!

Astronomers now estimate that the whole universe contains at least 125 billion galaxies. The Hubble Space Telescope transmits images of thousands of these galaxies to Earth.

Think of a friend holding up a dime between two fingers so that you can look at it. Now think of that friend standing down the hallway two classrooms away, still holding up the dime for you to see. That very small size is equal to the area of sky that the Hubble Space Telescope focussed on to capture the image shown in Figure 12.17. The jewel-like areas scattered throughout the image are not single stars but whole galaxies. Each of the 1500 or so galaxies in this region of space contains at least 100 billion stars. To get a sense of how many stars that is, imagine again a star being the size of a grain of sand. Now picture an 18-wheeled tractor-trailer fully loaded with sand racing past you. If many of the same-sized trucks were to continue driving past you at a rate of one each second, 24 hours a day for three years, that number of grains of sand would approximate the number of stars in the known universe.

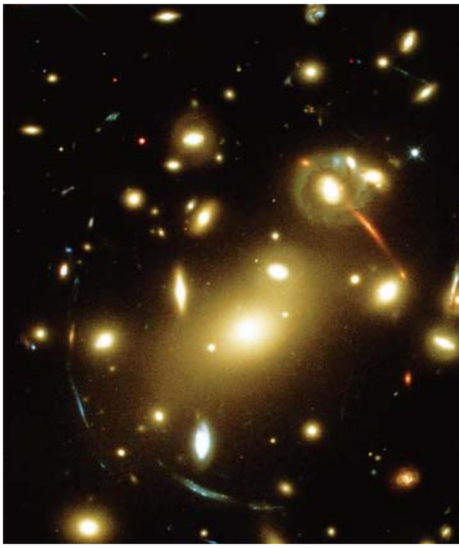


Figure 12.17 Galaxy cluster Abell 2218 shines brightly in this image, with many other galaxies visible farther behind it.

Galaxy Shapes

Despite the immense number of galaxies, most can be classified according to one of three basic shapes: spiral, elliptical, and irregular.

- A **spiral galaxy**, when viewed from above, looks like a pinwheel, with many long "arms" spiraling out from a centre core (Figure 12.18 on the next page). Viewed from along its edge, a spiral galaxy looks like a paper plate with an orange inserted into its centre. The central bulge is made up of stars that formed long ago. The disk circling it is made of gas, dust, and newly forming stars. The glow that surrounds the whole structure is called the halo (Figure 12.19 on the next page). The Milky Way is a spiral galaxy. When we see that long band of light that stretches across the night sky, we are looking at the galaxy from a side view. Earth is located in one of the spiral arms of the Milky Way, toward the centre of the galaxy.
- An **elliptical galaxy** is one that ranges in shape from a perfect sphere

to a stretched-out ellipse. Some, for example, are similar to the shape of a football and others to the shape of a cigar (Figure 12.20). These galaxies contain some of the oldest stars in the universe. Well over half of all galaxies are believed to be elliptical. The largest galaxies in the universe are elliptical.

- An **irregular galaxy** is one that does not have any regular shape such as spiral arms or an obvious central bulge (Figure 12.21). These galaxies are made up of a mix of newly forming stars and old stars.

Figure 12.18 A spiral galaxy as it looks from above

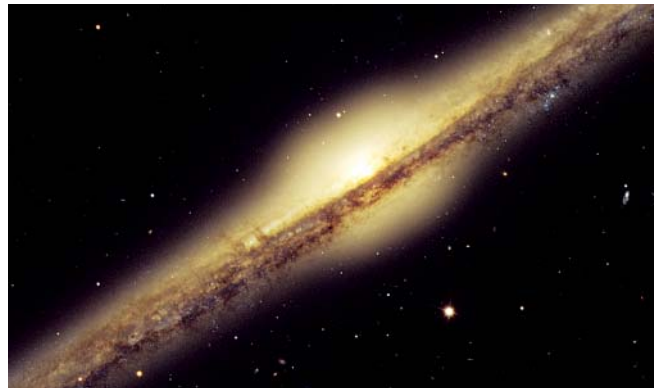


Figure 12.19 A spiral galaxy as it looks from the side

Figure 12.20 An elliptical galaxy

Figure 12.21 An irregular galaxy

Did You Know?

When galaxies get too close together, the gravitational force of a larger galaxy can pull apart a smaller galaxy. Eventually, the big galaxy will even pull the pieces of the little neighbour into its own more massive structure. This process is referred to by astronomers as "galactic cannibalism."

Galaxies vary in other ways besides shape. They also differ in size, mass, colour, brightness, and speed of spin. All of these differences are determined by the number of stars, type of stars, and the amount and type of gas and dust making up a galaxy.

The Birth of a Star

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.

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 12.22).

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.

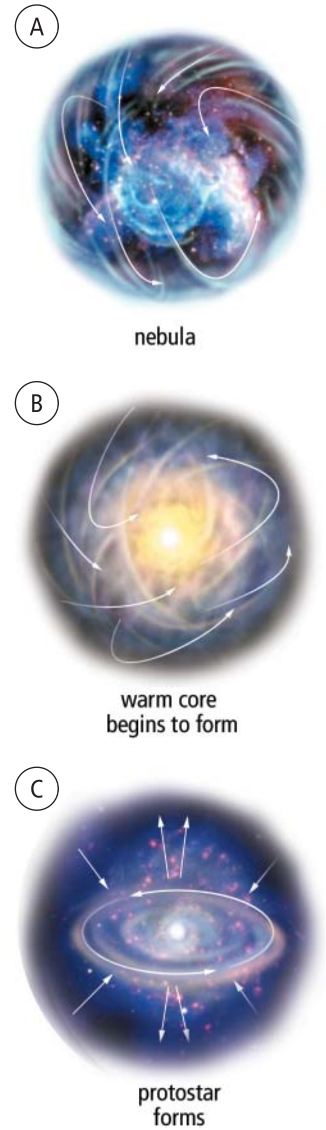


Figure 12.22 Stages in the formation of a star

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 12.23 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.

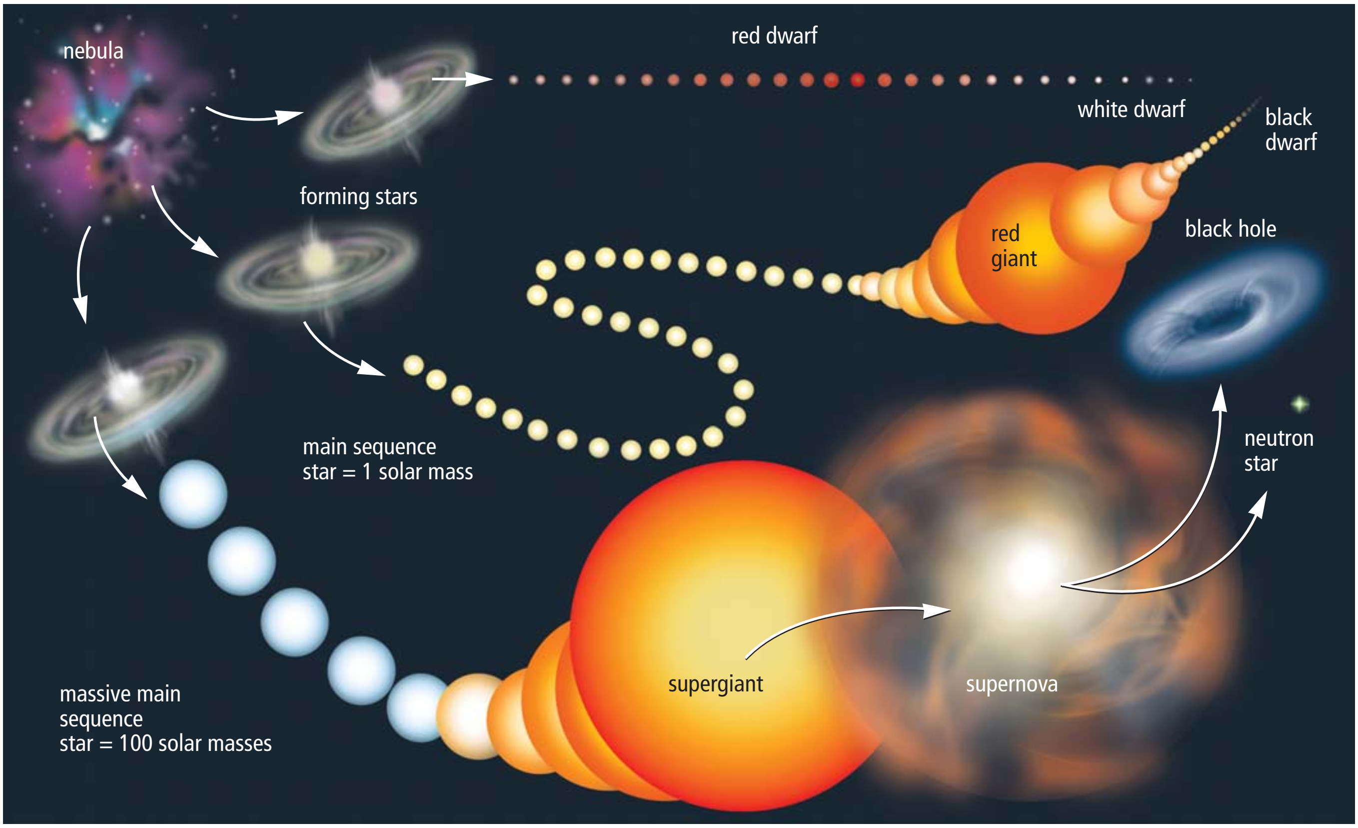


Figure 12.23 The three main life paths of stars

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.discoveringscience9.ca** and follow the links.

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.

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, which can be measured. Another is the effect that the gravity of black holes has on passing stars and galaxies. 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.

Quasars

As the powerful force of gravity pulls matter into a black hole, the black hole can become "supermassive." It is believed that most galaxies contain a supermassive black hole at their centres. As the supermassive black hole continues to attract more matter, a region of powerful electromagnetic energy can develop around it. This region of extremely high energy is known as a **quasar**. Quasars get their energy from the gravitational energy of matter falling into the black hole. This energy makes them the brightest objects that we know of in the universe. In fact, because they are so bright, they can be mistaken for nearby galaxies. However, their spectra show a large red shift, meaning they are very far away. Some quasars are billions of light-years away.

It was only about 30 years ago that sensitive-enough telescopes were developed to allow astronomers to study quasars. Scientists do not yet completely understand how quasars form or what they are made of. Because most quasars are located in parts of the universe far away from Earth, the light that reaches us from quasars is very, very old. Everything we learn about quasars can help us to better understand the origin and early development of the universe.

