**CHAPTER 1**

**HERE AND NOW**

As you study astronomy, you will learn about yourself. You are a planet-walker, and this chapter will give you a preview of what that means. The planet you live on whirls around a star that moves through a Universe filled with other stars and galaxies which are all results of billions of years of history and evolution. You owe it to yourself to know where you are in the Universe and also to know when you are in its history because those are important steps toward knowing what you are. In this chapter, you will consider three important questions about astronomy:

* Where is Earth in the Universe?
* How does human history fit into the history of the Universe?
* Why study astronomy?

1-1 WHERE ARE WE?

* You surveyed the Universe by taking a cosmic zoom in which each **field of view** was 100 times wider than the previous field of view.
* Astronomers use the metric system because it simplifies calculations and **scientific notation** for very large or very small numbers.
* You live on a **planet**, Earth, which orbits our **star**, the Sun, once a year. As Earth rotates once a day, you see the Sun rise and set.
* The **Solar System** includes the Sun at the center, all of the major planets that orbit around it—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune—plus the moons of the planets and other objects such as asteroids, comets, and **dwarf planets** like Pluto, bound to the Sun by its gravity.
* The **astronomical unit (AU)** is the average distance from Earth to the Sun. The **light-year (ly)** is the distance light can travel in one year.
* Astronomers have found thousands of planets orbiting stars other than our Sun, even though such distant and small bodies are very difficult to detect.
* The Milky Way, the hazy band of light that encircles the sky, is the **Milky Way Galaxy** seen from inside. **Galaxies** contain many billions of stars. The Milky Way Galaxy is about 80,000 ly in diameter and contains over 100 billion stars, including our Sun.
* Our galaxy is just one of billions of galaxies that fill the Universe in great clusters, clouds, filaments, and walls—the largest structures in the Universe.

1-2 WHEN IS NOW?

* Astronomers have evidence that the Universe began about 14 billion years ago in an event called the Big Bang that filled the Universe with hot gas.
* The hot gas cooled, the first galaxies began to form, and stars began to shine about 400 million years after the Big Bang.
* The Sun and planets of our Solar System formed about 4 .6 billion years ago.
* Life began in Earth’s oceans soon after Earth formed but did not emerge onto land until 400 million years ago, less than 1/30 of the age of the Universe. Dinosaurs evolved relatively soon after that and went extinct just 65 million years ago.
* Humanlike creatures developed on Earth only about 4 million years ago, less than 1/3000 of the age of the Universe, and human civilizations developed just 10,000 years ago.

1-3 WHY STUDY ASTRONOMY?

* Although astronomy seems to be about stars and planets, it describes the Universe in which you live, so it is really about you. Astronomy helps you answer the question, “What are we?”
* As you study astronomy, you should ask, “How do we know?” and that will help you understand how science gives us a way to understand nature.
* In its simplest outline, science follows the **scientific method**, in which scientists test hypotheses against evidence from experiments and observations. This method is a powerful way to learn about nature.

CHAPTER OUTLINE

**1-1 Where Are We?**

**1-2 When Is Now?**

**1-3 Why Study Astronomy?**

*How Do We Know? 1-1: The Scientific Method  
What Are We? Participants*

KEY TERMS

astronomical unit (AU)

dwarf planet

field of view

galaxy

light-year (ly)

Milky Way Galaxy

planet

scientific method

scientific notation

Solar System

star

**RESOURCES AND TIPS**

1. Ask students to watch this cosmic zoom sequence, which is similar to the one in the chapter and a second version of a famous earlier film.  
   Powers of Ten™ (1977) by Charles and Ray Eames: [*http://www.youtube.com/watch?v=0fKBhvDjuy0*](http://www.youtube.com/watch?v=0fKBhvDjuy0)   
   Which power of ten is most surprising to them and why?
2. A good explanation of the Milky Way can be found here: [*http://en.wikipedia.org/wiki/Milky\_Way*](http://en.wikipedia.org/wiki/Milky_Way). This may provide extra help when providing directions (Review Question 12) and give additional context to where we are in the Universe.

