

time?” Either alternative is difficult to imagine: time going back indefinitely into the past, or an actual moment when the universe began (but, then, what was there before?). And what about the size of the universe? Is it infinite in size? It is hard to imagine infinity. Or is it finite in size? This is also hard to imagine, for if the universe is finite, it does not make sense to ask what is beyond it, because the universe is all there is.

In the last few years, so much progress has occurred in astrophysics and cosmology that many scientists are calling recent work a “Golden Age” for cosmology. Our survey will be qualitative, but we will nonetheless touch on the major ideas. We begin with a look at what can be seen beyond the Earth.

33-1 Stars and Galaxies

According to the ancients, the stars, except for the few that seemed to move (the planets), were fixed on a sphere beyond the last planet. The universe was neatly self-contained, and we on Earth were at or near its center. But in the centuries following Galileo’s first telescopic observations of the heavens in 1610, our view of the universe has changed dramatically. We no longer place ourselves at the center, and we view the universe as vastly larger. The distances involved are so great that we specify them in terms of the time it takes light to travel the given distance: for example, 1 light-second = $(3.0 \times 10^8 \text{ m/s})(1.0 \text{ s}) = 3.0 \times 10^8 \text{ m} = 300,000 \text{ km}$; 1 light-minute = $18 \times 10^6 \text{ km}$; and 1 **light-year** (ly) is

$$\begin{aligned} 1 \text{ ly} &= (2.998 \times 10^8 \text{ m/s})(3.156 \times 10^7 \text{ s/yr}) \\ &= 9.46 \times 10^{15} \text{ m} \approx 10^{13} \text{ km.} \end{aligned}$$

Light-year (unit)

For specifying distances to the Sun and Moon, we usually use meters or kilometers, but we could specify them in terms of light. The Earth–Moon distance is 384,000 km, which is 1.28 light-seconds. The Earth–Sun distance is $1.50 \times 10^{11} \text{ m}$, or 150,000,000 km; this is equal to 8.3 light-minutes. Far out in our solar system, the ninth planet, Pluto, is about $6 \times 10^9 \text{ km}$ from the Sun, or $6 \times 10^{-4} \text{ ly}$. The nearest star to us, other than the Sun, is Proxima Centauri, about 4.3 ly away. (Note that the nearest star is about 10,000 times farther from us than the outer reaches of our solar system.)

On a clear moonless night, thousands of stars of varying degrees of brightness can be seen, as well as the long cloudy stripe known as the Milky Way (Fig. 33-1). Galileo first observed, with his telescope, that the Milky Way is comprised of countless individual stars. A century and a half later (about 1750), Thomas Wright suggested that the Milky Way was a flat disc of stars extending to great distances in a plane, which we call the **Galaxy** (Greek for “milky way”).



FIGURE 33-1 A section of the Milky Way. The thin line is the trail of an artificial Earth satellite.