UNIT

4 Space Exploration

Scientists from around the world use the W.M. Keck Observatory in Hawaii. They are working hard to unravel the many mysteries of the universe, including how it formed and how it has changed.

Key Ideas

10 **Scientific evidence suggests the universe formed about 13.7 billion years ago.**

11 **The components of the universe are separated by unimaginably vast distances.**

12 **Human understanding of Earth and the universe continues to increase through observation and exploration.**

Getting Started

Humans have always gazed into space with wonder and a longing to understand what is out there.

Imagine being born and raised on a tiny, remote island in the middle of a large ocean. If you and your neighbours had little ability to travel far from the island, your knowledge of the ocean and what lay beyond the horizon would be limited. You might come to understand the behaviour of the sea life on your island's shores and to notice patterns in the objects in the night sky. However, it would be impossible for you to develop any sense of the world beyond what you could see with your naked eye. Your knowledge would grow only when you had better ways of leaving your island and exploring new areas.

Earth is like an island in the universe, and humans are constantly looking for ways to explore and learn more about the universe and Earth's place in it. Step by step, as our technology has improved, we have increased our ability to get information from places that are very difficult to reach. Most of the time we collect information from Earth with the aid of tools such as telescopes, which help us see objects that lie far away. Over the past century, however, we have also developed the ability to send instruments such as satellites and space probes out into space to collect information for us. Even sending humans off the "Earth island" and into space has become common.

The Dominion Radio Astrophysical Observatory, located near Penticton, B.C., is an example of a facility that enables scientists to study space from Earth. Among the projects carried out at the observatory is that of collecting information about the Milky Way **galaxy**. A galaxy is an enormous collection of gases, dust, and billions of stars all held together

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To learn more about the work being carried out at the Dominion Radio Astrophysical Observatory, visit **www.bcscience9.ca**.

by gravity. A **star** is an object in space, with a spherical shape. Its core is like a furnace, which means that it makes its own thermal energy.

Our Sun is one of the billions of stars that make up the Milky Way. When you look into the sky on a clear night, every single star you see is part of the Milky Way.

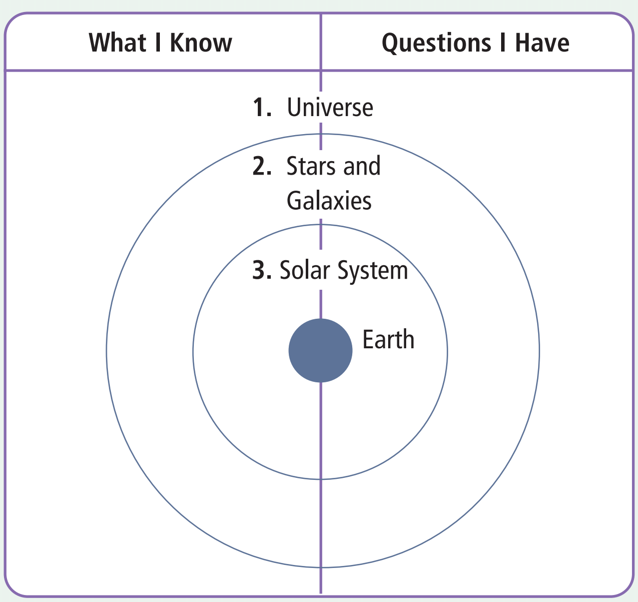
The Dominion Radio Astrophysical Observatory near Penticton, B.C.

What Do You Know about the Universe? Find Out ACTIVITY

The universe contains many different types of objects. How many do you know about? In this activity, you will brainstorm what you know about the universe already and what you would like to learn. The chart you create will help you organize your thoughts as you read through the unit.