Explore More

The mass of a typical black hole is 10 times the mass of the Sun, but black holes with a million times the mass of the Sun have been detected in the centres of extremely large galaxies, including our Milky Way. Find out more about black holes and how they affect objects around them. Begin your research at **www.discoveringscience9.ca**.

Did You Know?

The quasar that appears brightest in our sky is in the constellation Virgo. Because it is so far away, it has an apparent magnitude of 12.8 and appears bright enough to be seen with a small telescope, but not with the naked eye. It is really about two trillion times brighter than our Sun!

Suggested Activity

Core Lab Conduct an Investigation 12-2A on page 451

Star Sizes

Many stars visible from Earth are much larger than our Sun. Some of these are shown in Figure 12.24. 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.

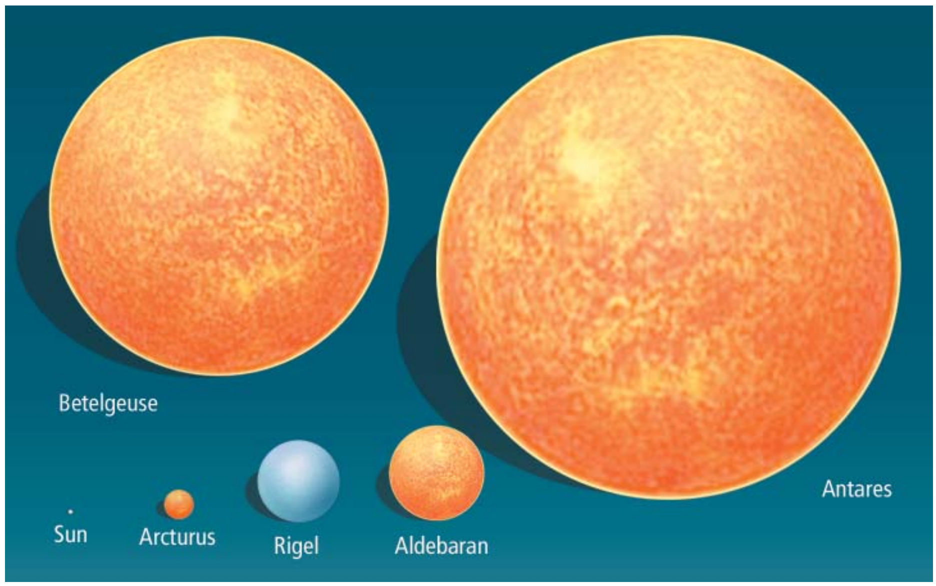


Figure 12.24 The size of the Sun compared with five other stars

Reading Check

1. What is interstellar matter composed of?
2. What is the main factor that affects a star's path of development?
3. Describe the life path the Sun is expected to follow.
4. What is the explosion of a mass star called?
5. Why do astronomers call a black hole "black"?

12-2A Sizes of Stars

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Classifying
- Communicating
- Explaining systems
- Working cooperatively

In this activity you will compare and contrast the characteristics of stars we can see from Earth, and prepare a model to show their position relative to our solar system.

Question

What do the characteristics of stars tell us about their origin and life path?

Procedure

1. With the other members of your group, develop a plan to find out about the stars in the list below. For each star, research the following:
   - the star's location
   - the distance the star is from Earth
   - the star's magnitude
   - the star's size
   - the star's colour
   - the star's position in our sky
   - any other interesting information you find about the star

Vega	Betelgeuse
Canopus	Rigel
The Sun	Delta Orionis
Arcturus	

2. On large paper, develop a data table to organize the results of your research.
3. Design and build a model to show the positions and distances of at least four of the above stars from the Earth. Alternatively, design and build a model to compare the sizes of at least four of the stars. What materials will you use for your model? How much space will you need for it?
4. Plan how to present your model to the class. Everyone in your group must have a role in the presentation. Post your data table in the classroom.

Science Skills

Go to Science Skill 11 for information about how to construct a data table.

Analyze

1. Which star is the largest? Which is the smallest?
2. Is there a relationship between the colour and size of the stars? If so, what is it?
3. Look at the data table you created. Describe the "average" star.

Conclude and Apply

1. What stars stand out most as being different from the average star? In what ways are they different?
2. How does our Sun compare to other nearby stars?
3. Write a hypothesis about the life path of two of the stars you investigated based on the information you gathered and the information on pages 447 to 449 of this textbook.

12-2B Spying Spectra

Find Out ACTIVITY

Many characteristics of a star are revealed in the light it produces. Temperature, composition, age, and direction of travel are contained in a star's spectrum. In this activity, you will observe how different sources of light and gas produce different spectra.

Safety

- NEVER look directly at the Sun.

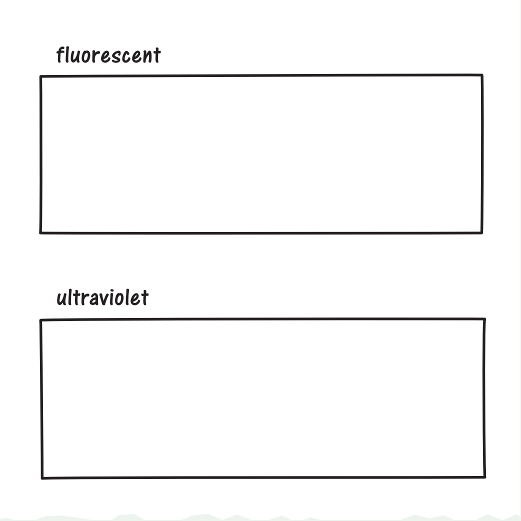
Materials

- spectroscope
- 4 different light sources (for example, Sun, fluorescent, incandescent, ultraviolet, energy-saver lamp, frosted light, holiday lights)
- gas discharge tubes (for example, mercury, xenon, hydrogen, sodium)
- paper
- pencil
- ruler
- pencil crayons

What to Do

Part 1 Analyzing Light Spectra

1. On a piece of paper, draw four rectangles as shown below. Make one rectangle for each of the four light sources you plan to observe, and label the rectangles with the name of the source.



2. Carefully look at each light source, one at a time, through the spectroscope. With the pencil crayons, colour the spectrum you observe for each light source in the appropriate rectangle.
3. Experiment with viewing the light sources through the spectroscope at different angles. Record what you observe.

Part 2 Analyzing Gas Spectra

4. On a second piece of paper, draw a series of rectangles as you did in step 1 of Part 1. Label them with the names of the specific gas discharge tubes selected by your teacher.
5. With your teacher's assistance, observe each of the elements in the gas discharge tubes. Use the pencil crayons to colour the spectrum for each gas.

What Did You Find Out?

Part 1 Analyzing Light Spectra

1. Where do you see the spectra in the spectroscope?
2. In which order do the colours appear?
3. How did changing the angle of the spectroscope affect the appearance of the spectra?

Part 2 Analyzing Gas Spectra

4. How were the spectra from the gas discharge tubes different from the spectra of the light sources in Part 1?
5. How would knowing the spectra for specific elements help astronomers determine the composition of stars?

Career Connect

Radio Astronomer

Dr. Marcin Sawicki is an assistant professor of astronomy and physics at Saint Mary's University in Halifax and a Canadian Space Agency Space Science Fellow. He studies the formation and evolution of galaxies. Dr. Sawicki's research takes him to places such as Hawaii and Chile, and to a time when the universe was just a fraction of its age today.

Q. What do you research?

A. I study how galaxies formed. Galaxies are some of the earliest objects that formed after the Big Bang. They are also factories that make new stars, like the Sun, as well as complex chemical elements that are necessary for life. So they are a very important part of where we humans come from.

Q. What types of equipment do you use?

A. I use giant telescopes on the ground and in space. On the ground, I use telescopes on the mountaintops in Hawaii and Chile, such as the Canada-France-Hawaii Telescope and the Gemini telescopes. And I use data from the Hubble and Spitzer telescopes that are in space. But most of my time is spent not at a telescope, but at a computer, analyzing data. Good computer programming knowledge is essential.

Q. What do you enjoy most about your research?

A. I especially enjoy those moments when I learn something about the universe that no one has known before. The universe is not devious, but it has its secrets, and I get to find them out. It gives me a very strong sense of connection with this enormous universe that we are all part of. And, of course, I love all the travel!

Q. What are the biggest challenges you face as a researcher?

A. I think the hardest challenge is something that many people face: how to manage one's time. There are so many different things that compete for my time (in addition to being a researcher, I have teaching and administrative duties at my university) that it's sometimes difficult to even decide what I should be doing at any given moment! So the most challenging thing for me is to find the right balance between my diverse duties so that all things get done on time and in the right order.

Q. What advice do you have for students interested in your field?

A. First, find out as much as you can about the field. Read, read, read. Astronomy and astrophysics are based on physics, which in turn uses mathematics as an important tool, so if you are interested in becoming a professional astronomer, then take all the science and math courses that you can. And learn how to program in a computer language if you have the opportunity. Even if you do not end up becoming a professional astronomer, science and math courses will teach you ways of thinking that will come in very handy throughout your life and in whatever career you end up choosing in the end.

Questions

1. Name the telescopes that Dr. Sawicki uses. Look for descriptions of those telescopes. What types of telescopes are they?
2. Why might Dr. Sawicki use both land-based and space-based telescopes?
3. What kind of knowledge does Dr. Sawicki say is essential to his work?

Science Math connect

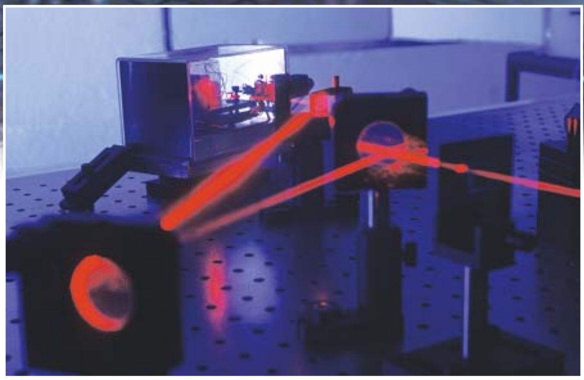
Way Faster Than a Speeding Bullet—the Speed of Light

From ancient times, the speed of light was considered to be infinite and unmeasurable. Not until the invention of the telescope did the ability to finally determine this elusive number seem possible. In the late 1600s, Danish astronomer Ole Rømer used a telescope and the orbit of Jupiter's moon Io to calculate light speed. Even with that very early technology, his calculated speed turned out to be off by only about 25 percent.

Light from the Cat's Eye Nebula has taken 3000 years to reach Earth.

About a century later, another scientist further refined the speed of light calculation. English astronomer James Bradley reasoned that the light from a star would strike Earth at an angle. This angle could then be determined by comparing the speed of light with the speed at which Earth was travelling. His calculation yielded a speed of light equal to 298 000 km/s.

