

# Galaxies and the Universe

## As You Read

### What You'll Learn

- Identify the three main types of galaxies.
- List several characteristics of the Milky Way Galaxy.
- Describe evidence that supports the Big Bang theory.

### Vocabulary

galaxy  
Big Bang theory

### Why It's Important

Studying the universe could help scientists determine whether life is possible elsewhere.

## Galaxies

Long ago, people believed that Earth was the center of the universe. Today you know that the Sun is the center of the solar system. But where is the solar system in relation to the galaxy? Where is the galaxy located in the universe?

You are on Earth, and Earth orbits the Sun. Does the Sun orbit anything? How does it interact with other objects in the universe? The Sun is one star among many in a **galaxy**—a large group of stars, gas, and dust held together by gravity. The galaxy in which Earth is found is called the Milky Way. It might contain as many as one trillion stars, including the Sun. Galaxies are separated by huge distances—often millions of light-years.

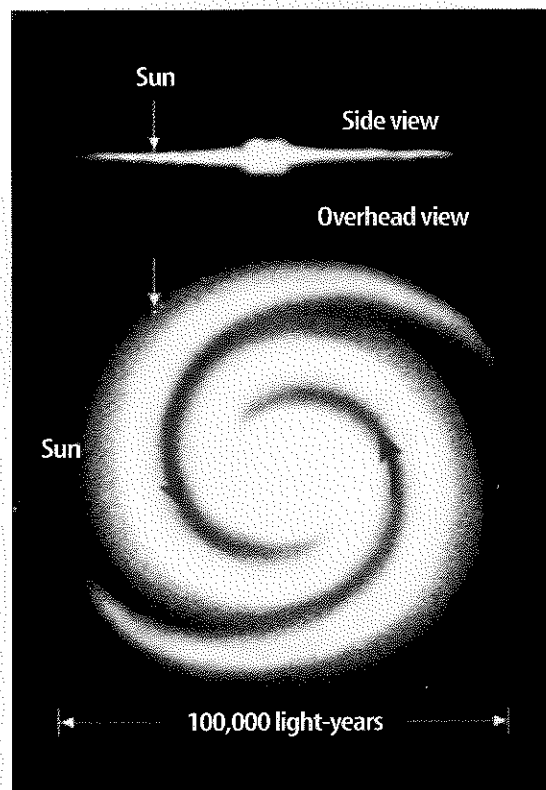
In the same way that stars are grouped together within galaxies, galaxies are grouped into clusters. The cluster that the Milky Way belongs to is called the Local Group. It contains more than 30 galaxies of various sizes and types. The three major types of galaxies are spiral, elliptical, and irregular.

**Spiral Galaxies** The Milky Way is a spiral galaxy, as shown in **Figure 16**. Notice that spiral galaxies have spiral arms that wind outward from inner regions. These arms are made up of bright stars and dust. The fuzzy patch seen in the constellation of Andromeda is a spiral galaxy. It's so far away that you can't see its individual stars. Instead, its combined light appears as a hazy spot in the sky. The Andromeda Galaxy is about 2 million light-years away and is a member of the Local Group.

Arms in a normal spiral start close to the center of the galaxy. Barred spirals have spiral arms extending from a large bar of stars and gas that passes through the center of the galaxy.

**Figure 16**

This illustration shows a side view and an overhead view of the Milky Way. What group of galaxies is the Milky Way part of?



**Elliptical Galaxies** A common type of galaxy is the elliptical galaxy. **Figure 17** shows an elliptical galaxy in the constellation Andromeda. These galaxies are shaped like large, three-dimensional ellipses. Many are football shaped, but others are round. Some elliptical galaxies are small, while others are so large that several galaxies the size of the Milky Way would fit inside one of them.

**Irregular Galaxies** The third type—an irregular galaxy—includes most of those galaxies that don't fit into the other classifications. Irregular galaxies have many different shapes. They are smaller than the other types of galaxies. Two irregular galaxies called the Clouds of Magellan orbit the Milky Way. The Large Magellanic Cloud is shown in **Figure 18**.

### Reading Check

How do the three different types of galaxies differ?

