Key Terms

Milky Way
galaxy
star cluster
open cluster
globular cluster
Local Group
supercluster

9.1 Galaxies

If you have viewed the night sky far from city lights, you have probably seen the Milky Way. On very clear nights, you can see the bright and dark areas shown in **Figure 9.1**. The **Milky Way** is a galaxy, and it includes the solar system. A **galaxy** is a collection of stars, gas, dust, and planets held together by gravity. Brightest in the summertime, the Milky Way appears as a hazy white band extending from the southern horizon and across the sky overhead. The ancient Greeks gave the Milky Way its name. They imagined that the white band was milk, spilled by the goddess Hera while she was feeding her son Heracles.

Milky Way the galaxy that includes the solar system; appears as a hazy white band in the night sky

galaxy a huge collection of stars, planets, gas, and dust that is held together by gravity

The Discovery of Galaxies

William Herschel (1738–1822) was a multi-talented British astronomer. He discovered the planet Uranus, and he coined the word *asteroid*. He and his sister, Caroline, were famous for building and selling fine telescopes. When William Herschel pointed one of his best telescopes at the Milky Way around 1780, he expected to see fuzzy white clouds. He was astonished to see a huge number of stars. Larger telescopes showed even more stars. Herschel had discovered that the Milky Way is a gigantic system of stars that we know today as a galaxy. Every star that you see in the sky on a clear night is part of the Milky Way.

Figure 9.1 In a dark sky on a clear night, the Milky Way looks like a band of white in the night sky.

The Shapes of Galaxies

A galaxy forms when gravity causes a large, slowly spinning cloud of gas, dust, and stars to contract (become smaller). The Sun is one of an estimated 100 billion stars in the Milky Way. All the stars in the universe belong to a galaxy.

Galaxies come in different shapes and sizes. Generally, they are classified as either spiral or elliptical, according to their appearance. Galaxies that do not fit into these general classifications are called irregular galaxies.

- A *spiral galaxy*, when viewed from above, looks like a pinwheel. It has many long "arms" spiralling out from a centre core. When viewed from the side, a spiral galaxy looks like a plate with a bulge in the middle, as if it had an orange inserted in its centre. **Figure 9.2A** shows a spiral galaxy viewed from above, and **Figure 9.2B** shows a spiral galaxy viewed from the side.
- *Elliptical galaxies* range in shape from a perfect sphere to a stretched-out ellipse. Some elliptical galaxies, for example, are similar in shape to a football, and others are similar in shape to a cigar. **Figure 9.2C** shows an elliptical galaxy. Elliptical galaxies contain some of the oldest stars in the universe. Astronomers believe that well over half of all galaxies are elliptical. The largest galaxies in the universe are elliptical.
- *Irregular galaxies* are galaxies that do not have a regular shape, such as spiral arms or an obvious central bulge. They are made up of newly forming stars and old stars. The galaxy in **Figure 9.2D** is an irregular galaxy.

Study Toolkit

Base Words Understanding a word's base can help you understand and remember the word's meaning. The base of the word *galaxy* is the Greek word for milk, *gala*. What connection can you make with the word *gala* and the meaning of *galaxy*?

Figure 9.2 **A** This is an image of a spiral galaxy as it looks from above. **B** This is an image of a spiral galaxy as it looks from the side. **C** This is an image of an elliptical galaxy taken by the Hubble Space Telescope. **D** This image of an irregular galaxy was also taken by the Hubble Space Telescope.

Understanding the Milky Way Galaxy

It has taken astronomers many years to learn about the Milky Way galaxy. William Herschel started putting together the pieces of the puzzle. By counting stars, Herschel figured out the approximate shape of the Milky Way galaxy. Herschel proposed that the Milky Way is a huge disk of billions of stars, flattened like a dinner plate, in which the Sun is embedded. He also proposed that the Sun might be at the centre of the Milky Way.

Star Clusters

In the early 20th century, American astronomer Harlow Shapley (1885–1972) helped to put together more pieces of the puzzle. While studying the Milky Way, he was also studying star clusters. A **star cluster** is a collection of stars held together by gravity. There are two types of star clusters: open clusters and globular clusters. Both types are shown in **Figure 9.3**. **Open clusters** contain 50 to 1000 stars and appear along the main band of the Milky Way. **Globular clusters** contain 100 000 to 1 000 000 stars. The stars in a globular cluster are arranged in a spherical shape. Globular clusters appear around the centre of the Milky Way.