Materials

- chart paper
- felt pens



What to Do

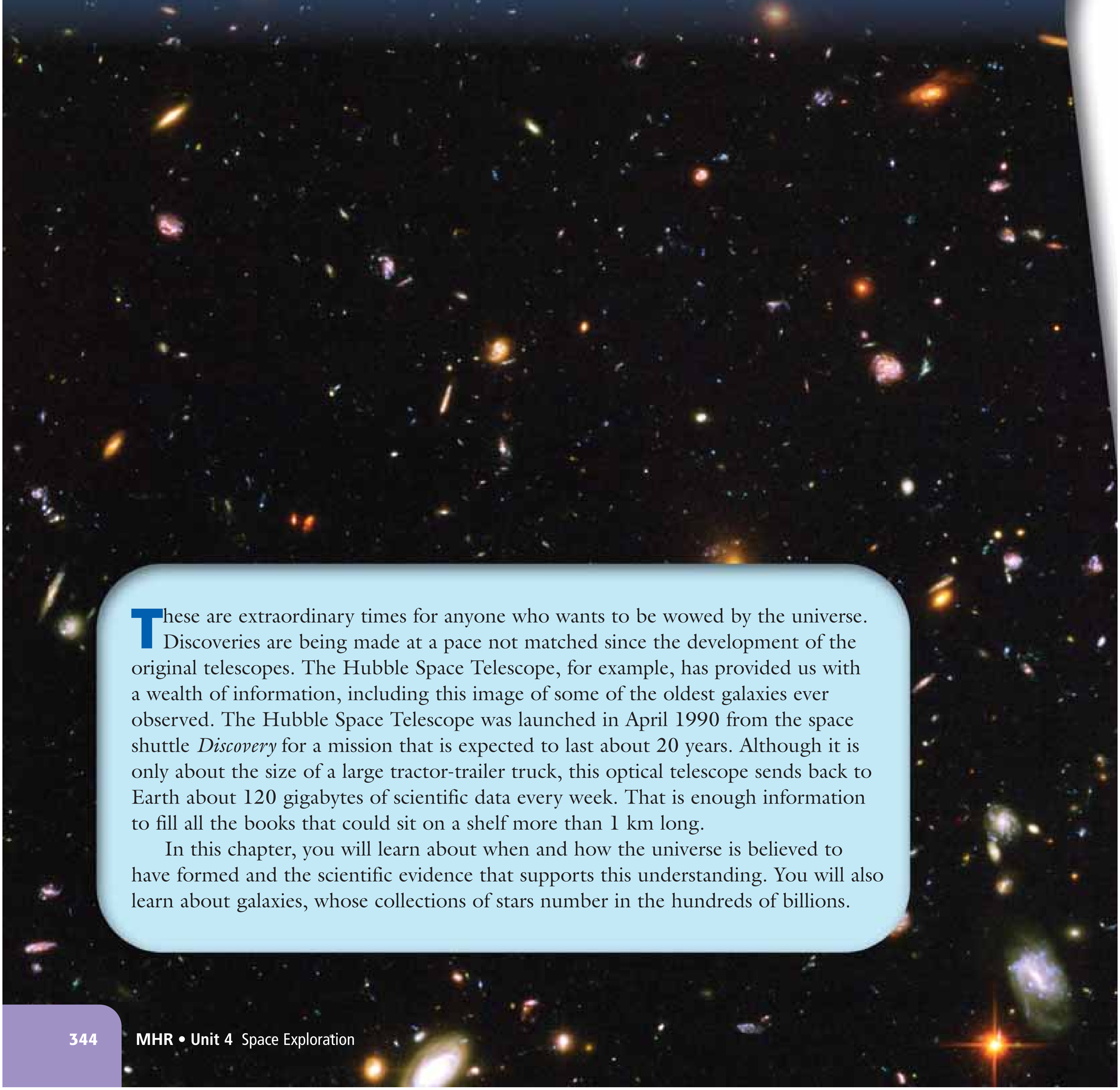
1. Working with a partner or small group, use the chart paper and felt pens to make a graphic organizer like the one shown here.
2. Brainstorm objects you think are found in space. On the graphic organizer under "What I Know," write each object under one of the following three categories: universe, stars and galaxies, or solar system. Try to place the object in the category that best describes its location relative to Earth.
3. Write at least one question per category on the "Questions I Have" section of the graphic organizer.

What Did You Find Out?

1. When you have finished brainstorming, look at another group's graphic organizer and read the objects listed. Discuss with your group any changes or additions you would like to make to your group's organizer.
2. As a class, discuss the different objects identified by the groups.
3. Post your organizer on a wall in the classroom. As you advance through this unit, add new terms about the universe to the organizer.

Chapter 10

Scientific evidence suggests the universe formed about 13.7 billion years ago.



