

● ACTIVITY 1

The Celestial Sphere and Sky Maps

Learning Goals

In this activity, you will learn more about the features of the sky: where to look, when to look, how the sky changes, and why it changes. After completing this activity, you should be able to

1. contrast daily and yearly motion of the stars.
2. state the altitude of the north celestial pole (Polaris) from your location.
3. describe how stars move over the course of a year.
4. identify constellations that lie on the meridian and the ecliptic.
5. identify the locations of the solstices and equinoxes on the celestial sphere.
6. evaluate the effectiveness of viewing the night sky from different reference frames.

Key terms: celestial sphere, constellation, ecliptic, zodiac, celestial equator, equinox, solstice, zenith, horizon, meridian, latitude, north celestial pole (NCP), circumpolar, rotate, revolve

Step 1—Background

The **celestial sphere** is an imaginary sphere around Earth, with all the objects of the sky painted upon it. It's a useful idea for thinking about how the sky changes over the course of the year. Astronomers divide the entire sky into 88 **constellations**—distinct, irregularly shaped regions much like countries on Earth. The date, time, and location of an observation determine which constellations can be seen. Star maps show half of the sky as it appears on a particular date and time, and from a particular location.

The **ecliptic** is the path the Sun takes through the sky against the background stars. If the Sun is in the direction of Virgo, we might say, "The Sun is in Virgo." The set of constellations along the ecliptic make up the **zodiac**. The planets of our Solar System are always close to the ecliptic in the sky.

The **celestial equator** is directly above Earth's equator. Because Earth's pole is tilted with respect to its orbit, the celestial equator is tilted with respect to the ecliptic. The two locations in the sky where the celestial equator and the ecliptic cross are called **equinoxes**. This term is also used for the dates when the Sun is at those locations. For example, the northern vernal (spring) equinox is the position of the Sun on March 21, so March 21 is also known as the vernal equinox in the Northern Hemisphere. Solstices mark the locations on the ecliptic where the Sun is farthest from the equator, and also indicate the date when the Sun is at those locations. The star maps used in this activity show the sky at midnight on the dates for the northern vernal equinox, northern summer **solstice** (Sun is its farthest north of the celestial equator), northern autumnal equinox, and northern winter solstice (Sun is at its farthest south of the celestial equator).

At any time and in any location, the **zenith** is the point directly above your head. The **horizon** is a circle around you such that if you point at the zenith with one arm and the horizon with the other, your arms form a 90-degree angle. The **meridian** is the imaginary line

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in the sky that passes from due north to due south through the zenith. The star maps are completely accurate if we lived on the equator, with the celestial equator passing through our zenith and the north celestial pole on the northern horizon. The star maps used here have been modified slightly to show the approximate east-to-west horizon for 30 degrees and 45 degrees north **latitudes**, as well as the ecliptic.

We may never actually travel to the North Pole, but we can investigate the sky as it would look if we did stand there. If we were to look straight up—at our zenith—we would see the **north celestial pole (NCP)** directly overhead. The celestial equator wraps around our horizon, and all of the northern hemisphere stars are **circumpolar**—they neither rise nor set but are always above the horizon. We may see only half of the sky at the North Pole, but the stars we see never set.

Our emphasis will be on what is viewable at midnight as we look south on the dates of the equinoxes and solstices. We will be asking: Which constellations are rising in the east? Which ones are on the meridian? Which ones are setting in the west?

The Sun, Moon, and the stars rise in the east and set in the west, with an approximate 24-hour cycle. This motion is because Earth **rotates** on its axis—counterclockwise from west to east—as seen if we were looking down from above the North Pole, as sketched in **Figure 1.1**. Earth also **revolves** around the Sun in a counterclockwise direction. Another way of saying this is “Earth orbits the Sun counterclockwise.” These two motions of Earth explain why the sky changes.

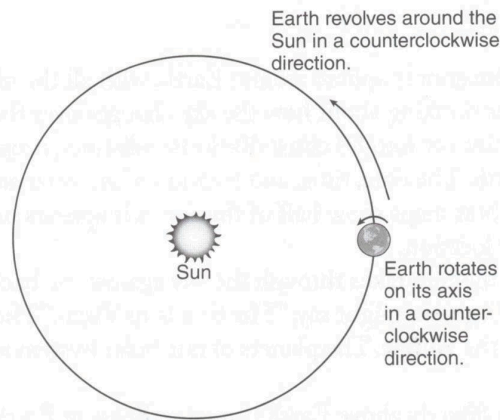


FIGURE 1.1

1. The locations on the celestial sphere where the ecliptic and celestial equator cross are called
 - a. solstices
 - b. equinoxes
 - c. celestial poles
 - d. zeniths

Step 2—Daily versus Yearly Motions of the Sky

The sketches in **Figure 1.2** indicate the motions you would see in the night sky looking north while using a camera and exposures of a few hours. East is to the right and west is to the left. Notice that one star, Polaris, stays in the same position in all three sketches. This is because Polaris is located very close to the north celestial pole (NCP).