## The Milky Way Galaxy

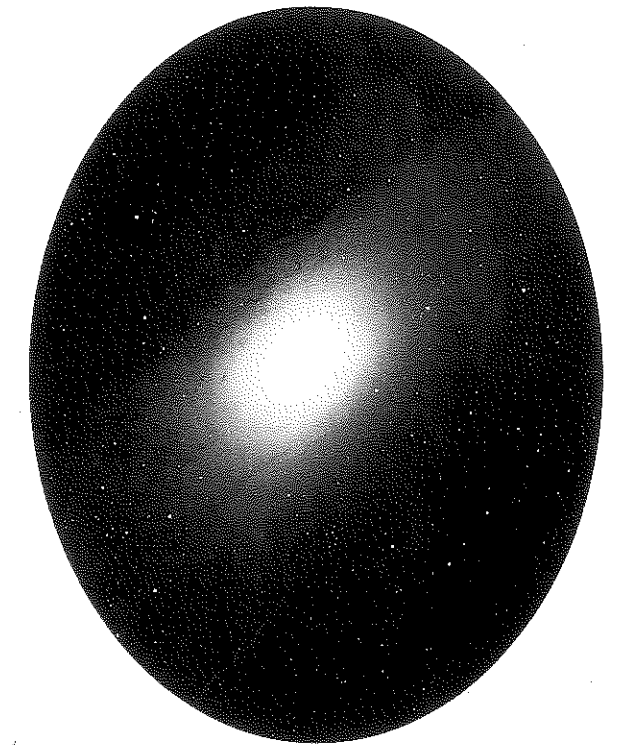
The Milky Way might contain one trillion stars. The visible disk of stars shown in **Figure 16** is about 100,000 light-years across. Find the location of the Sun. Notice that it is located about 30,000 light-years from the galaxy's center in one of the spiral arms. In the galaxy, all stars orbit around a central region, or core. Based on a distance of 30,000 light-years and a speed of 235 km/s, the Sun orbits the center of the Milky Way once every 240 million years.

The Milky Way usually is classified as a normal spiral galaxy. However, some evidence suggests that it might be a barred spiral. It is difficult to know for sure because astronomers have limited data about how the galaxy looks from the outside.

You can't see the normal spiral or barred shape of the Milky Way because you are located within one of its spiral arms. You can, however, see the Milky Way stretching across the sky as a misty band of faint light. You can see the brightest part of the Milky Way if you look low in the southern sky on a moonless summer night. All the stars you can see in the night sky belong to the Milky Way.

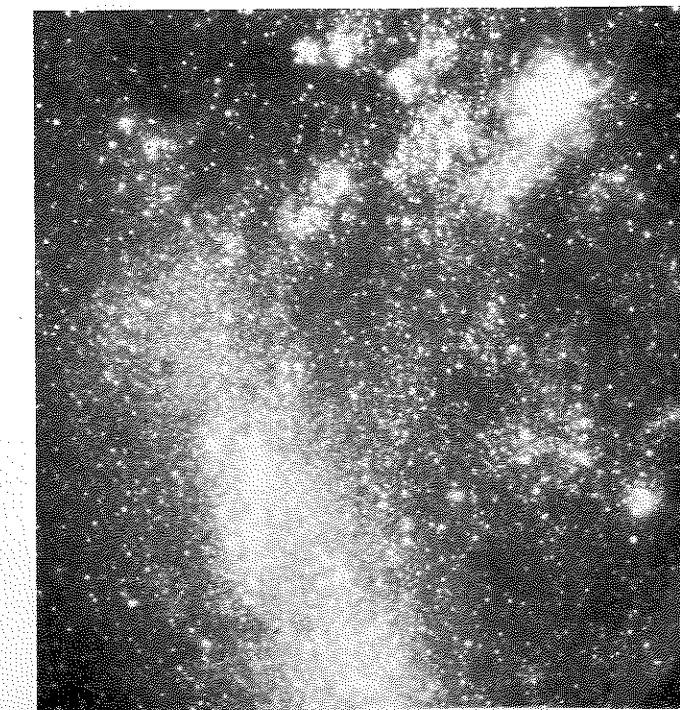
**Figure 17**

This photo shows an example of an elliptical galaxy. What are the two other types of galaxies?



**Figure 18**

The Large Magellanic Cloud is an irregular galaxy. It's a member of the Local Group, and it orbits the Milky Way.



## Mini LAB

### Measuring Distance in Space

#### Procedure

1. On a large sheet of paper, draw an overhead view of the Milky Way. If necessary, refer to **Figure 16**. Choose a scale to show distance in light-years.
2. Mark the approximate location of the solar system, which is about two thirds of the way out on one of the spiral arms.
3. Draw a small circle around the Sun indicating the 4.3 light-year distance of the next-closest star to Earth, Proxima Centauri.

#### Analysis

1. What scale did you use to represent distance on your model of the Milky Way?
2. At this scale, interpret how far away the next-closest spiral galaxy—the Andromeda Galaxy—would be.

## Origin of the Universe

People have long wondered how the universe formed. Several models of its origin have been proposed. One model was the steady state theory. It proposed that the universe always has been the same as it is now. The universe always has existed and always will. As matter in the universe expands outward, new matter is created to keep the overall density of the universe the same or in a steady state. However, evidence indicates that the universe was much different in the past from what it is today.