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
- **explain** how astronomers use technologies to advance our understanding of the universe
- **describe** the formation and characteristics of galaxies

Why It Is Important

Gaining a better understanding of the universe's age and formation gives us better insight into the possible origin of everything around us.

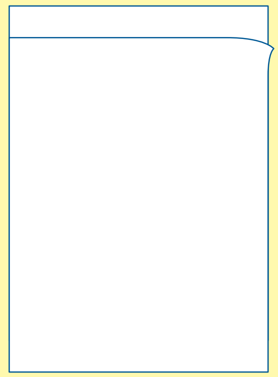
Skills You Will Use

In this chapter, you will
- **model** the expanding universe and the effects of galaxy motion
- **estimate** the number of galaxies in the universe
- **model** the distances separating galaxies
- **simulate** the forces affecting the motion of galaxies

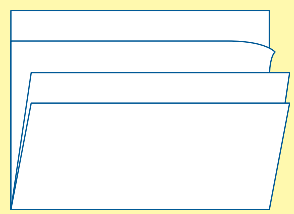
FOLDABLES™ Reading & Study Skills

Make the following Foldable to take notes on what you learn in Chapter 10.

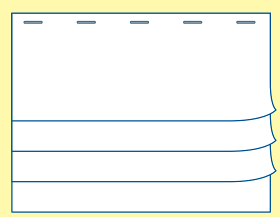
STEP 1 **Stack** two sheets of paper so that the back sheet is about 2.5 cm higher than the front sheet. (**Hint**: From the tip of your index finger to your first knuckle is about 2.5 cm.) **Bring** the bottom of both sheets upward and **align** the edges so that all of the layers or tabs are the same distance apart.



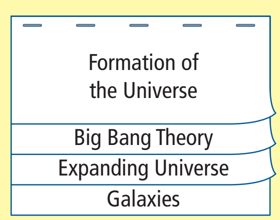
STEP 2 When all tabs are an equal distance apart, **fold** the paper and **crease** well.



STEP 3 **Staple** the papers along the mountain of the fold.



STEP 4 **Label** the Foldable as shown.



Summarize As you read the chapter, summarize what you learn under the appropriate tabs.

10.1 Explaining the Early Universe

Astronomer Edwin Hubble discovered that all galaxies in space are moving away from each other. According to the Big Bang theory, the universe is believed to have begun during an unimaginably rapid expansion of a tiny volume of space, about 13.7 billion years ago. All the matter in the universe is thought to have been created at that moment. Evidence for the Big Bang theory includes observations that show the universe is expanding and the presence of microwave radiation that exists throughout space.

Words to Know

astronomers
Big Bang theory
celestial bodies
cosmological red shift
electromagnetic radiation
red shift
spectroscope

If you were studying space exploration 100 years ago, you would have been told that everything in "outer space" never changes. This was as much as **astronomers** (people who study objects in space) were able to observe by using the best instruments of the time, early telescopes. Astronomers formed theories to explain observations 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. **Celestial bodies** is a general term for all the objects in the sky, including the Sun, Moon, planets, and stars.

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. 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 10.1). Not only that, but the speed at which they were moving apart varied depending on the galaxies'