Shapley became interested in globular clusters in particular. He reasoned that globular clusters should be evenly distributed around the galaxy. He noticed, however, that they appear only in the direction of the constellations Hercules, Scorpius, Ophiuchus, and Sagittarius—not all around us. Shapley reasoned that his observations could only be explained if he were observing the globular clusters from a position well away from them. He concluded that the Sun must be nowhere near the globular clusters.

star cluster a collection of stars held together by gravity

open cluster a collection of 50 to 1000 stars; open clusters appear along the main band of the Milky Way

globular cluster a collection of 100 000 to a million stars, arranged in a distinctive spherical shape; globular clusters appear around the centre of the Milky Way

Study Toolkit

Skim, Scan, or Study
The text on this page contains three boldfaced terms. What does that tell you about the speed at which you should read the text?

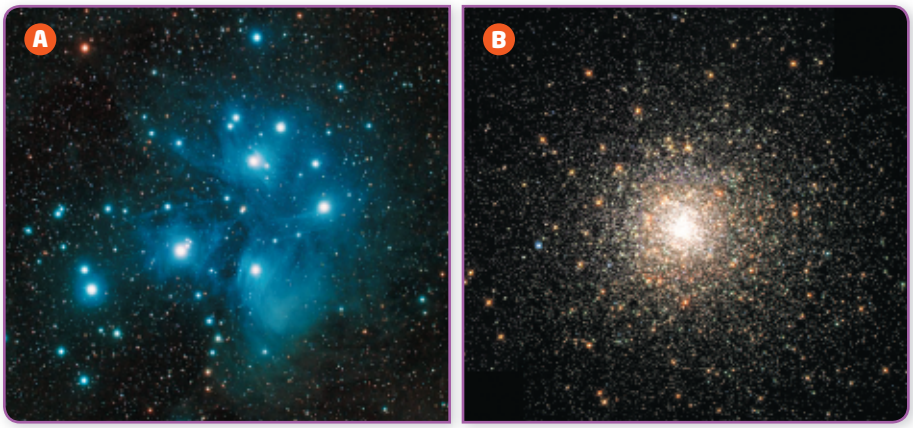


Figure 9.3 **A** The Pleiades open star cluster is in the constellation Taurus. **B** Globular clusters contain many more stars than open clusters.

The Diameter of the Milky Way Galaxy

Recall from Chapter 8 that radio waves can travel through clouds. Radio waves can also travel through the dust and gas between the stars. By mapping the galaxy with radio waves, astronomers have been able to determine its diameter and shape. Astronomers have determined that the diameter of the Milky Way galaxy is about 100 000 light-years and the shape of the Milky Way is disk-like. Recall from Chapter 7 that a light-year is the distance that light travels in one year: 9.5×10^{12} km.

The Centre of the Milky Way Galaxy

Using radio waves as well as infrared radiation, astronomers next confirmed that the centre of the Milky Way galaxy is surrounded by a bulge of stars. Around the bulge, there is a sphere of globular clusters, as shown in **Figure 9.4**. When Shapley was observing globular clusters, he was looking toward the centre of the Milky Way galaxy from a position well away from the centre of the halo of globular clusters that surround the galaxy.

Figure 9.4 Globular clusters form a sphere around the centre of the Milky Way galaxy.

The Shape of the Milky Way Galaxy

Knowing that the Milky Way galaxy has a disk-like shape, with a central bulge of stars, astronomers have concluded that it is a spiral galaxy. Recent observations suggest that the Milky Way has two major spiral arms and numerous minor arms. The Sun is approximately 28 000 light-years from the centre region of the Milky Way. Astronomers estimate that the visible mass of the Milky Way galaxy is about 200 billion solar masses.

Today, astronomers know much more about the structure of our galaxy. Thanks to telescopes that can detect radiation from different parts of the electromagnetic spectrum, astronomers have been able to take images of various regions of the Milky Way, as shown in **Figure 9.5**.