ANSWERS TO REVIEW QUESTIONS

1. The width increases by a factor of 100 (from 16 m across to 1.6 km, i.e., 1600 m across), as does the length in any direction.

2. (Answers will vary.) For a distance traveled by one’s own power, most people will have covered a distance of a few miles at some time and a few may well have covered more on an extended backpacking or bicycling trip. A smaller number may have driven across a continent or flown to the opposite side of the world.

3. Our Solar System contains the Sun and objects that orbit it, including the eight planets, comets, and asteroids. Our Galaxy contains approximately 100 billion stars, of which the Sun is one, as well as clouds of gas and dust between the stars. The Universe contains all physical matter and energy; its basic constituents are clusters of galaxies.

4. The Moon refers to the rocky body orbiting Earth, whereas “moon” refers to any satellite of any planet.

5. Although Pluto does have some of the characteristics required to be defined as a planet (e.g., spherical, non-luminous, orbits a star), its small size and the fact that it is not alone in its orbit mean that it is better defined as a dwarf planet.

6. We use light-years instead of astronomical units or kilometers to measure the distances to stars and galaxies for the same reason that we measure the distances between cities in miles and not inches. When measuring distance between stars or galaxies, the distances are very large. The average distance between stars in the Milky Way galaxy is about 5 light-years. That’s a number relatively easy to remember. Distances to stars and galaxies given in astronomical units or kilometers would require very large numbers (e.g., the distance to the nearest star is about 300,000 AU or 4.5 × 1013 km). Additionally, light-years are used when discussing the distances to galaxies because the distance in light-years tells us how far back in time we are viewing the galaxy.

7. Seeing planets around other star systems is very difficult for three reasons. First, they are small and so will appear as small points from Earth. Second, planets are much fainter than the stars that they orbit. This is because planets are not perfect reflectors, so only a *portion* of the light from their star is reflected away. Third, planets are too close to their (larger, brighter) star, making the planet even more difficult to notice.

8. On photographs, the diameter of a star is related to its *apparent* intensity or *apparent* brightness. Bright stars make larger spots on a photograph than do faint stars. Therefore, the size of a star in an image tells you how bright it appears at Earth, not the actual size of the star.

9. The Milky Way is a fairly narrow band of faint diffuse light around the celestial sphere. The Milky Way Galaxy is a spiral galaxy of about 100 billion stars. All of the objects visible with the unaided eye in the night sky, except the Andromeda galaxy, Large Magellanic Cloud, and Small Magellanic Cloud, are part of the Milky Way Galaxy.

10. The Galaxy’s spiral arms are places where stars form from clouds of gas and dust.

11. Filaments and walls (i.e., large strings of superclusters of galaxies) appear to be the largest structures in the Universe.

12. We are located within the Local Group of galaxies, one of which is the Milky Way Galaxy. Within the Milky Way Galaxy, our Solar System is located in one of the spiral arms. Within our Solar System, we are the third planet away from the Sun.

13. The age of the Solar System is 4.6 billion years, so a life span of 75 years is about 0.000000016 (1.6 ×10-8) of the age of the Solar System. Compared to the age of the Universe (14 billion years), the fraction shrinks to about 0.000000005.

14. (Answers may vary.) Studying astronomy allows us to understand what we are and how we fit into the history of the Universe. The atoms that make up our bodies were born in the Big Bang that created the Universe. Studying astronomy also allows us to understand more fully how we learn about the natural world through science, preparing us to critically examine statements about the world around us in the future. I may encounter astronomy in the future, whether it is considering funding a space program or through future discoveries made about our Universe.

15. Astronomy helps answer the question “What are we?” in many ways. Astronomy tells us how particles that make up the atoms in our bodies were created during the Big Bang, when the Universe began, and then rearranged inside generations of stars. Astronomy locates us in space and time, and shows how we fit into the physical processes that govern the Universe.