Finally, what we know today to be the true speed of light was determined in 1887 by Albert Michelson and Edward Morley, two American scientists. They were actually looking for the speed at which Earth travels through a substance then called "ether." Ether was believed to be the material necessary for light to travel through. Michelson and Morley invented a device called an interferometer, which involved splitting a beam of light into two parts and then reflecting the parts off mirrors. The result was an incredibly accurate calculation of light speed. The experiment also proved that the mystical material called ether did not exist.



A device like the one shown in the figure helped scientists in the late 1800s determine accurate values for the speed of light.

As you have probably realized while reading this chapter and Chapter 11, distances in space are so enormous that they exceed the bounds of our current technology. At least by knowing the speed of light, astronomers have a practical unit with which to measure the universe's vast distances. Even our *nearest* neighbouring star outside our solar system, Proxima Centauri, is more than 40 trillion (4.0×10^{13}) km away. Expressed in light-years, that distance is 4.2 light-years, which is a much more manageable figure. A light-year is about 9.5 trillion km (a trillion kilometres is a million million kilometres).

Questions

1. Imagine we wanted to send a signal at the speed of light to Canis Major dwarf, one of the nearest galaxies to ours, the Milky Way. If Canis Major dwarf is 25 000 light-years from Earth, how much time would pass between the time our signal was sent and the time we received a reply?
2. Astronomers have found a neutron star that is 855 trillion km from Earth. How many years does it take for light from there to reach Earth?
3. James Bradley calculated the speed of light to be 298 000 km/s. Using the following formula, determine the percent error of that calculation. (Recall that the actual speed of light is about 300 000 km/s.)

$$\text{Percent error} = \frac{(\text{actual speed of light}) - (\text{calculated speed of light})}{(\text{actual speed of light})} \times 100\%$$

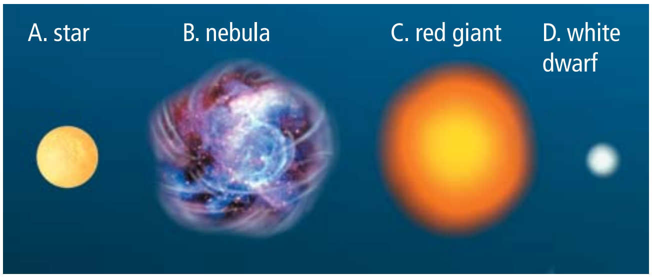
Checking Concepts

1. What material makes up most of interstellar matter?
2. How do galaxies form?
3. The photographs that follow show different shapes of galaxies.

   (a) Identify the type of galaxy shown in each photo.
   (b) Which type of galaxy is the Milky Way?
   (c) Which has a mixture of old and new stars?
   (d) Which represents the shape of very large galaxies?
   (e) Which has a halo around it?
4. What is "galactic cannibalism"?
5. Briefly explain how a star forms.
6. Describe the steps of development followed by each of the following categories of stars:
   (a) low mass stars
   (b) intermediate mass stars
   (c) high mass stars

Understanding Key Ideas

7. What advances in technology have allowed astronomers to "see" through the interstellar dust?
8. Describe what occurs during nuclear fusion.
9. What will eventually happen to all the stars in the universe?
10. Place the following in order from youngest to oldest:



11. How does the death of a star benefit the universe?
12. Why do black holes have such extraordinary gravitational pull?
13. What are three pieces of evidence that support the existence of black holes?
14. What allows quasars to be the brightest objects we know of in the universe?

Pause and Reflect

This image of the Antennae galaxies was taken by the Hubble Space Telescope.

The Antennae galaxies, shown here, are 45 million light-years away. They are the nearest and youngest examples of colliding galaxies. Astronomers believe that most galaxies will undergo at least one collision in their lifetimes.

Write a brief paragraph explaining how events like galaxy collisions could affect our universe.

12.3 Our Future in Space

Space technology is progressing at an amazing rate. More than 400 astronauts have now travelled to space. Optical telescopes and telescopes that focus waves from other parts of the electromagnetic spectrum operate on Earth and in space. Probes and landers observe regions in space that are too difficult for humans to explore. These advances in technology enable us to refine and expand our understanding of the universe. To what extent should Canada be part of the adventure? Is human space flight worth the money and the risk?

Key Terms

adaptive optics
Hubble Space Telescope
reflecting telescopes

Our success in learning about the sky and beyond has long depended on the tools available to extend our vision. The telescopes available to observe the sky improved in the 17th century, leading to many new discoveries. Suddenly, people were able to see details they could never have imagined were there before. More recently, further improvements to telescopes in the early 1900s allowed astronomers to observe galaxies in distant parts of the universe.

Constant improvement of a range of tools and technologies has helped astronomers continue to make new discoveries, both from Earth and by going into space (Figure 12.25).

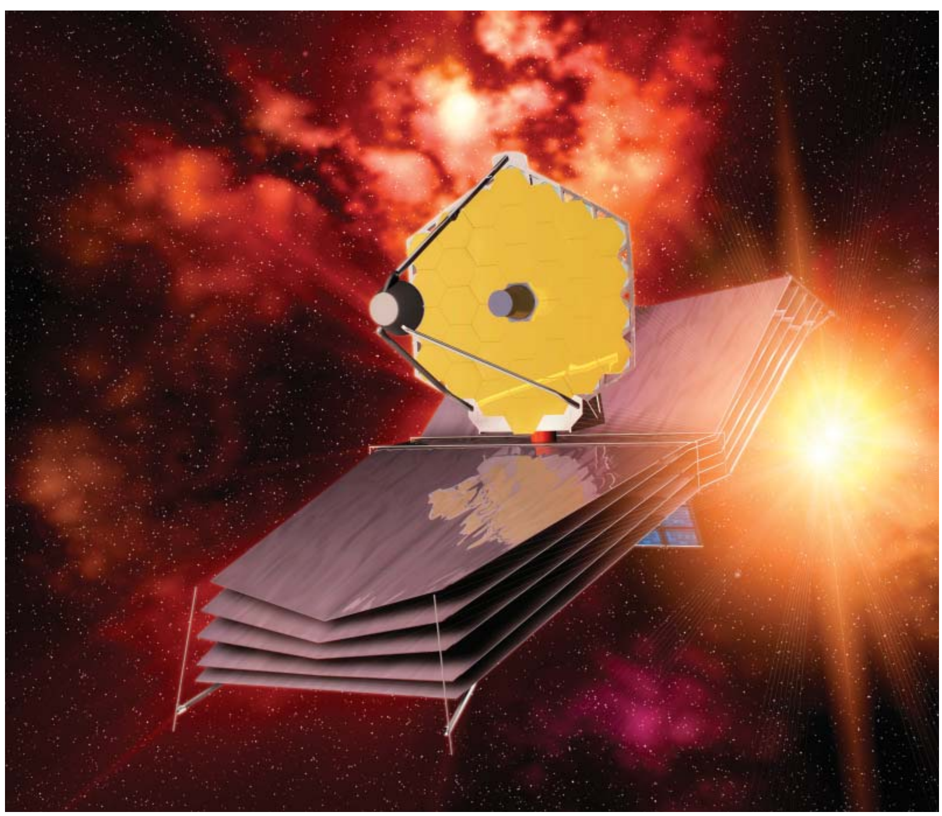


Figure 12.25 The James Webb Space Telescope—due to be launched in the next decade—will see farther into space and, therefore, farther back in time to just after the Big Bang. Who knows what we might learn by using powerful new telescopes like this one.

Future Telescopes

You read in Chapter 10 that Galileo used a refracting telescope to observe detail on the Moon and the phases of Venus. Refracting optical telescopes use lenses to gather and focus light. **Reflecting** telescopes use a series of mirrors to collect light and focus the image to an eyepiece. Because mirrors are lighter than lenses, and large mirrors do not cause as much distortion as large lenses do, reflecting telescopes can be much larger than refracting telescopes can be. The largest reflecting telescopes in the world today are the twin Keck Telescopes built at an altitude of 4200 m on Mauna Kea in Hawaii. The main mirror of each Keck Telescope is 10 m in diameter. Each is composed of 36 individual hexagonal segments. Even bigger than the two Keck Telescopes will be the Thirty Meter Telescope, with a 30 m diameter mirror. It is now in the planning stages and is expected to be completed in 2015. It should be able to help us see objects more than 150 times fainter than can be seen by the Hubble Space Telescope. Canadian astronomers are participating in the Thirty Meter project and will be able to use the telescope once it is built.

In Chapter 11, you learned that the view of objects in space from Earth-based telescopes is distorted by the Earth's atmosphere. The light from the stars is distorted by the turbulent atmosphere of Earth, causing the stars to appear to "twinkle." Telescopes can now be made with mirrors that can change shape slightly to compensate for the distortion caused by the atmosphere. This design is called **adaptive optics.** Computers monitor the atmosphere while the telescope is being used, and small mechanisms slightly change the shape of the mirror to compensate for this distortion. As a result, these telescopes offer much better views of distant objects. The Thirty Meter Telescope will use this new technique.

Observing at multiple frequencies

Distant objects such as stars, nebulae, and galaxies emit electromagnetic radiation at many different frequencies. By observing these objects with telescopes that can detect radiation of various frequencies, a better overall understanding of the characteristics of these objects can be obtained. For example, visible light will not penetrate the dust in between the stars, but radio waves and infrared light can penetrate this dust, allowing you to see through the dust and deeper into a galaxy.

internet connect

Many secrets of the universe are revealed when we use instruments that search for energy from all parts of the electromagnetic spectrum, not just the narrow band of visible light. Research the different types of telescopes that obtain "non-visible" information about celestial objects, the frequencies that they detect, and the information that they allow us to "see." Start at **www.discoveringscience9.ca**.

Telescopes in Space

Ideally, a telescope would observe all frequencies of radiation at the same time—from the very long radio waves to the very short and energetic gamma rays. Unfortunately, telescopes have to be designed specifically to detect a particular range of frequencies, so astronomers need to use many different telescopes. In addition, not all frequencies pass through Earth's atmosphere. Some infrared rays and more energetic ultraviolet rays, X rays, and gamma rays are absorbed by the atmosphere and do not reach the surface of the Earth (Figure 12.26). To detect these rays, telescopes must be placed above the atmosphere, in space.

