27.6 Galaxies

EXPLAIN THIS Most of the celestial objects discussed so far in this and the preceding chapter are located in what galaxy?

Look up into the clear nighttime sky away from the city lights and you will see plenty of stars. In between the stars you'll also see plenty of black. Before the early 20th century, the abundance of black in the night sky led many people to conclude that the universe consisted of an island of millions of stars nestled within a vast sea of emptiness. In addition to stars, however, are the cloudlike nebulae, some of them with a distinct spiral-shaped structure. As early as the 1750s, the German philosopher Immanuel Kant proposed that these spiral clouds were other islands of stars called *galaxies*. But without powerful telescopes, there was no way to tell whether that was true.

The debate about whether the universe consisted of one or many islands of stars was settled by the American astronomer Edwin Hubble. In 1927, working with the newly built largest telescope in the world at Mt. Wilson in California, Hubble made out individual stars within the Andromeda spiral nebula (Figure 27.22). Some of these stars he noticed to be *Cepheids,* which are stars that change their luminosity over short periods of time. Using photos of cepheid variables in the Magellanic clouds, Henrietta Leavitt had earlier discovered a relationship between cepheids' periods and their luminosities. So, by measuring the rate at which they changed luminosity, Hubble could estimate their distances, which he found to be much farther away than any star within our own galaxy. Spiral nebulae were not simply clouds—they were neighboring islands of stars within a vast emptiness that potentially extended forever.

But Hubble took his research a step further and discovered something even more amazing. He knew that the color of light emitted by a star or galaxy receding away from us shifts to the red because of the Doppler effect (see Section 10.8). The degree of redshift could be measured quantitatively by focusing on the line spectrum of hydrogen (see Section 12.6). The greater the shift in the lines of hydrogen's spectrum, the faster the receding speed. His research team measured

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Galaxies are cataloged by two systems. The first catalog is based on the work of Charles Messier, who in 1781 published a list of heavenly structures, such as galaxies, relatively easy to observe with small telescopes. The Andromeda galaxy, for example, is the 31st entry of this catalog and is thus listed as M31. A "New General Catalog" was begun in 1888 that was subsequently used to identify all structures, including the many more that became visible with the advent of more powerful telescopes. Under this system, the Andromeda galaxy is cataloged as NGC 224. You can use these catalog numbers in your Internet search engine to learn more about these objects, including their location in the nighttime sky.

VIDEO: Galaxies

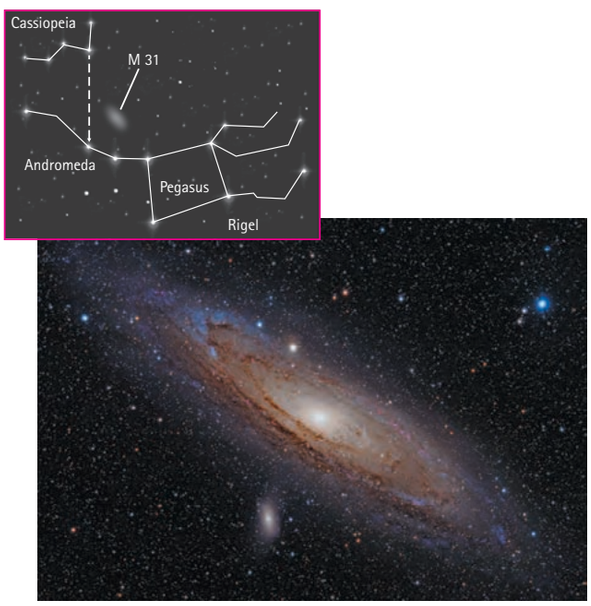

FIGURE 27.22
Hubble showed that the great spiral nebula within the Andromeda constellation was not just a swirling cloud of gas, but a neighboring galaxy of stars, which is now called the Andromeda galaxy and cataloged as M31. You can see the Andromeda galaxy for yourself by looking between the constellations of Cassiopeia and Pegasus in the late fall nighttime sky. The galaxy appears huge, covering an area six times that of the full Moon. It is, of course, much dimmer than the Moon. Best viewing comes with a good pair of binoculars far away from city lights.

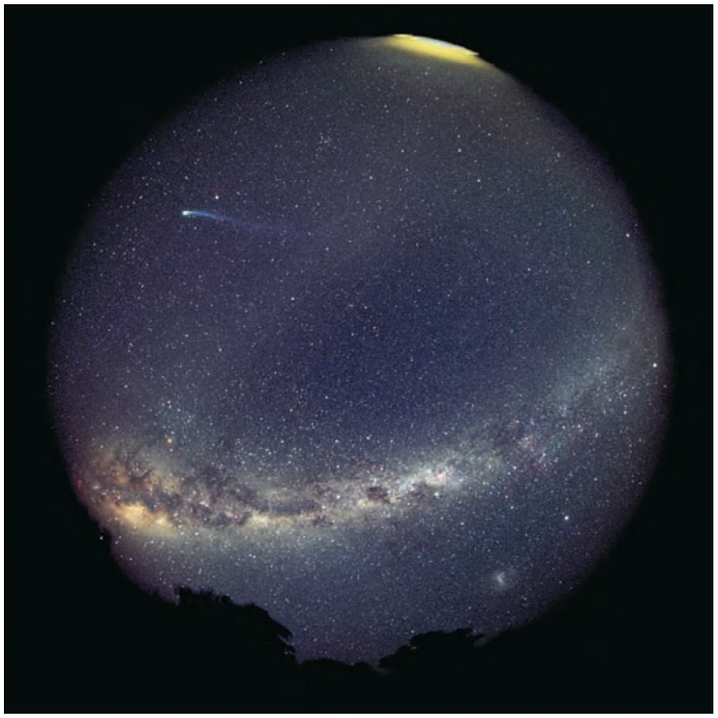

FIGURE 27.23
A wide-angle photograph of the Milky Way, which appears as a north–south cloudlike band of light. The dark lanes and blotches are interstellar gas and dust obscuring the light from the galactic center. If it weren't for this dust, the Milky Way would be a much more spectacular nighttime display. This photograph also shows Comet Hyakutake, which appeared in 1996.

both the distances and redshifts of numerous galaxies and discovered that the farther the galaxy, the greater the redshift. This meant that the galaxies were not static islands. Rather, they were receding from us in every direction, which meant that the universe itself was expanding.