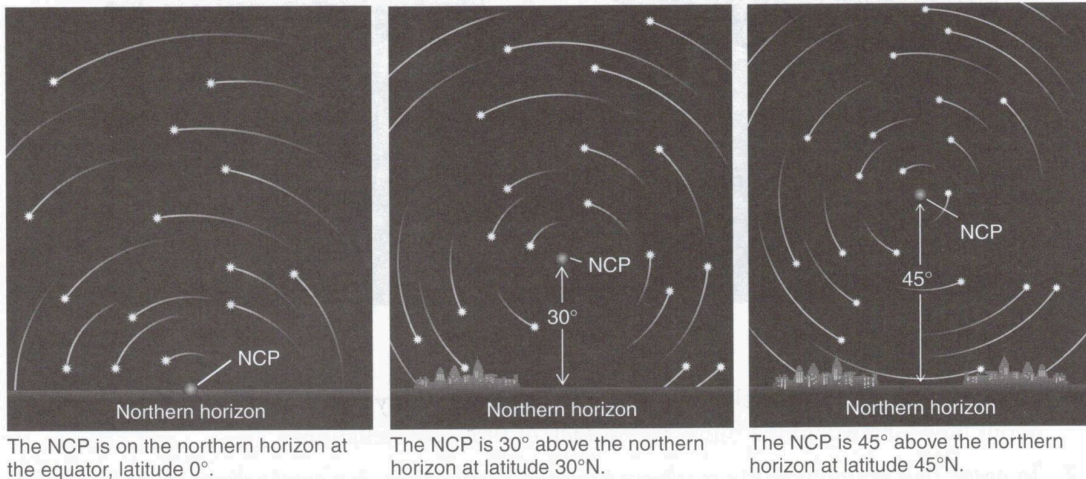


FIGURE 1.2

- There is definitely a trend in the altitude of the NCP above the northern horizon as viewed from different northern latitudes. State that trend.
- At what latitude are you currently? latitude _____
- If tonight were clear and you went out to find the star Polaris, how many degrees would it be above the northern horizon? _____
- Is the motion of the stars around Polaris (the NCP) due to the ____ **rotation** (daily motion) or ____ **revolution** (yearly motion) of Earth?

As Earth revolves around the Sun, the apparent position of the Sun against the background constellations changes. As **Figure 1.3** shows, on September 1 the Sun is seen in the direction of Leo. At midnight on September 1, we would look in the direction of the constellation Aquarius. By December 1, after 3 months have gone by, Earth has traveled far enough in its orbit that the Sun is in Scorpius. At midnight on that date, we would look into the direction of Taurus. Note the location of Earth with respect to the Sun at the equinoxes and solstices.

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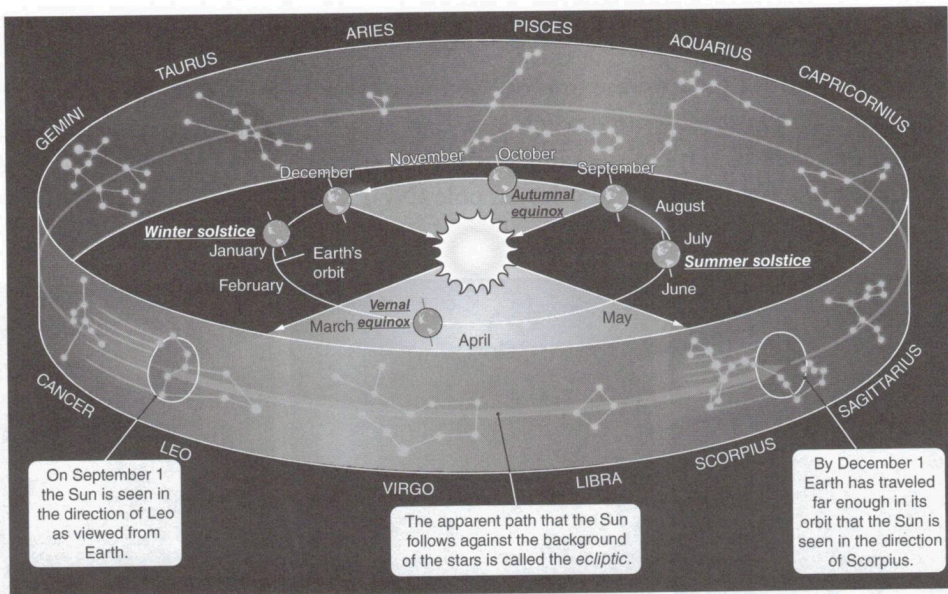