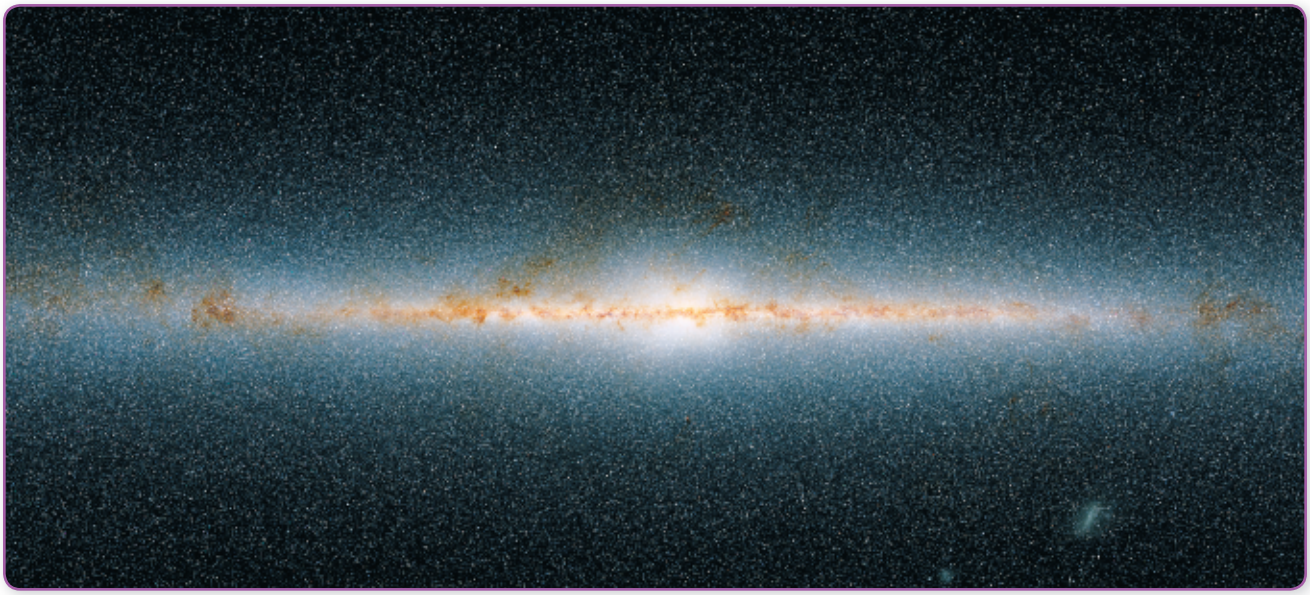


Figure 9.5 The dark, reddish-brown areas across the centre of this image of the Milky Way galaxy are called lanes. Lanes are enormous clouds of gas and dust. The gas and dust block the light from the background stars in the galaxy.

The Local Group

The Milky Way belongs to a group of about 40 galaxies called the **Local Group**. Some of these galaxies are shown in **Figure 9.6**. The diameter of the Local Group is about 10 million light-years. The Milky Way and Andromeda galaxies are the largest galaxies in the Local Group. Most of the galaxies in this group are small ellipticals and companions to the larger galaxies.

