10.2 Galaxies

A galaxy is a collection of stars, gas, and dust held together by gravity. Astronomers estimate that at least 125 billion of these structures exist. Galaxies occur in three basic shapes: spiral, elliptical, and irregular. The Milky Way galaxy, where our Sun is located, is a spiral galaxy. Just as gravitational force pulls stars together to form a galaxy, so it pulls individual galaxies together into galaxy clusters and those clusters into even larger clusters.

Words to Know

elliptical galaxy
irregular galaxy
nebula
spiral galaxy
star cluster

Every star you see in the sky on a clear night is part of the Milky Way (Figure 10.9). 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.

Word Connect

The word "galaxy" comes from the ancient Greek word for milk, *galaktos*. Suggest why the ancient Greeks chose that word to describe what they saw in the night sky.

Figure 10.9 Astronomers estimate that our galaxy, the Milky Way, is almost as old as the estimated age of the universe.

10-2A Matter in Motion

Find Out ACTIVITY

Astronomer Edwin Hubble determined that there were many galaxies other than our own Milky Way. He was also one of the first astronomers to classify galaxies based on their shape. In this activity, you will model the rotational motion of galaxies using different materials to simulate stars.

Materials

- 600 mL beaker
- water
- medicine dropper
- small samples of food colouring, cocoa powder, and powdered milk

What to Do

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

Material	Sketch of Pattern		
	First rotation	Slower rotation	Faster rotation
Powdered milk			
Cocoa powder			
Food colouring			

2. Fill the beaker approximately half full with water.
3. Carefully holding the beaker in one hand, lift it up and make the water inside swirl by slowly moving the beaker in small circles.
4. With the water still swirling, place the beaker on a table and carefully squeeze a few drops of food colouring onto the centre of the water surface.
5. Observe what happens and immediately sketch your observations in the table while the water is still swirling.
6. Discard the water and repeat steps 2 to 4 two times, first swirling the water more slowly than before and then swirling it faster than before.
7. Repeat steps 2 to 6 for each of the dry materials, adding a pinch of each to the water.

Step 4

What Did You Find Out?

1. How did the different materials react once dropped in the swirling water?
2. Did any material behave differently than the others? Explain.
3. How does changing the speed of rotation affect the pattern you observed?
4. How is this activity similar to galaxy motion?

The Number of Galaxies in the Universe

For a long time, astronomers thought that our galaxy was the only one in the universe. A discovery by Edwin Hubble in 1925 changed such thinking. While observing what he thought was just a bright **nebula**, a cloud of gas and dust, Hubble realized that in fact he was looking into an enormous collection of individual stars. He had identified another galaxy, the one now named Andromeda. It is our nearest neighbouring galaxy.

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.

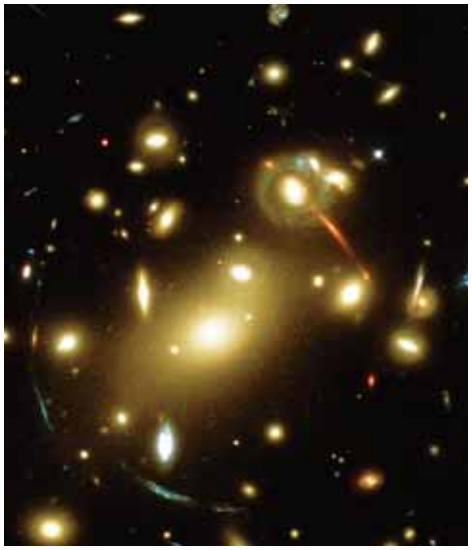


Figure 10.10 Galaxy cluster Abell 2218 shines brightly in this image, with many other galaxies visible farther behind it.

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 10.10. 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 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 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.

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" spiralling out from a centre core (Figure 10.11). 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 10.12). 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 10.13). 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 10.14). These galaxies are made up of a mix of newly forming stars and old stars.