If distant galaxies were all moving away from one another, that could only mean that they were once much closer together. Running the cosmic movie backward would inevitably lead to a moment when all the galaxies were gathered together, perhaps within a single point. The universe as we know it, therefore, had a beginning. This moment has come to be known as the **Big Bang,** which we will discuss in more detail in Chapter 28. For the remainder of this chapter, however, we will simply describe the different kinds of galaxies and how they are organized within the observable universe.

A **galaxy** consists of a large assemblage of stars, interstellar gas, and dust. Galaxies are the breeding grounds of stars. Our own star, the Sun, is an ordinary star among more than 100 billion others in an ordinary galaxy known as the Milky Way galaxy (Figure 27.23). With unaided eyes, we see the Milky Way as a faint band of light that stretches across the sky. The early Greeks called it the "milky circle" and the Romans called it the "milky road" or "milky way." The latter name has stuck.

The masses of galaxies range from about a millionth the mass of our galaxy to some 50 times more. Galaxies are calculated to have much more mass than can be seen with the telescope. A small proportion of the invisible mass is simply matter that has grown so cold that it doesn't emit enough light for us to see. The bulk of the invisible mass, however, is likely an unknown form of matter, called *dark matter,* that does not absorb or emit light. It does, however, possess mass and so its gravitational effects are quite measurable. In the next chapter we describe how dark matter probably played a key role in the formation and distribution of galaxies.

FIGURE 27.24
This small elliptical galaxy, Leo I, found within the constellation Leo, is only about 2500 light-years in diameter. For comparison, the diameter of our Milky Way galaxy is about 100,000 light-years.

Elliptical, Spiral, and Irregular Galaxies

The millions of galaxies visible in photographs can be separated into three main classes—elliptical, spiral, and irregular. *Elliptical galaxies* are the most common galaxies in the universe. They tend to have a spheroidal shape (round like a ball but often oblong) and most of their stars are crowded toward the center. Most contain little gas and dust, which makes them easy to see through. They also tend to be yellow, which tells us that they consist primarily of older stars—older stars are yellow, while hot young stars tend to be blue. Most ellipticals are small, consisting of fewer than a billion stars (Figure 27.24). An exception is the giant elliptical galaxy M87 (Figure 27.25). The largest ellipticals are about 5 times as large as our galaxy, and the smallest are 1/100 as large.

Spiral galaxies, such as the Andromeda galaxy, shown in Figure 27.22, are perhaps the most beautiful arrangements of stars. Some spirals, such as the Sombrero galaxy of Figure 27.26, have a spheroid central hub. Others, like the one shown in Figure 27.27, have a hub shaped like a bar. The Milky Way galaxy is thought to look much like the NGC 6744 spiral galaxy, which is an intermediate between a barred and unbarred spiral (Figure 27.28, next page). An artist's depiction of our galaxy is shown in the chapter-opening photograph.

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The Andromeda galaxy is our closest spiral neighbor, being only some 2.5 million light-years away. It contains many more stars than the Milky Way, which makes it more luminescent. Also, its diameter is about 220,000 light-years, compared to the Milky Way's 100,000 light-years. Thus, our view of the Andromeda is likely more spectacular than the Andromeda's view of us.

FIGURE 27.25
The giant elliptical galaxy M87, one of the most luminous galaxies in the sky, is located near the center of the Virgo cluster, some 50 million light-years from Earth. It is about 120,000 light-years across and about 40 times as massive as our own galaxy, the Milky Way.

FIGURE 27.26
False-color image of the Sombrero galaxy, cataloged as M104. This spiral is about 80,000 light-years in diameter and about 32 million light-years from Earth. At its center is one of the most supermassive black holes measured in any nearby galaxy.

Elliptical and/or spiral galaxies sometimes cross paths or even collide. In such cases, gravity causes the shape of the galaxy to become distorted. These distorted looking galaxies are called *irregular galaxies*. Most irregular galaxies are small and faint and are difficult to detect. They tend to contain large clouds of gas and dust mixed with both young (blue) and old (yellow) stars. The irregular galaxy first described by the navigator on Magellan's voyage around the world in 1521 is our nearest neighboring galaxy—the Magellanic Clouds. This galaxy consists of two "clouds," called the Large Magellanic Cloud (LMC) and the Small Magellanic Cloud (SMC), both of which are slowly being pulled into the Milky Way. The LMC is dotted with hot young stars with a combined mass of some 20 billion solar masses, and the SMC contains stars with a combined mass of about 2 billion solar masses (Figure 27.29, next page). The supernova 1987A described earlier occurred in the LMC. Some irregular galaxies, such as NGC 4038 shown in Figure 27.30 on page 779, are the aftermaths of galactic collisions.

FIGURE 27.27
The beautiful barred spiral galaxy NGC 1300 is about 100,000 light-years across and some 70 million light-years away.