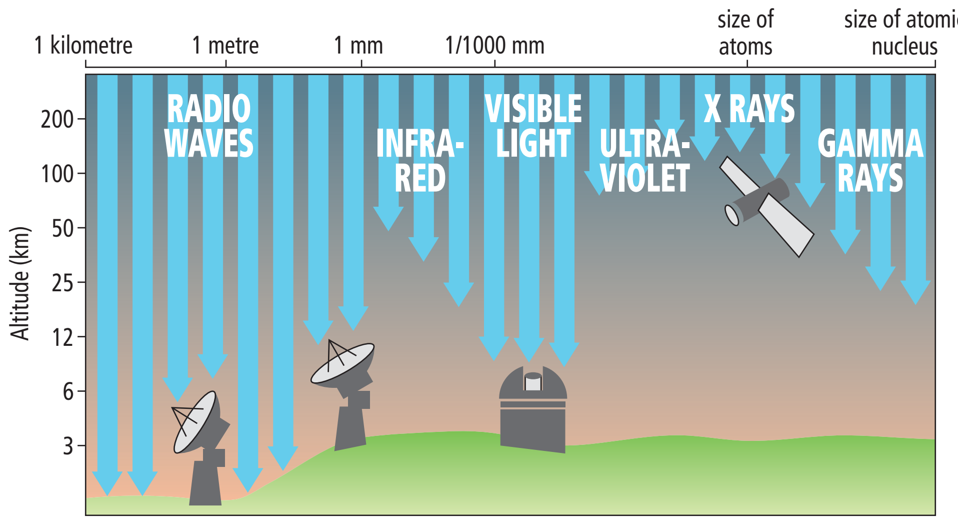


Figure 12.26 Not all frequencies of light make it through the atmosphere to Earth's surface. While radio waves do reach the surface, gamma rays only reach 25 km to 100 km above it.

Did You Know?

The Hubble Space Telescope orbits once around the Earth every 96 min. It travels at a speed of about 8 km/s.

The **Hubble Space Telescope** is an optical telescope that has provided images of some of the oldest galaxies ever observed. Launched into Earth orbit on the space shuttle *Discovery* in 1990, the Hubble (named after Edwin Hubble of receding-galaxy fame) has changed astronomy. Its ability to provide clear images of far-away galaxies and stars has helped astronomers solve many problems in astronomy (Figure 12.27). For example, by using the Hubble Space Telescope, astronomers were able to determine that the universe is between 13 and 14 billion years old. By providing views of galaxies 10 billion light-years away—capturing light that took 10 billion years to reach us—it has shown us how galaxies looked not long after the Big Bang.

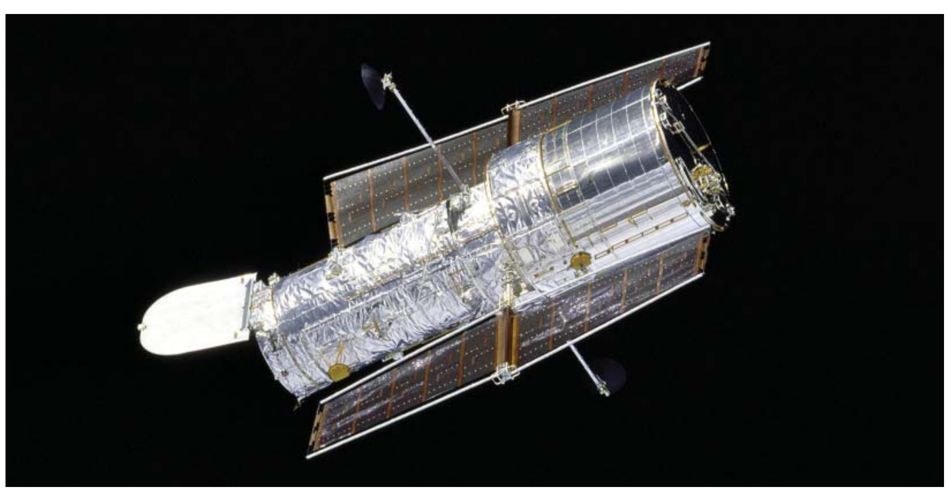


Figure 12.27 Because the Hubble Space Telescope observes from above Earth's atmosphere, the light that reaches its mirrors has not been distorted. It is able to see objects clearer than had ever been possible before.

Infrared telescopes enable astronomers to "see" through the dusty curtains of interstellar matter and into distant nebulas. They must operate from space because infrared rays do not penetrate Earth's atmosphere (Figure 12.28). In 2013, NASA plans to launch a new infrared telescope—called the James Webb Space Telescope—into orbit around the Earth to help astronomers observe some of the first galaxies that formed after the Big Bang.

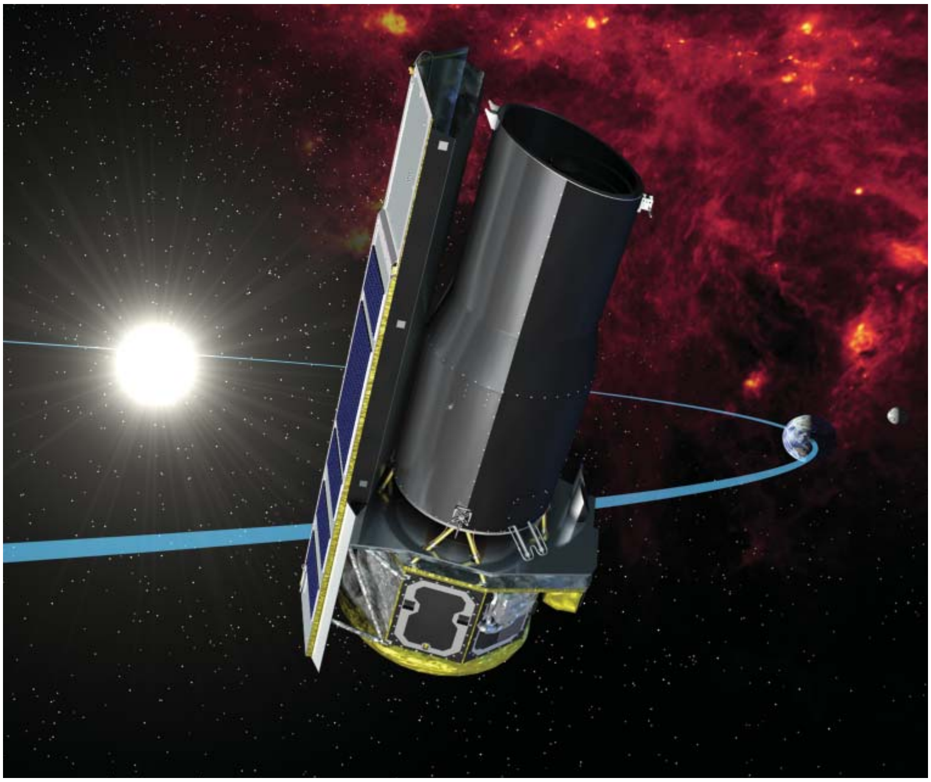


Figure 12.28 The Spitzer Space Telescope observes objects in infrared light. It detects the heat given off the centres of galaxies and newly forming planetary systems. To detect this heat, the detectors must be cooled to almost –273° C.

The Chandra X-ray Observatory detects high energy X rays in space. X rays are given off radiated exploding stars, black holes, and the centre of galaxies. The Fermi Gamma-ray Space Telescope also detects gamma rays from exploding stars, neutron stars, and galaxies (Figure 12.29 on the next page).

With all these telescopes working in space, astronomers can gather more information to test the existing theories of the formation and development of the universe and our solar system. One day, one of these telescopes will certainly provide information that will force astronomers to rethink their theories and create new ones. This trend has happened many times since Galileo first used a telescope and there is no reason to think it will not happen again.

Explore More

In 2008, carbon dioxide in the atmosphere of a planet orbiting another star was discovered by the Hubble Space Telescope. Although the planet does not support life because it is too hot, this discovery demonstrates that it is possible to determine whether life could be supported on other planets. Research some of the other discoveries made by space telescopes. Begin your research at **www.discoveringscience9.ca.**

Suggested Activity

Think About It 12-3A on page 465

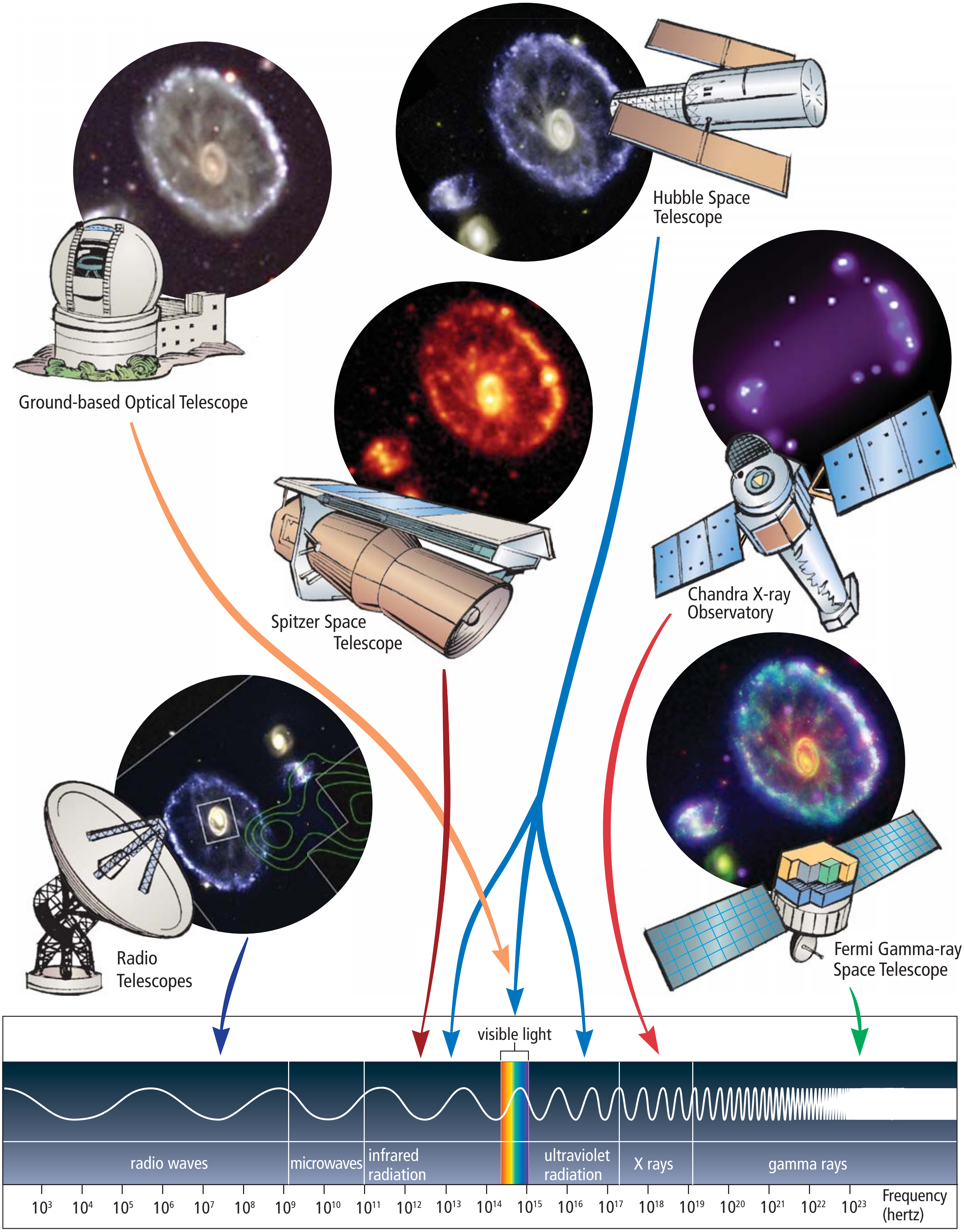


Figure 12.29 Different telescopes detect radiation from different parts of the electromagnetic spectrum, and allow us to observe different features of space.

