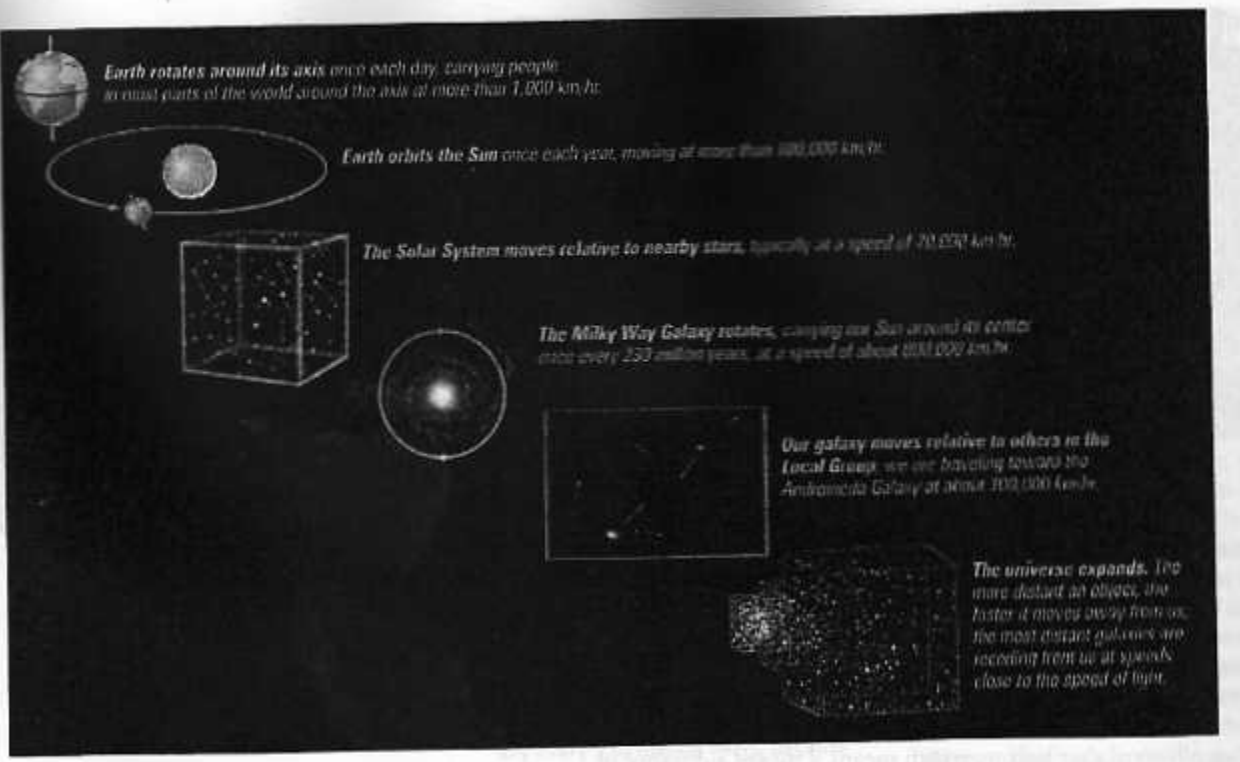


Figure 1.16

This figure summarizes the basic motions of Earth in the universe, along with their associated speeds.

light into spectra and observing what we call *Doppler shifts* [Section 5.2]. We still use the same technique today, illustrating how modern astronomy depends both on careful observations and on using current understanding of the laws of nature to explain what we see.

• Are we ever sitting still?

We and our planet are constantly on the move through the universe, and at surprisingly high speeds.

As we have seen, we are never truly sitting still. Figure 1.16 summarizes the motions we have covered. We spin around Earth's axis at more than 1,000 km/hr, while our planet orbits the Sun at more than 100,000 km/hr. Our solar system moves among the stars of the local solar neighborhood at typical speeds of 70,000 km/hr, while also orbiting the center of the Milky Way Galaxy at a speed of about 800,000 km/hr. Our galaxy moves among the other galaxies of the Local Group, while all other galaxies move away from us at speeds that grow greater with distance in our expanding universe. Spaceship Earth is carrying us on a remarkable journey.

THE BIG PICTURE

Putting Chapter 1 into Context

In this first chapter, we developed a broad overview of our place in the universe. As we consider the universe in more depth in the rest of the book, remember the following "big picture" ideas:

- Earth is not the center of the universe but instead is a planet orbiting a rather ordinary star in the Milky Way Galaxy. The Milky Way Galaxy, in turn, is one of billions of galaxies in our observable universe.
- We are "star stuff." The atoms from which we are made began as hydrogen and helium in the Big Bang and were later fused into heavier elements by massive stars. When these stars died, they released these atoms into space, where our galaxy recycled them into new stars and planets. Our solar system formed from such recycled matter some $4\frac{1}{2}$ billion years ago.
- Cosmic distances are literally astronomical, but we can put them in perspective with the aid of scale models and other scaling techniques. When you think about these enormous scales, don't forget that every star is a sun and every planet is a unique world.
- We are latecomers on the scale of cosmic time. The universe was already more than half its current age when our solar system formed, and it took billions of years more before humans arrived on the scene.
- All of us are being carried through the cosmos on spaceship Earth. Although we cannot feel this motion in our everyday lives, the associated speeds are surprisingly high. Learning about the motions of spaceship Earth gives us a new perspective on the cosmos and helps us understand its nature and history.