FIGURE 1.3

6. If we assume the 12 constellations of the zodiac were evenly distributed along the ecliptic, about how long would the Sun “stay” in each of those constellations? _____
7. Imagine that at noon on the northern summer solstice there is a total eclipse of the Sun, and you can see the background stars in the middle of the day. The sky might look something like the sketch in **Figure 1.4**. Notice that the Sun is in the constellation of Gemini. On the same day 6 hours later, in which constellation would the Sun be?
 - a. Cancer
 - b. Gemini
 - c. Taurus
 - d. Orion

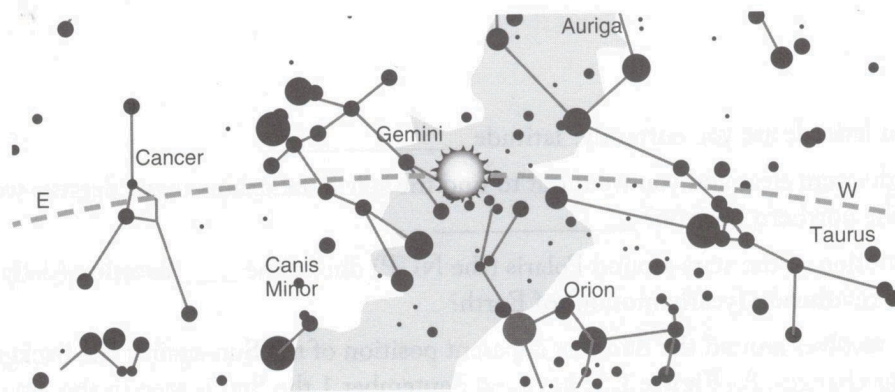


FIGURE 1.4

Step 3—Reading Star Maps

We saw how the background of stars and the constellations slowly changes over the course of a year in Figure 1.3. While objects rise and set on a daily basis, the time of rising and setting will not be the same over a year. The star maps shown in **Figures 1.5–1.8** in the appendix will help you visualize what the sky looks like at four instances during a year. Since these are drawn from the perspective of a viewer looking south, west is on the right and east is on the left.

8. Carefully study **Figure 1.5**, which shows the night sky at midnight on the vernal equinox, the first day of spring. Use a straight edge and draw in the meridian. List four constellations that are on or close to the meridian (and are above the southern horizon for your location) at around midnight on the vernal equinox.
9. This is also the sky at noon on September 21; that is, it is a map of the daytime sky on the autumnal equinox. In which constellation is the Sun located on the autumnal equinox?
 - a. Libra
 - b. Virgo
 - c. Leo
10. Draw in the meridian on **Figure 1.6**, as you did for Figure 1.5. This figure shows the night sky at midnight on the first day of summer, the summer solstice. List four constellations that are on the meridian and above the horizon at your latitude.
11. Pick one of the constellations that was on the meridian at midnight on the spring equinox (from Figure 1.5), name it, and describe how its location in the sky changed over one season.
12. The star map of Figure 1.6 also depicts the sky at noon on the winter solstice. Is the Sun _____ above or _____ below the celestial equator in the winter?
13. In which constellation is the Sun located on December 21?
 - a. Capricornus
 - b. Sagittarius
 - c. Libra
14. As you take a look at **Figure 1.7**, which shows the night sky at midnight on the autumnal equinox, note that the bright star in Lyra, Vega, that was on the meridian on the summer solstice, is now setting in the northwest. Approximately how much time has passed between Figure 1.6 and Figure 1.7?
15. How does that amount of time relate to Vega's change in its location in the night sky?
16. This map shows the stars in the sky at noon on March 21. In which constellation is the Sun on March 21?
 - a. Pegasus
 - b. Pisces
 - c. Aquarius
17. List five constellations shown in **Figure 1.8** that lie on the ecliptic. This figure shows the night sky at midnight on the first day of northern winter—the winter solstice.