Space Exploration and Space Travel

While telescopes provide us with huge amounts of data about space, there are some things that can only be learned by other types of observation. Scientists have travelled into space—to the Moon and to the International Space Station—to make observations and to carry out experiments. It is very difficult and costly to send humans into space because everything is so far away, and humans need enough food and air for long trips. Other challenges to sending humans so far away are protecting them from the extreme cold of space and trying to ensure that the spacecraft do not break down and leave humans stranded in space. Some destinations are simply too far away for humans to travel to.

We explore space to learn about the universe. But it is a costly adventure. The Hubble Space Telescope alone, launched in 1990, cost around $10 billion. Space exploration is also very dangerous. Lives have been lost in failed missions. Is exploring space worth the cost in dollars and in human lives?

Rewards of Space Exploration and Space Travel

One of the biggest rewards of space exploration is that it satisfies our curiosity about the world we live in. Humans are curious by nature, and our intelligence is based on exploring and making connections among the things we learn. We have already learned a lot by exploring space, and new technologies will enable us to learn even more.

A great deal of technology that was originally invented and designed for use in space has found new purpose on Earth. These spinoff technologies include hundreds of items we use in our day-to-day lives. The list is long, but some examples are freeze-dried foods, high-tech running shoes, bicycle helmets, cold weather clothing, light sportswear, sunglasses, insulin pumps, eye examination systems, locator beacons, and self-repairing computers (Figure 12.30).

Astronauts who spend months aboard the International Space Station experience a decrease in their bone density. This effect is similar to the symptoms of people on Earth who suffer from osteoporosis. What we learn about preventing this disease in astronauts can help us to treat people on Earth.

The lure of space travel is no longer reserved just for highly trained astronauts. Progress in space travel technology has meant improvements in safety and has significantly lowered costs. As a result, space tourism is now possible.

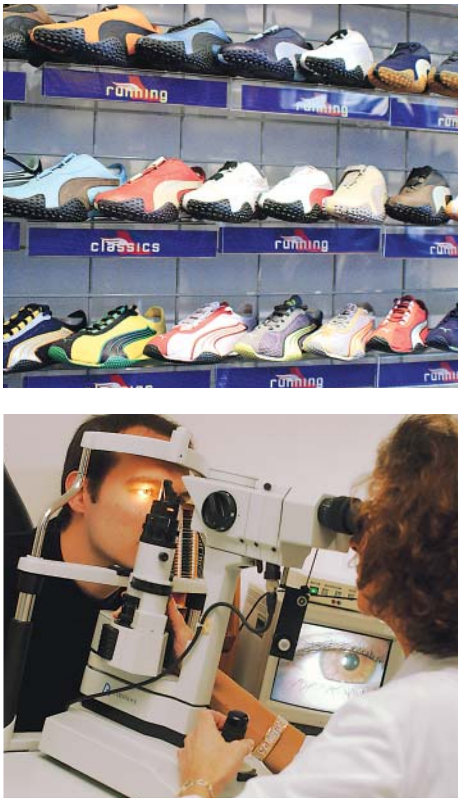


Figure 12.30 Many things you use every day were originally invented by scientists and engineers for use in space.

Risks of Space Exploration and Space Travel

The most obvious hazard of space flight is the ever-present risk of equipment failure. This risk can be caused by a malfunction during takeoff, collision with space debris, or a heat shield not protecting the spacecraft during re-entry into Earth's atmosphere. The fuel tank of a space shuttle holds more than 750 000 kg of highly explosive fuel, which is why takeoffs occur only after every safety precaution has been taken.

NASA estimates that there are more than a million pieces of debris orbiting Earth at any one time. These pieces of debris can range in size from flakes of paint and small bolts to old satellites. This "space junk," regardless of size, can damage anything it hits (Figure 12.31). In space, an apple-sized metal ball would crash into something with the explosive force of two dozen sticks of dynamite because it is travelling so quickly in its orbit. To avoid collisions, the paths of the larger pieces of debris are closely monitored using Earth-based radar. Steps are taken to avoid the objects when spacecraft take off and land.

Word Connect

The term "space junk" is used to describe the debris orbiting Earth. Part if this space junk includes a glove, a camera, a pair of pliers, and an entire tool box, which were accidentally dropped by astronauts on space missions.

Occasionally these objects hit molecules of the upper atmosphere, which slows down the objects slightly and lowers their orbit. The lower the objects go, the more molecules they hit, which slows them further until they enter the thicker parts of the atmosphere and friction causes them to become hot. Most of the materials falling toward Earth burn up in Earth's atmosphere, although large materials do occasionally crash to Earth's surface. In 1978, a Soviet satellite hit the ground in the Great Slave Lake area of northern Canada. In 2003, the space shuttle *Columbia* broke up when a damaged heat tile allowed hot gasses to enter the wing, claiming the lives of all six astronauts on board. Debris from *Columbia* was scattered over three American states. Nobody on the ground was hurt in either incident.

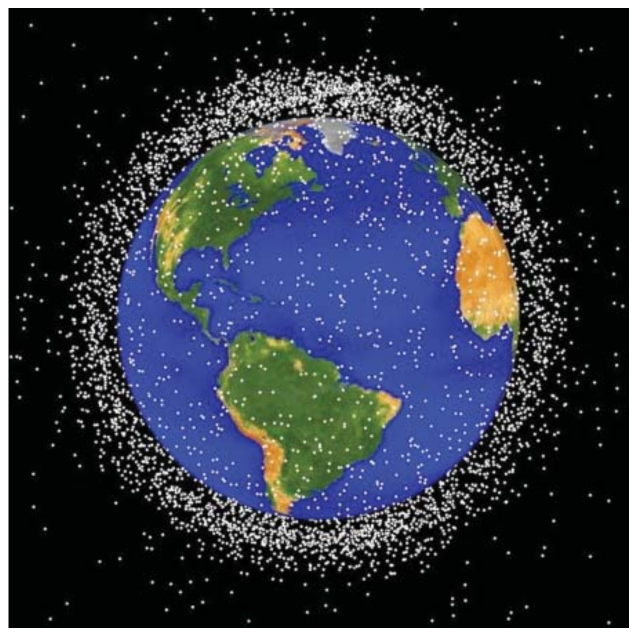


Figure 12.31 NASA estimates that at least two collisions a day occur between operational satellites and space junk in Earth orbit. This artwork shows a representation of all the known material in orbit around the Earth.

Recently, two uncrewed satellites collided over Siberia. This collision resulted in two large clouds of debris that may cause problems with satellites for many years. This debris could strike and damage other satellites, possibly endangering astronauts in the space station. Every few weeks, the astronauts on the space station have to adjust their orbit to steer clear of a piece of debris. Other space debris sometimes survives reentering the atmosphere and falls to Earth. In 1978, a Soviet satellite re-entered over the Arctic and spread harmful radiation over a large area, requiring a time-consuming and costly clean-up.

As well as these risks, astronauts in space are subjected to radiation from the Sun. Normally the Earth's magnetic field and atmosphere protect us from harmful radiation. There is some protection for the astronaut in Earth orbit, but astronauts on the International Space Station still receive more radiation than we do on Earth. Once astronauts go to the Moon or farther into the solar system, they are subjected to larger doses of radiation, which, during intense solar storms, could prove fatal.

The term **ethics** refers to the set of moral principles and values that guides a person's actions and helps him or her decide what is right and what is wrong. When discussing space exploration and the use of space resources, it is important to consider the ethical issues related to space travel. Closely tied to ethical issues are environmental and political issues. As with any resource, economic matters should be balanced with consideration for the environment and for people. Humans must consider the potential damage their actions might cause to humans' and Earth's well-being. The list below outlines some of the questions that humans will have to answer if we are to prevent the unethical use of space and its resources in future.

Did You Know?

In 1979, the first American space station, Skylab, broke into thousands of chunks during re-entry through Earth's atmosphere. These chunks crashed into the Indian Ocean, and some pieces landed in Australia. The Australian government fined the U.S. $400 for littering.

Table 12.1 Questions That Must Be Asked About Space Travel

Ethical	• How do we ensure that space resources will be used to help all humankind rather than just to provide an advantage for one country or another? • Do humans have the right to invade other unique environments around the solar system? • Do we have the right to take materials from other celestial bodies in the solar system? • Are there other problems on Earth that could be solved with the money now used for space programs?
Environmental	• What will be the effects of space travel on Earth's natural systems? • What effect does resource removal have on asteroids, moons, and planets? • Who is responsible for policing environmental impacts? • Who must be responsible for cleaning up any damage or debris from space development?
Political	• Who has ownership of space resources? • Should countries share technology and resources? • Who should decide how space resources will be used?

Because of the rate at which space exploration is proceeding, the issues facing Earth as a community need to be addressed. One of the biggest questions to be dealt with is, Should we be thinking about travelling to space before we deal with problems on our home planet? These concerns are not for some future generation but are ones that you will likely confront in the next several years.

Suggested Activity

Conduct an Investigation 12-3C on page 466

Your Future in Space Travel

What does the near future hold for people who want to travel to space? Even now, private citizens are buying trips to the International Space Station. These price tags are out of most people's price ranges ($20 to $30 million USD) but the space tourism industry will soon grow and the prices will fall. There are companies that will soon provide trips out of Earth's atmosphere where travellers will experience a few minutes of "zero gravity" and see the blackness of space (Figure 12.32). As more and more companies offer these excursions, prices will fall and a trip into space in 20 years may cost as much as a trip to the South Pole costs today.