Figure 10.11 A spiral galaxy as it looks from above

Figure 10.12 A spiral galaxy as it looks from the side

Figure 10.13 An elliptical galaxy

Figure 10.14 An irregular galaxy

Other Differences Between Galaxies

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.

In size, for example, some galaxies grow into supergiants whereas others remain relatively small and are classified as dwarfs. Think of the size of a Hula Hoop® relative to the size of a CD. In spin, how fast a galaxy revolves determines its overall shape. The more spin a galaxy has, the flatter it will be.

Most galaxies also contain two types of distinct formations of stars, called **star clusters**. One type is a globular cluster, which is composed of as many as 1 million stars, held together by their mutual gravity in a spherical shape (Figure 10.15).

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."

Figure 10.15 Globular clusters of stars are present around the central region of the Milky Way.

internet connect

In addition to the three main types of galaxies, there are several other subcategories. Learn more about the variety and shapes of galaxies by visiting **www.bcscience9.ca**.

The other type of star cluster is known as an open cluster. Open clusters contain from a few hundred to a few tens of thousands of stars (Figure 10.16).

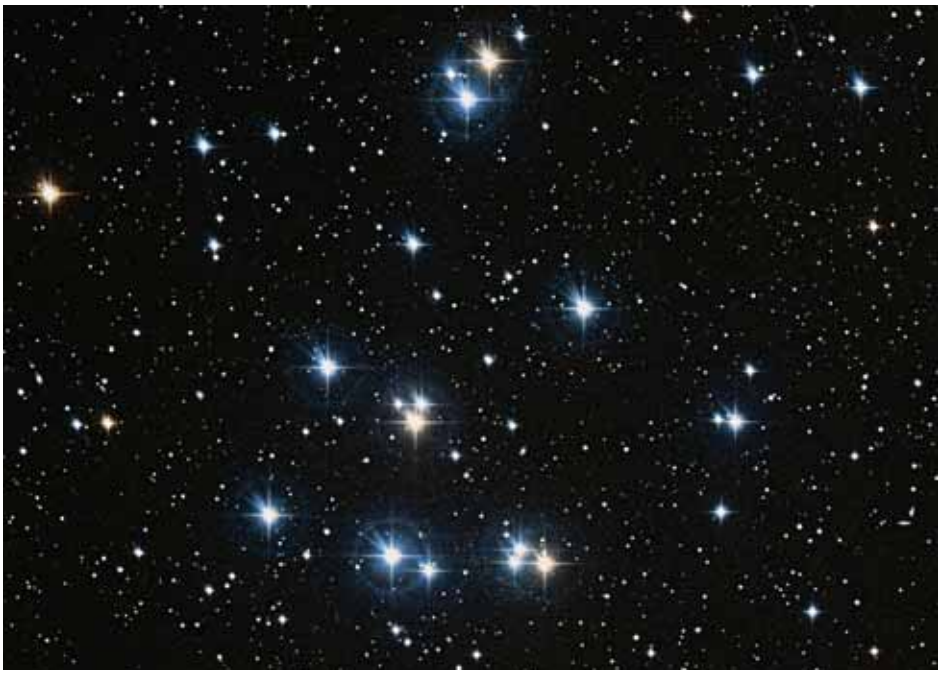


Figure 10.16 An example of an open cluster of stars

10-2B Modelling Galactic Distances

Find Out ACTIVITY

In this activity, you will interpret one means of modelling the incredible distances between galaxies.

Materials

- map of your school and the immediate vicinity, with scale
- map of your local region

What to Do

1. Copy the table below onto a piece of paper.

Galaxy	Distance (m)	Landmark
Magellanic Clouds	1.6	
Andromeda Galaxy	20.0	
Magellanic Galaxy NGC 2366	100.0	
Sombrero Galaxy	300.0	
Antennae Galaxies	630.0	
Cartwheel Galaxy	5 000.0	
Galaxies in the Hubble Deep Field	120 000.0	

2. Determine and record a landmark for each of the distances to the galaxies listed. Use your desk to represent Earth, the starting point. For instance, a galaxy 5 m away may equal the distance from your desk to the classroom door. (The distances shown in metres in the table represent much greater distances in reality, but they are correct relative to each other.)
3. Complete the table using the map to find landmarks at greater distances.