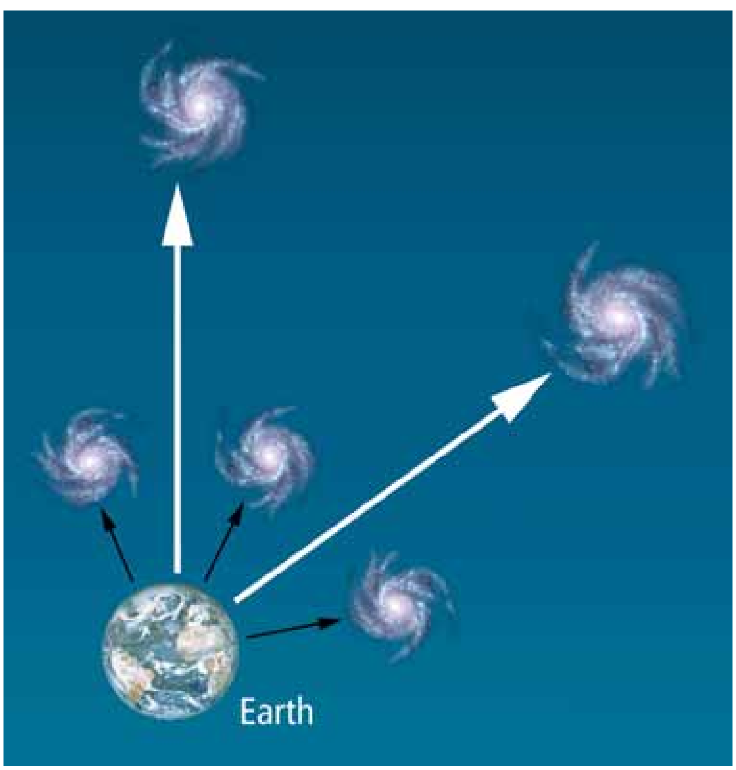


Figure 10.1 Edwin Hubble discovered that galaxies farther from our own Milky Way galaxy were moving away from each other faster than galaxies that are closer to ours. The arrows in the diagram represent the relative velocity (speed and direction) each galaxy is moving.

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.

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 10.2). 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.

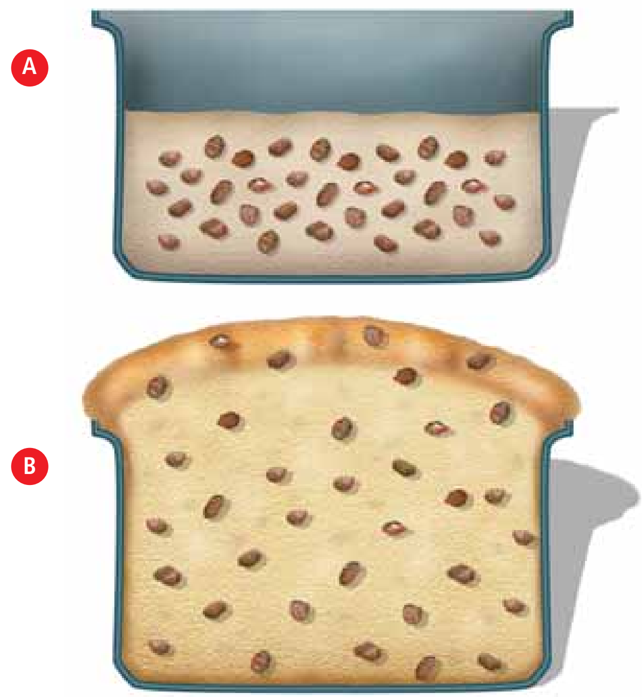


Figure 10.2 The raisins in this uncooked bread dough (A) all move away from each other as the bread bakes (B). In a similar way, galaxies in space are moving away from each other as the universe expands.

10-1A A Model of the Expanding Universe — Find Out ACTIVITY

In this activity, you will create a model that simulates the expanding universe. By observing the motion of dots on an expanding balloon, you will begin to develop an understanding of how objects in the universe appear to move in relation to each other.

Materials

- large, round balloon
- twist-tie
- felt pen

What to Do

1. Working with a partner, inflate the balloon to the point where it just begins to become round. Do not inflate it all the way.
2. Wrap the twist-tie around the balloon's neck to keep it inflated.
3. Using the felt pen, draw four dots on one side of the balloon at least 2 cm away from each other. Label the dot on the bottom right "M." This will represent the galaxy we live in, the Milky Way. Label the other dots "A" through "C." Each of these dots will represent other galaxies in space.
4. Now loosen the twist-tie and inflate the balloon fully. Have your partner observe what happens to the dots.
5. Record the observations in your notebook and draw a diagram of the dots before and after the balloon is inflated for a second time.

What Did You Find Out?

1. Imagine you were located in any of the galaxies (represented by the dots). How would the other galaxies appear to be moving in relation to you?
2. From the Milky Way galaxy, which galaxy appears to be moving away the fastest? Which appears to be moving away the slowest?
3. How is what you observed similar to what Edwin Hubble observed when he was investigating the motion of galaxies?

internet connect

In this section, the expanding universe is likened to a loaf of raisin bread baking in the oven. Find out more about different models of the universe. Start your search at **www.bcscience9.ca.**

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. To understand how this works, first you must understand electromagnetic waves and spectral patterns.