Local Group the small group of galaxies that includes the Milky Way

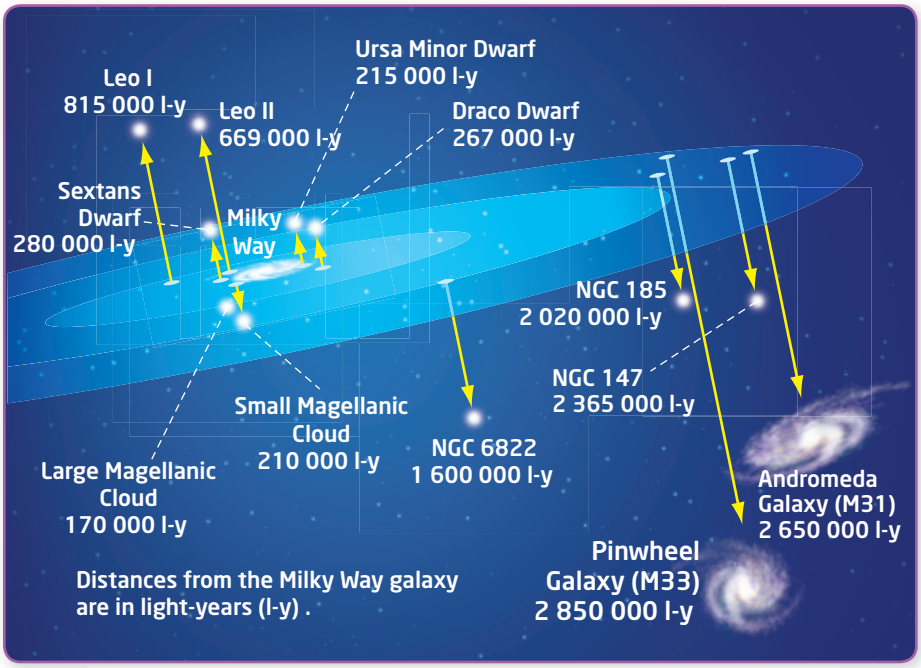


Figure 9.6 This image shows some of the galaxies in the Local Group. The yellow arrows are scaled to help you visualize the distances of each galaxy from the Milky Way.

Activity 9-2

How Big Is the Milky Way Galaxy?

The Milky Way galaxy, in which the solar system is located, is many times larger than the solar system. How large is the Milky Way galaxy, relative to the size of the solar system? In this activity, you will compare the size of the Milky Way galaxy with the size of the solar system.

Materials

- calculator

Procedure

1. The diameter of the Milky Way galaxy is approximately 6.33×10^9 AU. Calculate the diameter of the Milky Way in light-years. (1 AU = 1.58×10^{-5} light-years)
2. The Kuiper Belt has a diameter of 50 AU. Calculate the diameter of the Kuiper Belt in light-years.
3. Using the scale 1 mm = 1 light-year, how large is the Milky Way?
4. The Sun is approximately 28 000 light-years from the centre of the Milky Way. Based on the scale that you used in step 3, what is the distance, in millimetres, from the centre of the Milky Way to the Sun?
5. Based on the scale that you used in step 3, what is the diameter of the Kuiper Belt?

Questions

1. Suppose that you built a model of the Milky Way, using your results in this activity. Describe the approximate size of your model.
2. Would it be a problem to show the solar system in your model of the Milky Way? Why or why not?
3. How would you change your model to include Earth?

Learning Check

1. Using **Figure 9.2**, list and describe the three major types of galaxies.
2. How do galaxies form?
3. Describe how astronomers learned more about the Milky Way galaxy.
4. Use **Figure 9.6** to identify the two closest and the two farthest galaxies from the Milky Way galaxy.

Galaxy Superclusters

supercluster a gigantic cluster of 4 to 25 clusters of galaxies, which is hundreds of millions of light-years in size

Just as stars occur in clusters within galaxies, galaxies also occur in clusters throughout the universe. These clusters form **superclusters**, which may contain 4 to 25 clusters of galaxies and may span hundreds of millions of light-years across the universe. Astronomers hypothesize that there may be more than 125 billion galaxies, and nearly all of them seem to be organized in clusters.

Activity 9-3

Counting Galaxies by Sampling

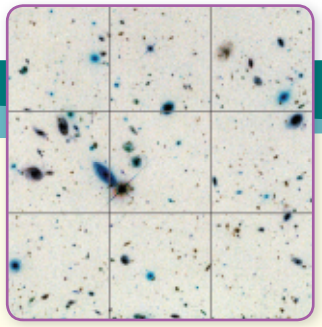
Have you ever wondered how scientists know how many hairs are on the average cat? Counting every hair on a cat would take a very long time. A mature house cat has about 3 million hairs (a reasonable number). It would take more than a month, counting one per second, 24 h a day, non-stop, to count every hair. A better and more accurate strategy is to estimate the number using a technique called sampling. In this activity, you will use sampling to estimate the number of galaxies that the Hubble Space Telescope (HST) can observe in a small area of the sky.