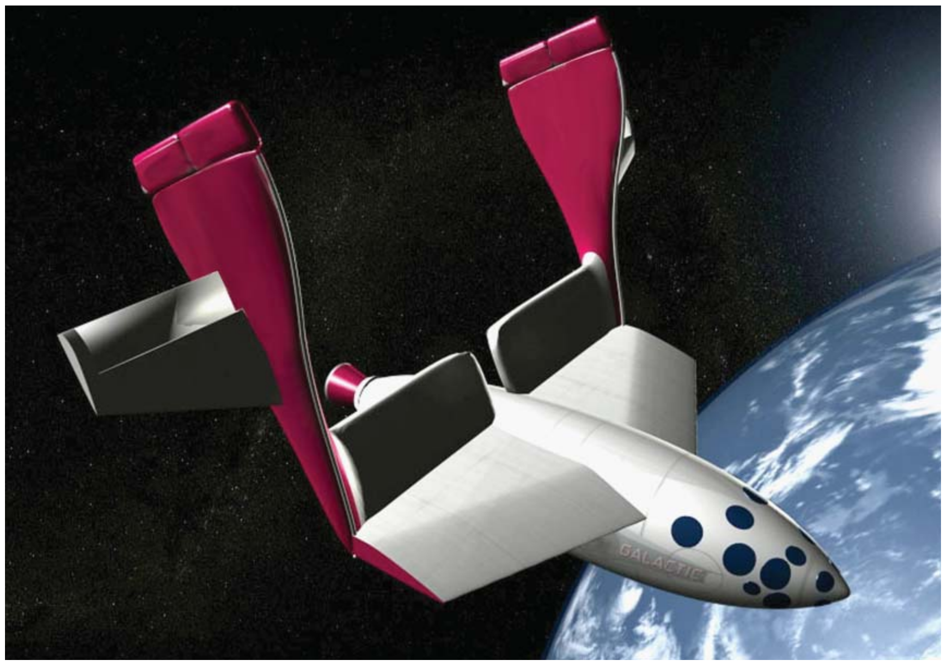


Figure 12.32 Soon tourists may fly in ships like this to the fringes of the atmosphere for short trips into space.

Plans to take people to the Moon and to other planets are not as clear. There are efforts underway to put people back on the Moon by 2020. Crews of four would spend a couple of weeks on the Moon, and ultimately a permanently inhabited base would be established. This base may be used as a training ground for future trips to Mars. But a trip to Mars is a very expensive multi-year venture that may still be decades away.

Reading Check

1. How has the invention of the telescope helped the science of astronomy?
2. What is the main difference between refracting and reflecting telescopes?
3. What is an advantage of an infrared telescope over an optical telescope?
4. Give three potential risks of space exploration and space travel.

12-3A Telescope Technology

Think About It

Astronomers use many different types of instruments to probe the universe. In this activity, you will show how the advance of technology has provided us with the information to alter existing, or form new, theories about the solar system, stars, galaxies, and the formation of the universe.

What to Do

1. Choose one of the following topics:
   (a) Research how astronomers are using optical or radio telescopes on Earth to study our universe. Explain how the work is carried out, list what they have observed, and relate some conclusions they have been able to draw.
   (b) Investigate how the use of telescopes in space is contributing to our understanding of the universe. What have space-based telescopes enabled us to see? How? What conclusions have scientists been able to draw based on these observations?
   (c) How has the use of the Canada-France-Hawaii Telescope and the Very Large Array radio telescope increased our knowledge of the universe? What have they allowed scientists to do that they could not do before these telescopes were built? How do scientists from different countries cooperate in using them?
2. Present your findings to the class in a short presentation or on a poster.

12-3B A Career in Space Exploration

Think About It

There are many space-related careers available today. In this activity, you will describe examples of science- and technology-based careers in Canada that are associated with space exploration.

What to Do

1. Research one of the following careers:
   (i) astronaut
   (ii) biologist
   (iii) structural engineer
   (iv) medical doctor
   (v) pilot
   (vi) computer technician

   Create a list or a table to show the main skills that the career requires and the main tasks someone in that career could be expected to perform.
2. Describe what people in the career you researched could do to help a space exploration team. If necessary, conduct more research to find out what roles people with similar careers have played in space exploration.
3. Design an advertisement for a job related to space and to the career you researched. Include the following:
   - what skills and experience the person should have
   - what the person will be expected to do on the job
   - who the person will work for
   - what the working conditions will be like (for example, indoors or outdoors, how many hours worked each day, whether travel will be required, and so on)

12-3C The Great Space Debate

Conduct an INVESTIGATION

Decision-Making Focus

SkillCheck

- Communicating
- Evaluating information
- Working co-operatively
- Identifying ethical issues

The Issue

Should large amounts of money be spent on space exploration rather than being used for projects on Earth?

Background Information

As technology opens up the "space age," new issues arise about the nature of space exploration. What was once the scientific pursuit of knowledge is quickly becoming a race to see who can make the most money from space. There is no doubt that space can provide limitless opportunity. However, as we have seen on Earth, exploitation of resources usually comes at some environmental cost. Humans need to assess the risks and rewards of space travel before making decisions that cannot be reversed. For some people who are thinking about the matter, the question "Can we go?" should be replaced with "Should we go at all?" This chapter focusses on the risks and rewards of space travel.

Identify and Analyze Alternatives

In this unit, you have been learning how humans use technology to observe, study, and explore space. The benefits and spinoffs of space exploration include great advances in health, communications, and Earth observation. However, as you have also learned, space exploration requires great amounts of resources and money. The drive to improve our understanding of the universe must be balanced with concern for the space environment, financial costs, and even the potential for battles over military control of space. Each year, it seems that "outer space" is becoming increasingly more accessible to humans. Hotels in orbit, vacations on the Moon, and even interplanetary travel are ideas that used to be considered science fiction.

The question constantly faced by the space industry is whether humans should be spending so much money on space exploration or instead putting these resources into solving Earth-bound issues and problems. Your goal in this activity is to choose a position, either for or against investing large sums of money in space exploration, and to support it with evidence. Conduct your research using the following resources.

1. Begin your research at **www.discoveringscience9.ca** to determine both the costs and benefits of space exploration.
2. Search print materials such as journals, magazines, and newspapers for articles relating to the positive and negative effects of space exploration.
3. Choose a viewpoint based on your research. Summarize your information in a short report.
4. Share your opinion with your classmates in the form of a presentation or a debate. It is important for you to be able to defend your point of view with appropriate data.

Science Skills

Go to Science Skill 3 for information about how to conduct your research.

Evaluate

Present your opinion and findings to your classmates as a presentation or a debate.

Check Your Understanding

Checking Concepts

1. What design feature of the Thirty Meter project will allow astronomers to see more objects in space than the existing Keck Telescopes?
2. What does the term "adaptive optics" mean?
3. What types of frequencies have difficulties passing through Earth's atmosphere?
4. What discoveries have been made possible by the use of the Hubble Space Telescope?
5. List some of the difficulties that occur when humans attempt to explore or travel in space.
6. Technology related to space exploration has led to the invention of many useful products for everyday life on Earth. Give five different spinoff technologies that we use in our everyday lives.
7. Explain why it is unlikely that terraforming of Mars will occur in your lifetime.
8. Most of the debris floating around Earth is smaller than a softball. Why should such small objects concern astronauts in space?
9. If you were to travel into space, what type of experiences could you expect to have?

Understanding Key Ideas

10. What advantage do reflecting telescopes have over refracting telescopes?
11. Describe a disadvantage of using a telescope positioned in space.
12. Astronomers use different telescopes for varying types of observations. Describe the type and general uses of the following telescopes:
    (a) Hubble Space Telescope
    (b) James Webb Space Telescope
    (c) Spitzer Space Telescope
    (d) Chandra X-ray Observatory
    (e) Fermi Gamma-ray Space Telescope
13. (a) What is "space junk"?
    (b) What happens to "space junk" when its orbit is lowered?
14. Imagine you are an astronaut about to travel to a base on the Moon. What three hazards could affect your flight?

Pause and Reflect

In this section, you have learned about the rewards of space exploration and space travel. You have also learned that such adventure does come with a degree of risk. If you were given a chance to be one of the first astronauts to journey to Mars, would you go or not? Write a short paragraph that explains your decision and why you came to that conclusion.

Chapter Review

Prepare Your Own Summary

Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 8 for help with using graphic organizers.) Use the following headings to organize your notes:

1. Technologies to understand and explain stars and galaxies
2. Theories to explain the origin and future of the universe
3. Measurement of distances in space
4. Exploration of space

Checking Concepts

1. What is a galaxy?
2. What name has been given to the main theory today about how the universe formed?
3. How long do scientists believe the universe has been expanding?
4. What did Edwin Hubble notice about the direction of travel of distant galaxies that led him to propose that the universe is expanding?
5. Astronomers say the light from distant galaxies is red-shifted. What does red shift mean?
6. Explain how each of the following are formed:
   (a) stars
   (b) planetesimals
   (c) planets
7. Why do we refer to inner planets as "terrestrial"?
8. Why are light-years used to measure distances in space?
9. What force holds the billions of stars in a galaxy together?
10. What kind of galaxy is the Milky Way?
11. What chemical reaction results in products that allow stars to glow?
12. Describe the physical characteristics of each of the following stages in a star's development:
    (a) red dwarf
    (b) white dwarf
    (c) red giant
    (d) black dwarf
    (e) supernova
    (f) neutron star
13. What advantages do orbiting telescopes, such as the Hubble Space Telescope, have over telescopes on Earth?
14. What is the advantage of a telescope with adaptive optics over a standard reflecting telescope?
15. Summarize some of the major discoveries made by the Hubble Space Telescope.
16. Why do infrared telescopes have to operate from space?
17. Explain why it is less expensive to send robotic explorers to another planet than it is to send human astronauts.
18. Many new technologies that have been developed for use in space have found new purposes on Earth. Name two space spinoffs you use in your daily life.

Understanding Key Ideas

19. What do astronomers suggest is the cause of cosmic background radiation?
20. What evidence led Hubble to believe the universe was expanding?
21. How is an inflating balloon similar to an expanding universe?
22. Imagine that an astronomer is observing a group of three galaxies. If the spectrum of each of the galaxies is shifted toward the red end, what can the astronomer conclude about the galaxies?