Electromagnetic waves

Visible light is only one type of electromagnetic radiation. **Electromagnetic radiation** is energy that is carried, or radiated, in the form of waves. Other types of electromagnetic radiation include microwaves, radio waves, and X rays. All of these differ in their wavelengths, as shown in Figure 10.3. Many objects in space radiate various forms of energy. Stars and galaxies, for example, radiate light waves, radio waves, and X rays.

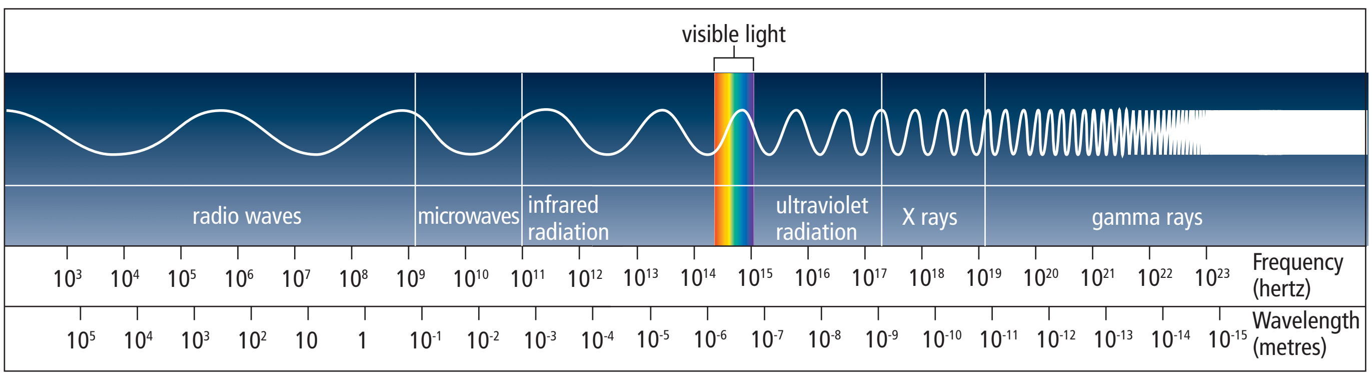


Figure 10.3 Visible light is only one small part of the electromagnetic spectrum. Waves can come in a variety of forms, from the high-energy, short wavelengths of gamma rays to the low-energy, long wavelengths of radio waves.

Spectral patterns

White light splits into bands of rainbow colours when it is passed through a prism (Figure 10.4). Light from a desk lamp and light from the Sun are examples of white light. This pattern of colours is called a **spectrum** (plural: spectra). Each colour of the spectrum represents different wavelengths. Light from distant stars can also be collected by astronomers and then divided into individual spectral patterns. A **spectroscope** is an optical instrument that acts like a prism to separate light into its basic component colours. A spectroscope allows the user to view the spectral lines produced by a light source and to measure their wavelengths.

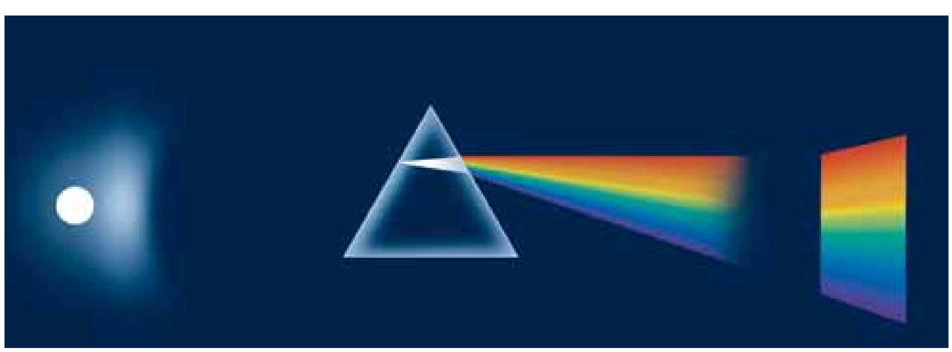


Figure 10.4 When white light shines through a prism, the light separates into a pattern of colours called a spectrum.