A second idea is called the oscillating model. In this model, the universe began with expansion occurring in all areas of the universe. Over time, the expansion slowed and the matter in the universe contracted. Then the process began again—repeating over and over, oscillating back and forth.

Neither of these theories can be proven or disproven, but evidence suggests that a third idea is more likely to be correct. The universe started with a big bang and has been expanding ever since. This theory will be described later.

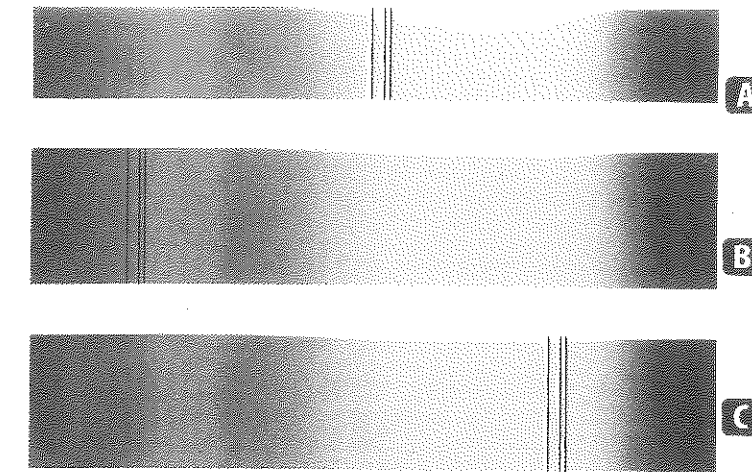
## Expansion of the Universe

What does it sound like when a train is blowing its whistle while it travels past you? The whistle has a higher pitch as the train approaches you. Then the whistle seems to drop in pitch as the train moves away. This effect is called the Doppler shift. The Doppler shift occurs with light as well as with sound. **Figure 19** shows how the Doppler shift causes changes in the light coming from distant stars and galaxies. If a star is moving toward Earth, its wavelengths of light are compressed. If a star is moving away from Earth, its wavelengths of light are stretched.

**The Doppler Shift** Look at the spectrum of a star in **Figure 20A**. Note the position of the dark lines. How do they compare with the lines in **Figures 20B** and **20C**? They have shifted in position. What caused this shift? As you just read, when a star is moving toward Earth, its wavelengths of light are compressed, just as the sound waves from the train's whistle are. This causes the dark lines in the spectrum to shift toward the blue-violet end of the spectrum. A red shift in the spectrum occurs when a star is moving away from Earth. In a red shift, the dark lines shift toward the red end of the spectrum.

**Red Shift** In 1929, Edwin Hubble published an interesting fact about the light coming from most galaxies. When a spectrograph is used to study light from galaxies beyond the Local Group, a red shift occurs in the light. What does this red shift tell you about the universe?

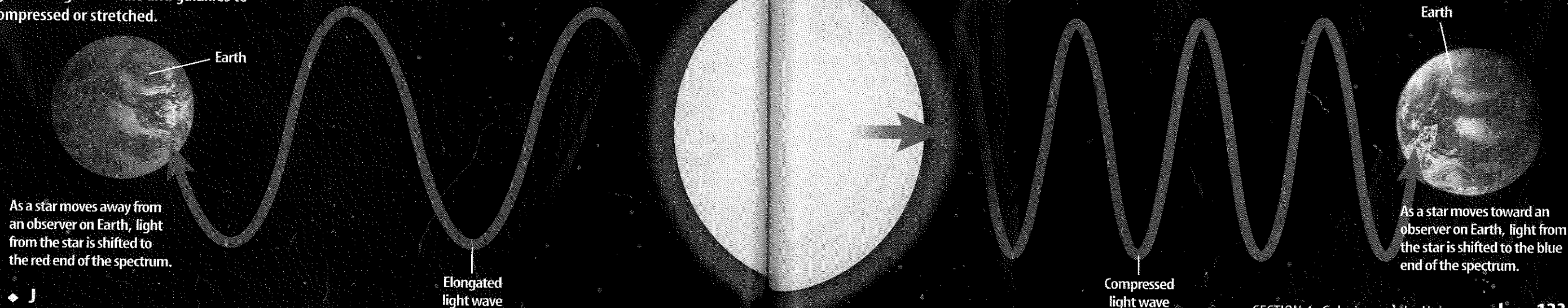
Because all galaxies beyond the Local Group show a red shift in their spectra, they must be moving away from Earth. If all galaxies outside the Local Group are moving away from Earth, then the entire universe must be expanding. Remember the Explore Activity at the beginning of the chapter? The dots on the balloon moved apart as the model universe expanded. Regardless of which dot you picked, all the other dots moved away from it. In a similar way, galaxies beyond the Local Group are moving away from Earth.