What Did You Find Out?

1. Does your scale model suggest any pattern to the distances of galaxies? Explain your answer.
2. Why would it be difficult to construct a scale model by pacing off these distances?

10-2C Galaxy Grazing

Conduct an INVESTIGATION

Inquiry Focus

SkillCheck

- Modelling
- Controlling variables
- Evaluating information
- Working co-operatively

Galaxies can interact with each other in many different ways, but gravity usually plays an important role in these interactions. In this investigation, you will simulate the interaction between galaxies by observing the nature of collisions between two magnetic objects.

Question

In what ways can galaxies interact with each other?

Materials

- two magnetic marbles

Procedure

1. Copy the table below into your notebook. Give your table a title.

Trial	Speed (fast/medium/slow)	Path of the Rolling Marbles	Interaction Between the Marbles	Sketch of Results
1				
2				
3				
10				

2. Find an open area of floor or a clean table. Working with a partner, position yourselves about 1 m apart on the floor or across the table. Each of you should be holding a marble.
3. Starting at the same time, roll the marbles toward each other and observe what happens. This will be your first trial. In the table, record the details of each trial and what you observed.
4. Repeat step 3 for each additional trial. Each time, try altering the speed and angle of collision.

Analyze

1. State the most common interaction between the marbles at a:
   (a) fast speed (b) slow speed
2. What occurred when the marbles hit each other directly?
3. What was the most important factor affecting the interaction between the marbles?
4. How would your results change if the marbles were the size of tennis balls?

Conclude and Apply

1. Describe at least three different interactions that you observed between the marbles.
2. Which interaction do you think most resembles the interaction between galaxies?
3. Describe two factors that affect the interaction between galaxies.
4. How are the forces of magnetism and gravity
   (a) similar? (b) different?

www Science

Is Anybody Out There?

Life on Earth seems to exist everywhere. Scientists are constantly discovering new species of organisms on this planet in places no one had previously imagined anything could live. We now know there is life beneath the frozen land mass of Antarctica, inside sulphur deposits several kilometres underground, and even in the superheated water in the cracks of rock surrounding volcanic magma chambers.

The ingredients that create organic molecules on Earth have recently been found in gas clouds in space. Discovering this has encouraged many people to search for extraterrestrial life—that is, life beyond Earth. Astrobiologists study the possibility that extraterrestrial life exists. They suggest that if life can be found in the most hostile environments on Earth, there is a good chance it can be found in environments on other planets, inside and outside of our solar system.

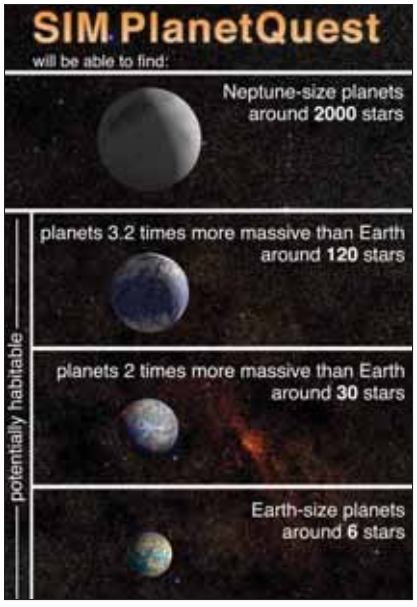
The Arecibo Observatory radio telescope is almost as wide as three football fields and can "listen" for signals from space.

Italian physicist Enrico Fermi proposed that if intelligent life exists in the universe, we should be able to detect it. The Search for Extraterrestrial Intelligence, or SETI, is an organization dedicated to looking for evidence of life in the universe. Several associations around the world are involved in the search.