Standing out across the bands of colour in a star's spectrum are lines called spectral lines (see Figure 10.5). These lines are created by the elements in a star, which you will learn more about in Chapter 11.

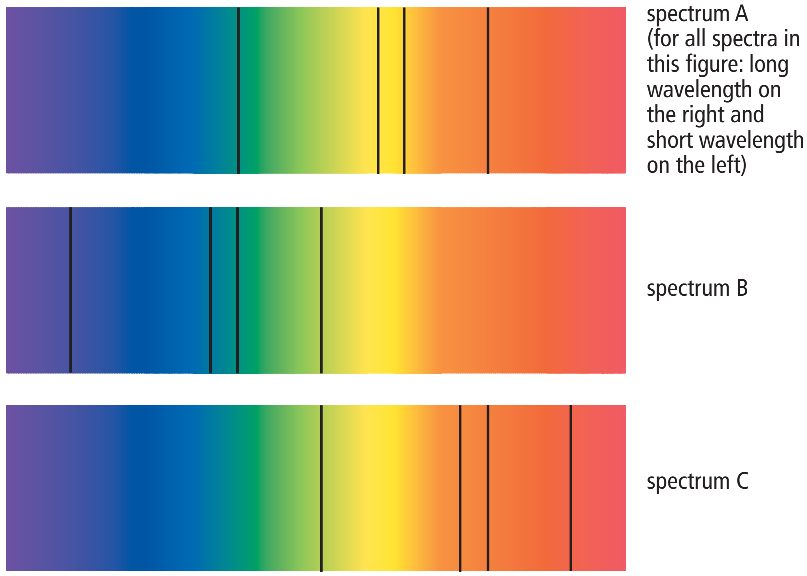


Figure 10.5 Spectrum A shows the spectral pattern in a star or galaxy that is stationary (not moving). Spectrum B shows the blue-shifted spectral pattern that indicates the star or galaxy is moving toward Earth. Spectrum C shows the red-shifted spectral pattern that indicates the star or galaxy is moving 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 10.6). "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 the **cosmological red shift**, and it became the main evidence for a theory that explained the formation of the early universe.

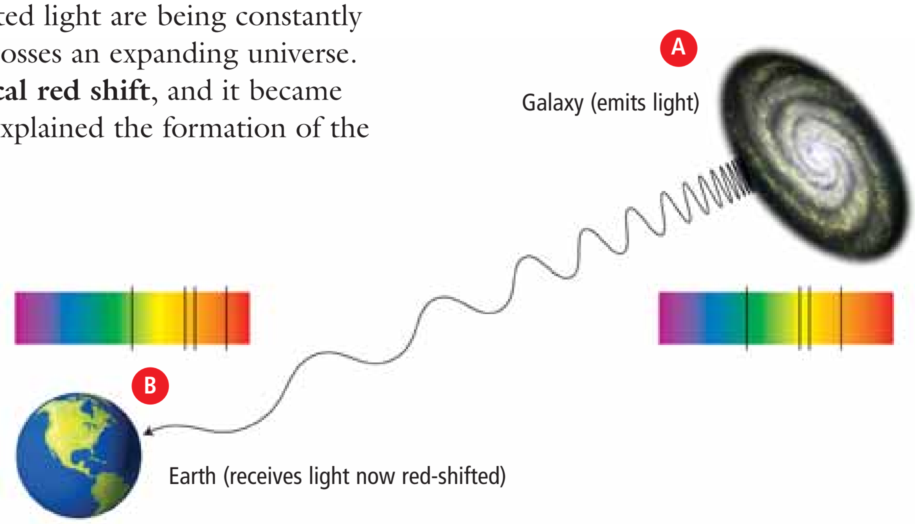


Figure 10.6 As space expands, so do the waves of radiation as they travel from the distant galaxies. When a galaxy at first emitted its electromagnetic waves so long ago, the waves were not red-shifted (A). Only as space expanded did it cause the waves to expand and become red-shifted (B).

Suggested Activity

Find Out Activity 10-1C on page 353

Reading Check

1. What did Edwin Hubble notice about the direction of movement of galaxies in space?
2. What conclusion did Hubble make when he observed that distant galaxies appeared to be moving away from each other?
3. Name four types of electromagnetic radiation.
4. (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?