**Figure 20**

**A** This spectrum shows dark absorption lines. **B** The dark lines shift toward the blue-violet end for a star moving toward Earth. **C** The lines shift toward the red end for a star moving away from Earth.

**Figure 19**  
The Doppler shift causes the wavelengths of light coming from stars and galaxies to be compressed or stretched.



As a star moves away from an observer on Earth, light from the star is shifted to the red end of the spectrum.

As a star moves toward an observer on Earth, light from the star is shifted to the blue end of the spectrum.

Figure 21

The Big Bang theory states that the universe probably began 12 billion to 15 billion years ago with an enormous explosion. Even today, galaxies are rushing apart from this explosion.

**A** Within fractions of a second of the initial explosion, the universe grew from the size of a pinhead to 2,000 times the size of the Sun.

**B** By the time the universe was one second old, it was a dense, opaque, swirling mass of elementary particles.

**C** Matter began collecting in clumps. As matter cooled, hydrogen and helium gases formed.

**D** More than a billion years after the initial explosion, the first stars were born.

## The Big Bang Theory

When scientists determined that the universe was expanding, they realized that galaxy clusters must have been closer together in the past. The leading theory about the formation of the universe, called the **Big Bang theory**, is based on this explanation. **Figure 21** illustrates the Big Bang theory. According to this theory, approximately 12 billion to 15 billion years ago, the universe began with an enormous explosion. The entire universe began to expand everywhere at the same time.

**Looking Back in Time** The time-exposure photograph shown in **Figure 22** was taken by the *Hubble Space Telescope*. It shows more than 1,500 galaxies at distances of more than 10 billion light-years. These galaxies could date back to when the universe was no more than 1 billion years old and are in various stages of development. One astronomer says humans might be looking back to a time when the Milky Way was forming. Studies like this eventually will allow astronomers to determine the approximate age of the universe.

Whether the universe will expand forever or stop expanding is still unknown. If enough matter exists, gravity might halt the expansion, and the universe will contract until everything comes to a single point. However, recent studies of distant supernovas indicate that some energy might be causing the universe to expand faster. If this is correct, the universe might expand forever.

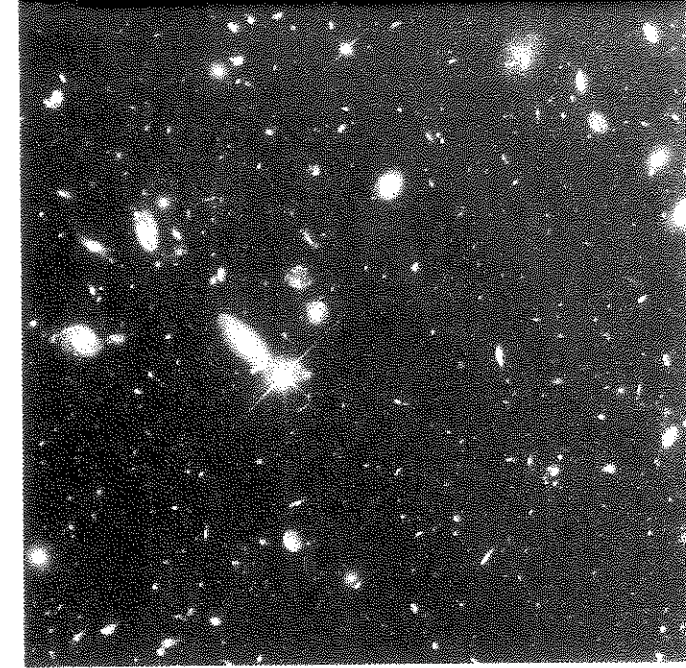


Figure 22  
The light from the galaxies in this photo mosaic took billions of years to reach Earth.

## Section 4 Assessment

1. List the three major types of galaxies. What do they have in common?
2. What is the name of the galaxy that you live in? What motion do its stars exhibit?
3. What is the Doppler shift?
4. How far away are the most distant galaxies?
5. **Think Critically** All galaxies outside the Local Group show a red shift. Within the Local Group, some galaxies show a red shift and some show a blue shift. What does this tell you about the galaxies in the Local Group?

### Skill Builder Activities

6. **Comparing and Contrasting** Compare and contrast the three models of the origin of the universe. For more help, refer to the *Science Skill Handbook*.
7. **Communicating** Research and write a report in your Science Journal about the most recent evidence supporting or disputing the Big Bang theory. Describe how the Big Bang theory explains observations of galaxies made with spectrometers. For more help, refer to the *Science Skill Handbook*.