16. Scientists try to form hypotheses that explain how nature works. If a hypothesis is contradicted by evidence from experiments or observations, it must be revised or discarded. If a hypothesis is confirmed, it must be tested further. The scientific method is a way of testing and refining ideas to describe better how nature works.

ANSWERS TO ACTIVE INQUIRY QUESTIONS

1. A variety of locations can be proposed but considerations may be made for aspects such as means of transportation and travel time. How you might get there, how long it would take, and what the world might look like when you got back are all things that might be considered in addition to what you might see at your destination.
2. Expecting the phone to work like your older phone would be a hypothesis that is tested when you start to make use of a feature and discover that it does or does not function as you expected. Often a period of trial-and-error then occurs, this is an example of refining a hypothesis based on a series of tests and results.

ANSWERS TO PROBLEMS

1. 12,760 (1.276 × 104) km, to 4 significant figures; 1.276 × 109 cm

2. 2160 mi

3. 1.5 × 108 is 150 million, or 150 × 106.

4. 1 × 1011 stars

5. 5.4 × 108 years ago

6. 1.1 × 108 km

7. 1.5 AU × 8 min/AU = 12 min

8. 8 min / 400 = 1.2 s

9. 9.5 × 1012 km; 9.5 × 1015 m

10. Betelgeuse is 640 ly away. The late 14th century (640 years ago) was approximately the start of the Renaissance in Europe and the Ming dynasty in China (answers may vary). Betelgeuse is nearby compared with most stars in the Universe, but farther than most stars visible with an unaided eye.

11. The visible disk of the Milky Way Galaxy is about 80,000 ly in diameter; light takes 80,000 years to travel 80,000 ly.

12. 2.4 × 1022 m ((2.5 × 106 ly) × (9.5 × 1012 km/ly) × (103 m/km))

13. Divide the distance given in Problem 12 (2.5 million ly) by 80,000 ly (diameter of the Milky Way Galaxy), which yields about 31 Galaxy diameters.

**ANSWER TO SENSE OF PROPORTION**

1. You; the Moon; Earth; the Moon’s orbit around Earth; the Sun; Earth’s orbit around the Sun; the Milky Way Galaxy
2. Center of Earth; the Moon; the Sun; Neptune
3. The radius of Earth’s orbit around the Sun
4. 168 inches = 14 feet; e.g., camper van or living room

**ANSWERS TO LEARNING TO LOOK**

1. The time at the center of Figure 1-4 is closest to noon. In this image, the right side of the Earth is turning away from the Sun (sunset) as indicated in the text. This means that the left side of the Earth is turning towards the Sun (sunrise). When viewed from above the North Pole, this rotation would appear to be counterclockwise.

2. If a planet’s orbit is circular, the Sun must be in the exact center. But, even in a figure on the scale of Fig. 1-6, you can tell that the dot representing the Sun is not at the center of Mercury’s orbit, which is the most noticeably elliptical of all the planetary orbits.

3. The field of view of Figure 1-9 is 17 ly, so approx. 2 stars lie within 5 ly of the Sun. That number would be roughly the same if Earth orbited any of the other stars in the figure.

4. In Figure 1-9, the distribution of stars is not uniform. In Figure 10-10 they look more uniformly distributed. The galaxies shown in Figure 1-12 are not distributed in a uniform manner, but instead form clusters. The galaxies in Figure 1-13 they look more uniformly distributed.

5. The object in this photograph is a galaxy, which contains stars, planets, and spiral arms.

6. The brighter a star appears in the sky, the larger its image on a photograph. So the brightest stars in this photograph are those whose images are largest, while the faintest stars have the smallest images. All stars are so far away that their disks cannot be photographed directly, so we cannot determine their size from photographs. Likewise, stars are much too distant and too bright for us to view any orbiting planets photographically.