23. An astronomer trying to use parallax to determine the distance to a star notices the star did not change position when observed from two different locations. What should the astronomer conclude from this observation?
24. How is the shape of a spiral galaxy different from that of an elliptical galaxy?
25. (a) Explain why black holes are invisible.
    (b) If black holes are invisible, how do astronomers know they exist?
26. How has the discovery of quasars led astronomers to a better understanding of the universe?
27. Carl Sagan stated that there are more stars in the universe than grains of sand on all the beaches of Earth. Explain this statement.
28. Many different types of telescopes have been developed to explore the far reaches of the universe. Describe the part of the electromagnetic spectrum that each of the following telescopes have been designed to detect:
    (a) Hubble Space Telescope
    (b) Chandra X-ray Observatory
    (c) Fermi Gamma-ray Space Telescope
    (d) Spitzer Space Telescope
29. What might be some difficulties that would be associated with the terraforming of a planet like Mars?
30. "Space junk" is a hazard for satellites in space. Is "space junk" a hazard for inhabitants of Earth? Explain.

Pause and Reflect

Technology related to exploration in space has led to the development of telescopes, the International Space Station, future plans for privatizing space travel, and discussions of the terraforming of other planets. To what extent should Canada be a part of these adventures? Is space exploration worth the risks and costs? Write a short paragraph that explains how much you think Canada should be involved in these developments.

Unit Summary

10 What we know about the universe has taken us thousands of years to learn.

- Patterns of stars in the sky are called constellations, from the Latin phrase meaning "with stars." (10.1)
- A star's brightness is described as its magnitude, which depends on how close the star is to Earth. (10.1)
- The observations and recordings by early astronomers significantly contributed to our current understanding of Earth and space. (10.2)
- By the 16th century, once it was understood that the Sun was at the centre of the solar system and the planets revolved around it, astronomers began to explain the motions of the planets. (10.3)

11 We continue to learn a lot about our solar system by using space exploration.

- Life is made possible from the Sun's heat and light. By studying the Sun, scientists have learned a lot about average-sized stars. (11.1)
- Planets, moons, asteroids, and comets—all in motion around the Sun—are part of our solar system. The eight planets in our solar system are separated by great distances. (11.2)
- Technology has enabled us to see farther into space and expand our understanding of the universe. One of the largest successes in NASA's space program has been the Canadian-designed and -built robotic arms. (11.3)
- The International Space Station (ISS) is in orbit around the Earth, so it is falling around the Earth. The gravitational pull of the Earth is keeping the ISS in orbit. (11.3)

12 We can use space exploration to learn about stars, nebulae, and galaxies outside our solar system.

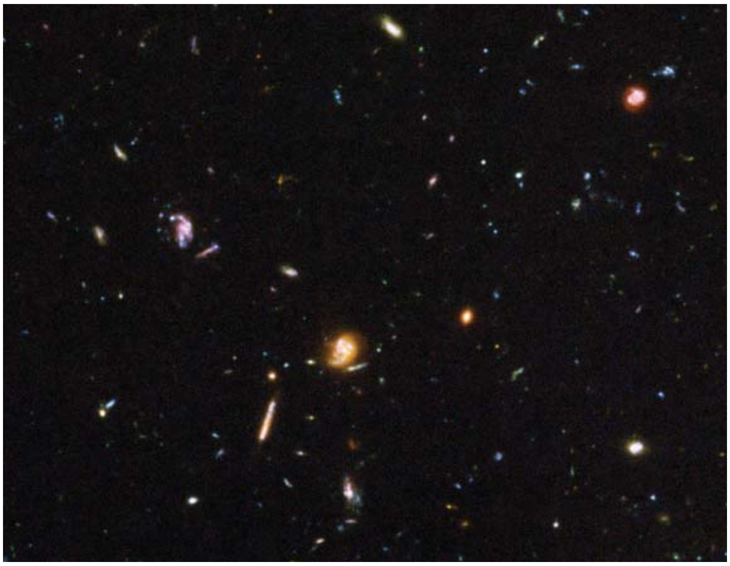
- About 13.7 billion years ago, the universe is believed to have begun during a rapid expansion of a tiny volume of space, which we now call the "Big Bang." (12.1)
- In order to talk about the enormous distances outside our solar system, astronomers have devised a measurement unit called a light-year. A light-year is the distance that light, which moves at 300 000 km/s, travels in a year. It is equal to about 9.5 trillion km. (12.1)
- 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. Our Sun is one of the estimated 100 billion stars in the Milky Way galaxy. (12.2)
- A range of tools and technologies are constantly improved to help astronomers continue to make new discoveries, both from Earth and by going into space. (12.3)
- Small pieces of debris orbiting Earth, regardless of their size, can damage anything they hit. NASA estimates that there are more than a million pieces of debris orbiting Earth at any one time. The paths of the larger pieces of debris are closely monitored to ensure spacecraft avoid the objects during takeoff and landing. (12.3)

Key Terms

- asterism
- astrolabe
- celestial body
- circumpolar constellation
- constellation
- ecliptic
- ellipse
- geocentric
- heliocentric
- magnitude
- orbit
- planet
- retrograde motion
- star
- telescope
- zodiacal constellations

Key Terms

- asteroid
- astronomical unit
- comet
- corona
- chromosphere
- dwarf planet
- geosynchronous orbit
- Kuiper Belt
- meteor
- meteorite
- meteoroid
- moon
- Oort Cloud
- optical telescope
- planet
- photosphere
- probe
- radio telescope
- rover
- satellite
- solar prominences
- solar radiation
- solar wind
- space weather
- sunspots
- thermonuclear reaction
- transit



Key Terms

- adaptive optics
- astronomical unit
- axis
- Big Bang theory
- black hole
- cosmological red shift
- electromagnetic radiation
- elliptical galaxy
- fusion
- galaxy
- Hubble Space Telescope
- interstellar matter
- irregular galaxy
- light-year
- nebula
- parallax
- planetesimal
- Oscillating theory
- quasar
- red shift
- reflecting telescopes
- revolution
- rotation
- spectroscope
- spectral lines
- spiral galaxy
- star
- supernova
- triangulation

Designing a Mining Town for the Moon

In this unit, you have learned much about the nature of space, developments in space exploration, and ideas about space travel. Many scientists believe that our nearest celestial neighbour, the Moon, offers large quantities of valuable resources such as iron and numerous other minerals.

Imagine that you are part of a design team that has been asked by a private company to assist it in designing and building a scale model of a modern mining town for colonists on the Moon.

Problem

What needs in a Moon-based colony must be met to ensure humans can safely live there and successfully mine minerals to send back to Earth?

Criteria

Your lunar base model must have a number of sections that are all connected together. The size, shape, and number of sections should be decided by your group, but your design and model must show that you have considered the following:

- living quarters
- transportation at the base
- recreation
- excavation strategies and technology for the minerals to be mined
- the physical and mental health of the colonists

Procedure

Part 1 The Design

1. With your group, brainstorm ideas about all the things you think people in a lunar mining base would need to live and work for several months at a time.
2. Think about the challenges for humans living on the Moon and decide how the various sections of your base will address those challenges. Ask your teacher for guidance if you require it, or go to **www.discoveringscience9.ca** for suggestions.
3. Draw a sketch of your model plans, using a suitable scale for your model. For example, a shoe box may be the right scale to represent the living quarters.
4. Make a list of the materials you could use to build the model of the base. Choose easy-to-find materials to represent the objects you want to add to each section or consider making the model and objects from cardboard or paper. Before you begin collecting materials, ask your teacher to review your list.

Part 2 Building Your Model

5. Using your sketch as a guide, gather your construction materials and build the scale model.
6. Once you have completed your model, review the criteria listed at the beginning of this project. Your model should be able to accommodate the moon colonists and should also be able to function as a mining operation.

Report Out

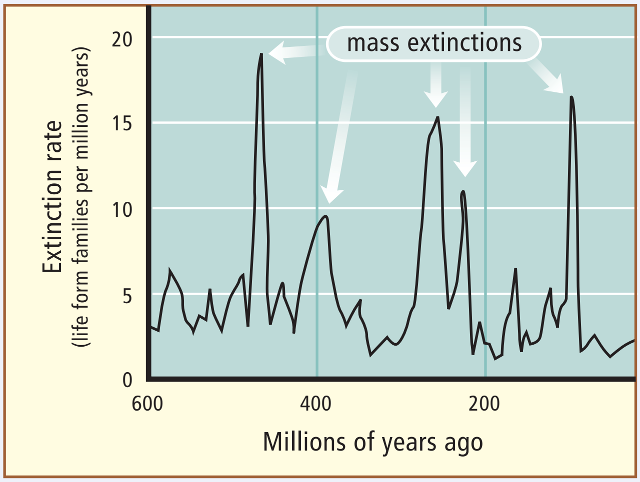
1. After you have completed your drawings and scale model, your teacher will provide you with instructions for presenting your project to the class. In your presentation, you will need to describe how you addressed all the items listed above under "Criteria." Compare your group's design with that of other groups. What was similar, and what were the differences?

"It's a Bird, It's a Plane, It's an Asteroid!"

"Near Earth Objects" are what astronomers call asteroids, comets, and similar-sized bodies whose orbits have brought them closer to Earth as a result of the planet's gravitational pull. A subset of Near Earth Objects is a group of asteroids known as Potentially Hazardous Asteroids. These asteroids are larger than 2 km wide and have the potential to strike Earth with a force that would generate as much energy as millions of megatonnes of explosives.

Background

Collisions between Earth and another large object from space are estimated to occur about once every 100 million years. That means the risk of Earth being struck is extremely low. When a collision does occur, however, the consequences are catastrophic. Past impacts are believed to have set off earthquakes around the world and to have ejected so much dust and debris into the atmosphere that sunlight was blocked and global climate patterns changed for years. Some scientists believe that an asteroid impact 65 million years ago led to the extinction of the dinosaurs.



What would happen if astronomers discovered a large asteroid headed for Earth? In a best-case scenario, the warning would come years before the collision. That still leaves the enormous problem of how to divert the asteroid from its collision course. Many scientists, engineers, and technologists have been thinking of a solution to the challenge for years. Ideas include trying to blow up or deflecting the asteroid using a gravitational deflection procedure. A spacecraft might use a rocket to push the asteroid out of the way. Even placing a solar sail on the asteroid, or painting one side dark to take advantage of long-term solar radiation, has been suggested. These methods must be used years, even decades, before the predicted collision.

A small asteroid could cause much localized damage on Earth. A Potentially Hazardous Asteroid could cause damage on a global level. Fortunately, Earth-asteroid collisions are extremely rare.