Materials

- image of galaxies taken by HST

Procedure

1. Your teacher will give you a copy of the image shown above. Each group will study one section of the image.
2. Tally the number of galaxies in your section. Every small smudge on the image is a galaxy, except the smudges that have "spikes" radiating from them. The spiked smudges are stars. (The spike effect is produced by the brightness of the stars in the lens of the camera.)
3. Collect the tallies for the other sections, add all the tallies together, and calculate the average number of galaxies per section.



This image of galaxies is from the HST.

4. Astronomers use degrees to represent measurements in the sky. For example, when measuring in degrees, the diameter of the full Moon is one half a degree, where the distance between the east horizon and the west horizon is 180°. One section in the image represents approximately 2.2×10^{-4} square degrees in the sky. The total area of the sky is 4.13×10^{4} square degrees. Estimate the total number of galaxies in the universe as follows:

Total number of galaxies

$$= \frac{\text{total area of the sky in square degrees}}{\text{area of one section}} \times \text{average number per section}$$

$$= \frac{4.13 \times 10^{4} \text{ square degrees}}{2.2 \times 10^{-4} \text{ square degrees}} \times \text{average number per section}$$

Questions

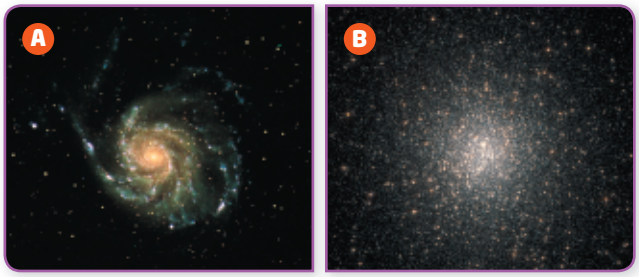
1. Approximately how many galaxies can HST see in this image?
2. Why is it better to average the tallies for all the sections to get the average number per section rather than use the results for a single section?
3. Why is sampling more practical than trying to do a more detailed count?

Section 9.1 Review

Section Summary

- Galaxies are generally classified as spiral, elliptical, or irregular. They occur in clusters throughout the universe. These clusters form superclusters, which may contain 4 to 25 clusters.
- The Milky Way galaxy is a spiral galaxy, about 100 000 light-years in diameter. It is part of the Local Group of about 40 galaxies.
- Astronomers used improved technology, such as telescopes that were able to detect different parts of the electromagnetic spectrum, to learn more about the Milky Way galaxy and other galaxies.

Review Questions



T/I **1.** Identify image A and image B on the right.

K/U **2.** What is the Local Group?

K/U **3.** Explain the difference between a galaxy cluster and a galaxy supercluster.

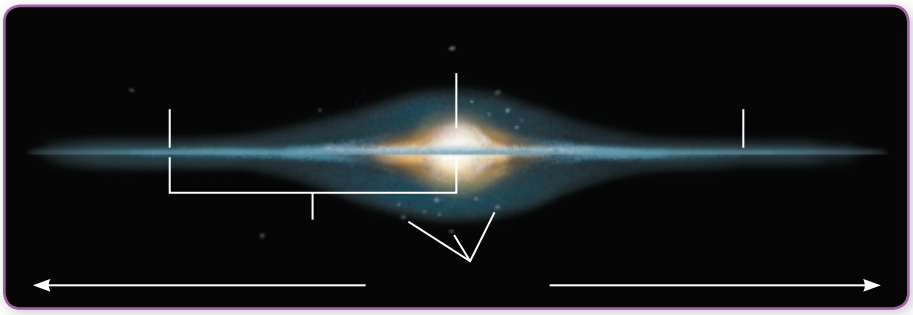
K/U **4.** William Herschel thought that the Sun was in the centre of the Milky Way galaxy. Was he correct? Why or why not?

C **5.** In a Venn diagram, compare open star clusters with globular star clusters.

C **6.** Draw a cartoon of what you would expect to see while riding in a spaceship looking down on the Milky Way galaxy.

C **7.** Review **Figure 9.2** and **Figure 9.3**. Describe the similarities and differences between globular clusters and galaxies.

K/U **8.** Copy the illustration below into your notebook. Add the following labels: Sun's location, bulge, 100 000 light-years, 28 000 light-years, globular clusters, disk.



This illustration is a side view of the Milky Way galaxy.