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.

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 come together to where they began the race at the start line. This 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 Big Bang theory is not the only theory about how and when the universe formed. However, with increasingly better tools developed, researchers are gaining additional evidence to support the Big Bang theory.

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. As you might remember from previous studies, **radiation** is the transmission of energy in waves. 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 10.7). 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.

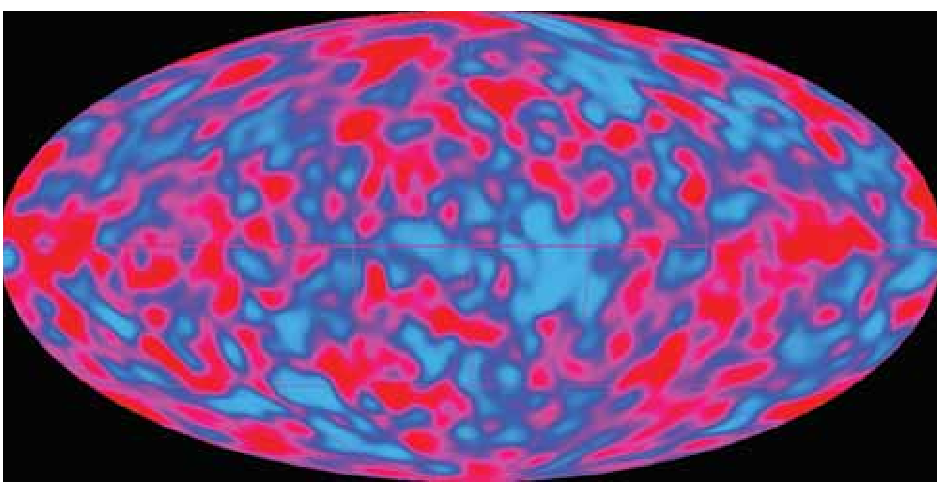


Figure 10.7 The COBE map of cosmic background radiation in the universe. This is the radiation that scientists believe is left over from the Big Bang expansion.

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.

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.

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.bcscience9.ca**.

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 has been mapped, as shown in Figure 10.8. Blue shows the slightly denser regions of the early universe. These, many scientists believe, are the areas 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.

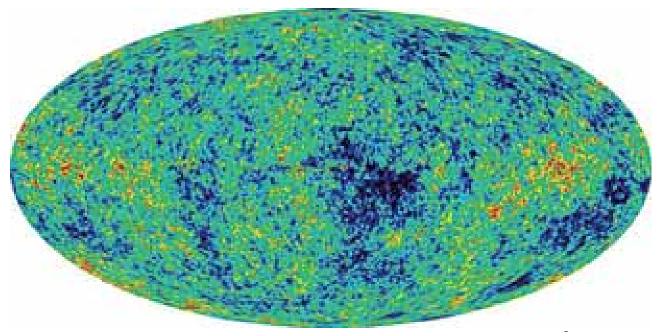


Figure 10.8 The WMAP microwave radiation map of the universe

10-1B The Universe in a Spoonful of Sand — Find Out ACTIVITY

In 1999, measurements taken by the Hubble Space Telescope led astronomers to speculate there were 125 billion galaxies in the universe. A German supercomputer has run simulations that suggest the number could even be as high as 500 billion galaxies. The numbers used to measure quantities in space are enormous. In this activity, you will compare the number of grains of sand in a given volume with the estimated number of galaxies in the universe.

Materials

- 100 mL sand
- one 0.5 mL measuring spoon
- paper
- 1 cm^3 box

What to Do

1. Working with a partner, place 0.5 mL of sand on a piece of paper and divide it in half into two samples. While you count the sand grains in one sample, your partner will count the grains in the other.
2. Add up your two counts. Compare your total with the totals counted by your classmates. Note the range in totals for the same quantity of sand.
3. Count the number of spoonfuls it takes to fill the 1 cm^3 box. Estimate the number of grains in that 1 cm^3 container.

What Did You Find Out?

1. Estimate how many grains of sand would be found in:
   (a) 1 m^3
   (b) a bathtub
   (c) 1 km^3
2. Determine the estimated volume required to hold 500 billion sand grains.
3. Why would it be incorrect to estimate the size of the universe based on the volume of 500 billion galaxies?
4. Why might the estimate of 500 billion galaxies be proven wrong?