Recall that many objects in space produce electromagnetic radiation of various forms, including radio waves, gamma rays, and X rays. Observers are therefore looking for any type of signal not produced by a source or for a reason they can otherwise explain. Giant radio telescopes, such as the Arecibo Observatory in Puerto Rico (shown at left), scan the sky in search of signals that stand out from the background radiation of the universe. To date, there have been a number of interesting signals but no actual detections.

Evidence of life can come in more forms than just radio signals. All the life forms on Earth are made from carbon-based molecules. Water provides an excellent environment in which organisms with a carbon-based chemistry can grow. For this reason, astronomers are searching for any celestial body that contains water. In addition, they are interested in studying the atmosphere of planets beyond Earth to look for telltale signs of life. Carbon dioxide is a product of cellular respiration, and oxygen is a product of photosynthesis. If these gases are found in the atmosphere of a planet, it may indicate the presence of some form of life.

Astronomers have already detected more than 200 planets revolving around stars thousands of trillions of kilometres away from us. Although most of these planets are very massive, a few have masses similar to Earth's.



An artist's impression of the type of other Earth-like planets astronomers are searching for.

Check Your Understanding

Checking Concepts

1. What is a nebula?
2. What is the difference between a nebula and a galaxy?
3. List the three basic shapes of galaxies.
4. What characteristics do all galaxies share?
5. What do we call stars that are bunched together in part of a galaxy?

Understanding Key Ideas

6. Even if humans had a spaceship that could travel at the speed of light, it is unlikely they would ever travel across our galaxy. Explain.
7. Not every star visible from Earth has a name. Why not?
8. Earth is located in one of the arms of the spiral galaxy, the Milky Way. How do you think the appearance of the night sky would differ if our location were much closer to the centre of the galaxy?
9. How does the speed at which a galaxy rotates affect its shape?
10. Besides shape, what other ways do galaxies differ from each other?
11. Does the statement "Galaxies would not exist if it were not for nebulas" make sense? Explain.
12. The image below shows the bright galaxy cluster Abell 2218 and the hundreds of other galaxies in this region of space. Explain what a galaxy cluster is and what causes it to form.

Pause and Reflect

You have learned in this section that galaxies are accumulations of millions or billions of stars held together by gravitational force. Do you think it is possible that another environment like Earth's exists in another galaxy?

Prepare Your Own Summary

In this chapter, you have investigated how a variety of technologies and scientific processes have advanced our understanding about the formation and evolution of the universe. Create your own summary of key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 12 for help with using graphic organizers.) Use the following headings to organize your notes.

1. The Origin of the Universe
2. Evidence for the Big Bang
3. The Formation of Galaxies
4. Types of Galaxies

Checking Concepts

1. What name has been given to the main theory today about how the universe formed?
2. What do astronomers use spectroscopes for?
3. What is the cosmological red shift?
4. How long do scientists believe the universe has been expanding?
5. What force holds the billions of stars in a galaxy together?
6. What did Edwin Hubble notice about the direction of travel of distant galaxies that led him to propose that the universe is expanding?
7. Astronomers say the light from distant galaxies is red-shifted. What does red shift mean?
8. List the following in order of size, from smallest to largest:
   universe
   nebula
   galaxy
   star
9. What kind of galaxy is the Milky Way?
10. What is the name of each of the different types of galaxies shown below?

A

B

C

Understanding Key Ideas

11. Defend the statement "Earth in space is like a small island in a large ocean."
12. Evidence shows that the early universe had tremendously high temperatures. Why was it necessary that the universe cool down before planets could form?
13. What do astronomers suggest is the cause of cosmic background radiation?
14. What evidence led Hubble to believe the universe was expanding?
15. How is an inflating balloon similar to the expanding universe?
16. 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?
17. How is the shape of a spiral galaxy different from that of an elliptical galaxy?
18. Galaxy collisions, like the one shown in the image below, are common in the universe. Explain why, when galaxies collide, the stars they contain rarely hit one another.

Pause and Reflect

How have the models used throughout this chapter helped you better understand various aspects about the formation and nature of the universe?