SUMMARY OF KEY CONCEPTS

1.1 OUR MODERN VIEW OF THE UNIVERSE

• What is our place in the universe?

Earth is a planet orbiting the Sun. Our Sun is one of more than 100 billion stars in the **Milky Way Galaxy**. Our galaxy is one of about 40 galaxies in the **Local Group**. The Local Group is one small part of the **Local Supercluster**, which is one small part of the **universe**.

• How did we come to be?

The universe began in the **Big Bang** and has been expanding ever since, except in localized regions where gravity has caused matter to collapse into galaxies and stars. The Big Bang essentially produced only two chemical elements: hydrogen and helium. The rest have been produced by stars and recycled within galaxies from one generation of stars to the next, which is why we are "star stuff."

• How can we know what the universe was like in the past?

We can actually see into the past by studying light from distant stars and galaxies. Light takes time to travel through space, so the farther away we look in distance, the further back we look in time. When we look billions of **light-years** away, we see pieces of the universe as they were billions of years ago.

• Can we see the entire universe?

No. The age of the universe limits the extent of our **observable universe**. For a universe that is 14 billion years old, our observable universe extends to a distance of 14 billion light-years. If we tried to look beyond that distance, we'd be trying to look to a time before the universe existed.

1.2 THE SCALE OF THE UNIVERSE

• How big is Earth compared to our solar system?

On a scale of 1 to 10 billion, the Sun is about the size of a grapefruit. Planets are much smaller, with Earth the size of a ball point and Jupiter the size of a marble on this scale. The distances between planets are huge compared to their sizes, with Earth orbiting 15 meters from the Sun on this scale.

• How far away are the stars?
On the 1-to-10-billion scale, it is possible to walk from the Sun to Pluto in just a few minutes. On the same scale, the nearest stars besides the Sun are thousands of kilometers away.

• How big is the Milky Way Galaxy?
Using a scale on which the Milky Way galaxy is the size of a football field, the distance to the nearest star would be only about 4 millimeters. There are so many stars in our galaxy that it would take thousands of years just to count them.

• How big is the universe?
The observable universe contains at least 100 billion galaxies. The total number of stars in the observable universe is roughly the same as the number of grains of dry sand on all the beaches on Earth.

• How do our lifetimes compare to the age of the universe?

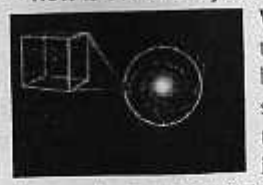
On a cosmic calendar that compresses the history of the universe into 1 year, human civilization is just a few seconds old, and a human lifetime lasts only a fraction of a second.

1.3 SPACESHIP EARTH

• How is Earth moving in our solar system?

Earth **rotates** on its axis once each day and **orbits** the Sun once each year. Earth orbits at an average distance from the Sun of 1 **AU** and with an **axis tilt** of $23\frac{1}{2}°$ to a line perpendicular to the **ecliptic plane.**

• How is our solar system moving in the Milky Way Galaxy?



We move seemingly randomly relative to other stars in our local solar neighborhood. The speeds of the stars are substantial by earthly standards, but they are so far away that their motion is undetectable to the naked eye. Our Sun and other stars in our neighborhood orbit the center of the galaxy every 230 million years, because the entire galaxy is rotating.

• How do galaxies move within the universe?
Galaxies move essentially at random within the Local Group, but all galaxies beyond the Local Group are moving away from us. More distant galaxies are moving faster, which tells us that we live in an expanding universe.

• Are we ever sitting still?

We are never truly sitting still. We spin around Earth's axis and orbit the Sun. Our solar system moves among the stars of the local solar neighborhood while orbiting the center of the Milky Way Galaxy. Our galaxy moves among the other galaxies of the Local Group, while all other galaxies move away from us in our expanding universe.

EXERCISES AND PROBLEMS

MasteringASTRONOMY

For instructor-assigned homework go to **www.masteringastronomy.com.**

REVIEW QUESTIONS

Short-Answer Questions Based on the Reading

1. What do we mean by a *geocentric* universe? In broad terms, contrast a geocentric view of the universe with our modern view of the universe.
2. Briefly describe the major levels of structure (such as planet, star, galaxy) in the universe.
3. What do we mean when we say that the universe is *expanding*? How does expansion lead to the idea of the *Big Bang*?
4. What did Carl Sagan mean when he said that we are "star stuff"?
5. How fast does light travel? What is a *light-year*?
6. Explain the statement *The farther away we look in distance, the further back we look in time.*
7. What do we mean by the *observable universe*? Is it the same thing as the entire universe?
8. Describe the solar system as it looks on the 1-to-10-billion scale used in the text. How far away are other stars on this same scale?
9. Describe at least one way to put the scale of the Milky Way Galaxy into perspective and at least one way to put the size of the observable universe into perspective.
10. Imagine describing the cosmic calendar to a friend. In your own words, give your friend a feel for how the human race fits into the scale of time.
11. Define *astronomical unit*, *ecliptic plane*, and *axis tilt*. Explain how each is related to Earth's rotation and/or orbit.
12. What is the shape of the Milky Way Galaxy? Where is our solar system located within the galaxy? How does our solar system move within the galaxy?
13. Distinguish between our galaxy's *disk* and *halo*. Where do most visible stars reside? Where does the mysterious *dark matter* seem to reside?
14. What key observations by Edwin Hubble lead us to conclude that the universe is expanding? Use the raisin cake model to explain how these observations imply expansion.