10-1C Investigating the Relative Motion of Galaxies in the Expanding Universe

Find Out ACTIVITY

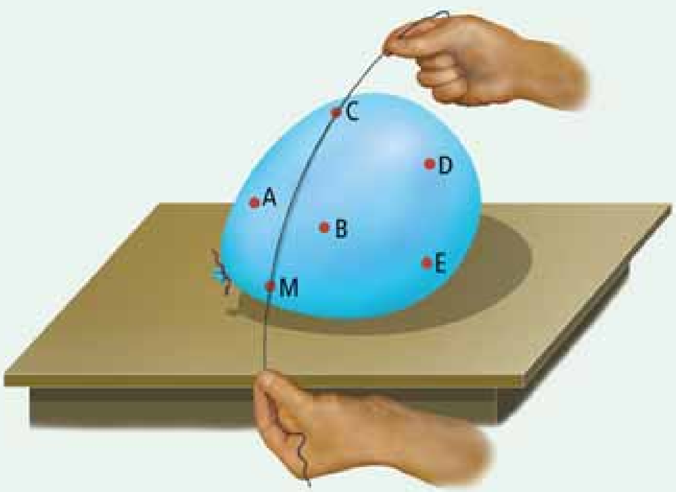
In this activity, you will use a model of the expanding universe to determine the apparent movement of galaxies relative to each other.

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

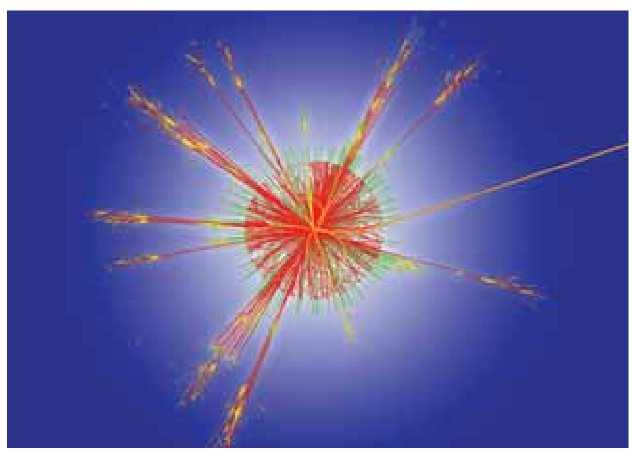
To answer questions such as "How did the universe form the way it did?" scientists have to try to re-create an event that happened billions of years ago. The challenges in doing this are obvious, since no one was there to record or witness it. The next best thing is to simulate small aspects of it.

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 five seconds. 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?

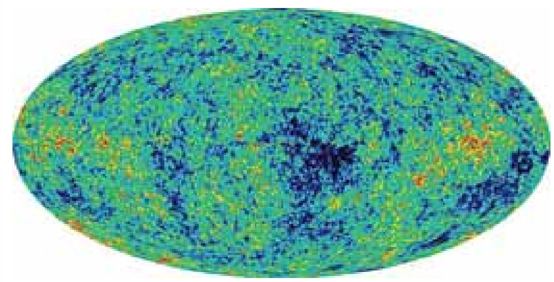
Check Your Understanding

Checking Concepts

1. What did Edwin Hubble discover about the spectra of the galaxies he observed?
2. What do we call radiation 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?

Understanding Key Ideas

8. What evidence did Edwin Hubble use to suggest the universe was expanding?
9. How is a loaf of raisin bread baking in the oven a simple model of Hubble's view of an expanding universe?
10. 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 from Earth?
11. How does the pattern shown in the WMAP map indicate that the presence of microwave radiation in the universe is not the same everywhere?



12. (a) How does cosmic background radiation provide evidence for the Big Bang theory of the origin of the universe?
    (b) Why is cosmic background radiation important in the study of the formation of galaxies?

Pause and Reflect

By studying the nature of space, we can get a better understanding of how the universe is organized, as well as how it first began. The difference in the COBE and WMAP data shows how new technology has advanced our scientific understanding of space. How have advances in technology for observing space further improved our understanding of the structure and formation of the universe?