Find Out More

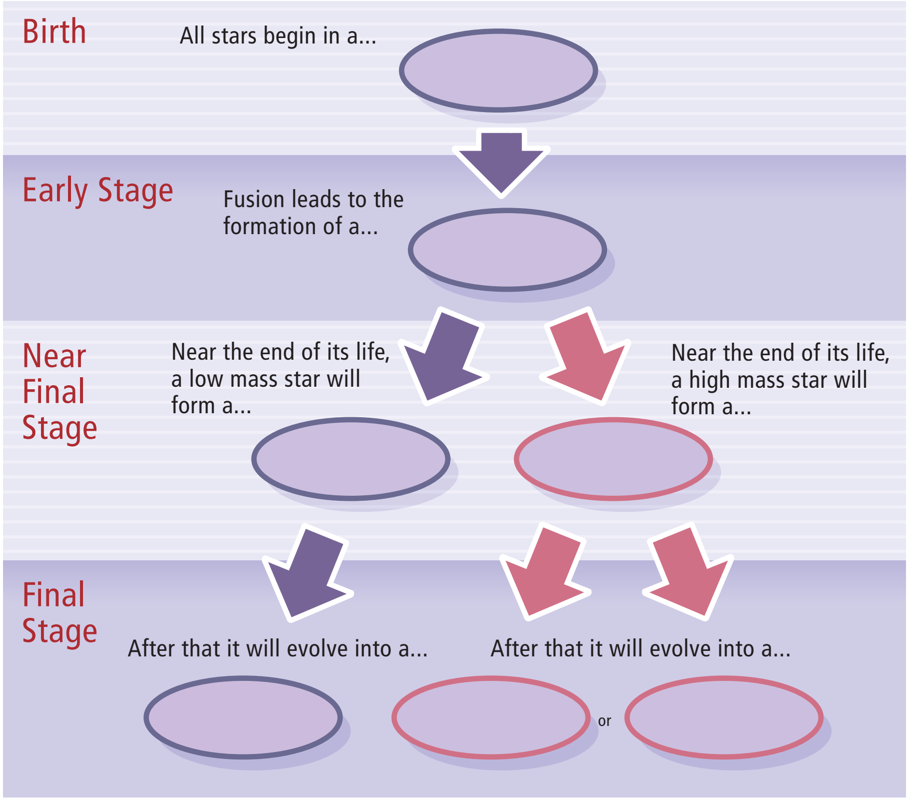
Research a range of techniques scientists have proposed for protecting Earth from Near Earth Objects, particularly asteroids. Use the Internet (start at **www.discoveringscience9.ca**), magazines, journals, and newspapers. You may also wish to contact a university astronomy department or the nearest chapter of the Royal Astronomical Society of Canada for relevant information.

Report Out

1. Choose one of the techniques you researched and prepare a report, poster, or model to present your findings.
2. For whichever form of presentation you use, be sure to answer each of the following questions.
   (a) Does the technology exist, or is it still being researched?
   (b) How much warning of an incoming asteroid would be required before the technique could be put into action?

Unit Review

1. Copy the concept map below into your notebook, and complete it by filling in the correct vocabulary words that describe the life cycle of stars.



Using Key Terms

2. In your notebook, state whether each of the following statements is true or false. If false, rewrite the statement to make it true.
   (a) A collection of planets that forms a pattern in the sky is called a constellation.
   (b) The Milky Way is an example of an asterism.
   (c) The heliocentric theory states that the Earth is the centre of the universe.
   (d) Jovian planets have rocky crusts.
   (e) The corona is the outermost part of the Sun's atmosphere.
   (f) Revolution describes a planet spinning on its axis.
   (g) A star's core is like a nuclear furnace.
   (h) Most stars form in a swirling cloud of gas and dust called a star cluster.
   (i) There are eight planets in our solar system.
   (j) Rovers are sent to orbit distant planets.
   (k) A group of millions or billions of planets is called a galaxy.
   (l) The Big Bang theory suggests the moment at which the Earth formed.
   (m) Distances to stars outside our solar system are measured in light-years.
   (n) Black holes have such intense gravitational force that not even light can escape from them.
   (o) Supernovas supply carbon to Earth's environment.

Checking Concepts

10

3. Early astronomers suggested that planets orbited the Sun in circular paths. What is the true shape of the planets' orbits?
4. (a) What is the geocentric model of the solar system?
   (b) Why do we know that the geocentric model of the solar system is incorrect?
5. What instrument did Ptolemy use to locate and predict the positions of the Sun, Moon, and stars?
6. What observations did Galileo make with his telescope?
7. What are the laws of planetary motion proposed by Kepler?
8. How did Sir Isaac Newton explain the movement of celestial bodies through the universe?

11

9. What nuclear process creates energy in stars?
10. What is the name of the part of the Sun that we see as its yellow surface?
11. Why do sunspots appear darker than the areas surrounding them?
12. What is an AU?
13. List four ways in which Mercury and Jupiter differ.
14. Why is Pluto now considered a dwarf planet?
15. What is a trans-Neptunian object? Give an example.
16. What is found in the payload section of a rocket?
17. What improvements were made to Canadarm 2 to make it more efficient than Canadarm 1?
18. What conditions led to a satellite being in a geosynchronous orbit?
19. What term should be used when astronauts appear to be floating?

12

20. (a) What is the name of the most widely accepted theory of how the universe formed?
    (b) How long ago do astronomers believe the universe formed?
21. Why do astronomers not use astronomical units to measure the distance to stars?
22. American astronomer Edwin Hubble noticed that the light from distant galaxies was shifted toward the red part of the spectrum. What explanation did he give for this?
23. What type of galaxy is shown below?

24. What type of star, in terms of mass, becomes a red giant in its life cycle?
25. Why did astronomers have to place telescopes above Earth's atmosphere?
26. List two rewards and two risks of space travel.

Understanding Key Ideas

27. Which planets were named after Roman Gods?
28. What two factors affect the magnitude of a star?
29. Explain why constellations appear to move through the night sky.

Unit Review

30. Summarize the contributions of the following astronomers:
    (a) Aristarchus
    (b) Erathosthenes
    (c) Ptolemy
    (d) Copernicus
31. Why are Kepler, Brahe, and Newton referred to as astrophysicists?
32. What are some of the possible effects the Sun can have on Earth and its environment?
33. What is the chromosphere?
34. Earth-based telescopes and satellites in space observe solar storms very carefully. How can storms on the Sun affect people on Earth?
35. Imagine that a new planet has been discovered between Mercury and Venus. Describe the characteristics you would expect this planet to have.
36. Explain how the Moon is thought to have formed.
37. What is the difference between an asteroid and a comet?
38. What type of research is being done on the International Space Station?
39. What are some of the design considerations that have to be considered when developing a space suit for astronauts?
40. Why does it make more sense to try to land a rover on the moon of an outer planet than on the planet itself?
41. (a) How are probes, satellites, and rovers similar?
    (b) How are they different?
42. (a) Which of the events below occurred first?
    A. formation of galaxies
    B. formation of the solar system
    C. formation of the universe
    (b) Which event occurred most recently?
43. Astronomers believe that the universe is expanding. What does this statement mean?
44. Is space empty? Explain.
45. Compare the life spans of low mass stars, intermediate mass stars, and high mass stars.
46. What are the brightest objects we can see in the universe?
47. Telescopes in space allow astronomers to gather information about space. Compare the types of observations that can be made by the following types of telescopes:
    (a) Hubble Space Telescope compared to Spitzer Space Telescope
    (b) Chandra X-ray Observatory compared to Fermi Gamma-ray Space Telescope
    (c) Ground observations compared to James Webb Space Telescope

Thinking Critically

48. Human understanding of the Earth and its place in the universe has evolved due to the contributions of many astronomers. Explain the statement, “standing on the shoulders of giants.” Support your answer with examples.
49. Like planets, some comets orbit the Sun in regular periods of time. Why do astronomers not consider comets to be planets?
50. Imagine a group of people who want to colonize a moon of Jupiter. Describe three problems they would need to overcome to be successful.
51. Give examples of how Canada has contributed to space exploration.
52. An astronomer is using parallax to calculate the distances between Earth and two stars. The astronomer uses the same reference star for both observations and notices that star A shifts far more than star B.
    (a) What could the astronomer conclude about how the distance from one star compares with the distance to the other star?
    (b) Explain how the astronomer is able to make this conclusion.

Developing Skills

53. The figure below shows a solar system many light-years from ours. Astronomers have classified the five planets as shown and determined their distances from the star they orbit. Astronomers believe there is a sixth planet in the solar system located somewhere in the region marked X.

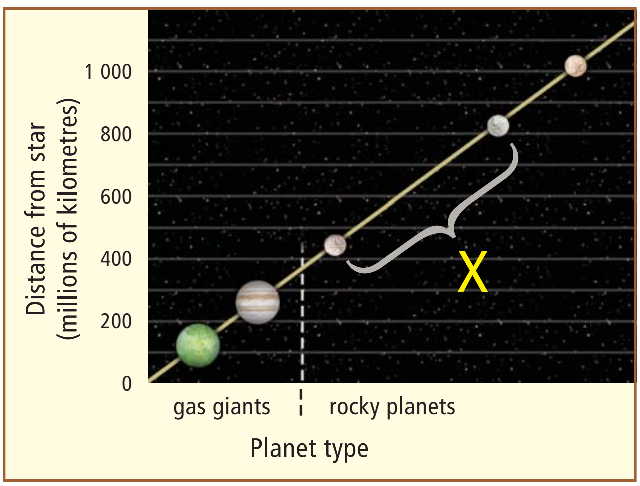
(a) What type of planet would you expect to find in this region?

(b) Explain your answer to (a).

(c) At what distance would you expect the new planet to be found?

(d) Why did you choose this distance?

(e) How is this solar system arrangement different from ours?



54. On Earth, if you drop something it falls to the ground. The rate at which it falls is called the acceleration due to gravity. If you were to drop something while standing on another object in space, the rate of acceleration due to gravity would be different. The table in the next column shows what the mass of a 70 kg person would be if he or she stood on a variety of different objects in space. You can calculate how gravity on Earth compares with gravity on the different objects. The example of Jupiter is provided for you.

Example: How much greater is the gravity on Jupiter than on Earth?

Assume that Earth's gravity = 1.

$$\frac{\text{mass of person on object}}{\text{mass of person on Earth}} = \text{gravity on object compared with gravity on Earth}$$

$$\frac{837\text{ kg}}{70\text{ kg}} = 12$$

(a) Copy the table below into your notebook and calculate the gravity relative to Earth for an asteroid, the Moon, the Sun, and a neutron star.

Object	Mass on Object (kg)	Gravity Relative to Earth
Earth	70.00	1.0
Jupiter	837.00	12
Asteroid	0.05	
Moon	12.00	
Sun	1 913.00	
Neutron star	19 000 000.00	

(b) Explain what factors determine whether the gravity of an object in space will be more or less than the gravity on Earth.

Pause and Reflect

In this unit, you have learned about the solar system, origin of the universe, and exploration of space. Humankind has always dreamed of venturing into space, but since the cost of these travel adventures has been millions of dollars for each excursion, space travel has been available to only a few private citizens. Should the general public be allowed to travel to the International Space Station?