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18. This star map also represents the sky at noon on June 21. Is the Sun located **above** or **below** the celestial equator in the summer?
19. In which constellation is the Sun on June 21?
 - a. Cancer
 - b. Gemini
 - c. Taurus

Step 4—Putting It Together

20. Return to Figure 1.3 and draw straight lines from Earth at each equinox and solstice through the Sun to the opposite constellation. Then, review your answers given in Step 3 for Figures 1.5–1.8. How does the way we view the yearly motion of Earth in Figure 1.3 relate to how we view the night sky using the star maps of Figures 1.5–1.8? Was investigating the sky from these two points of view helpful or not? Explain.
21. Start with listing at least three “points” (topics, concepts, visualizations) that this activity has covered. Then write an essay of around 200–300 words that summarizes what you have learned about those points. You should be able to use at least five of the key terms.

Appendix

FIGURE 1.5

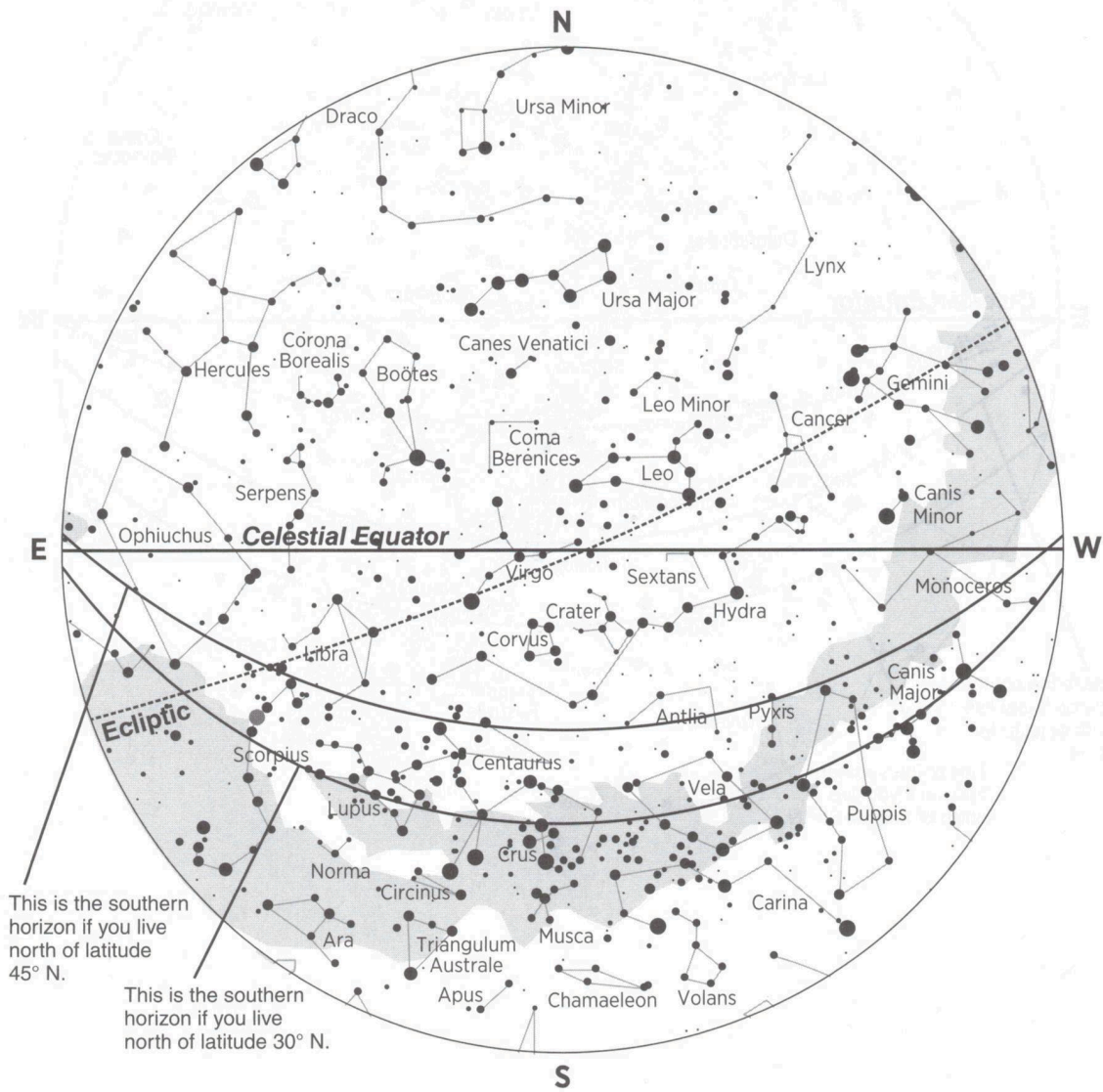


FIGURE 1.6

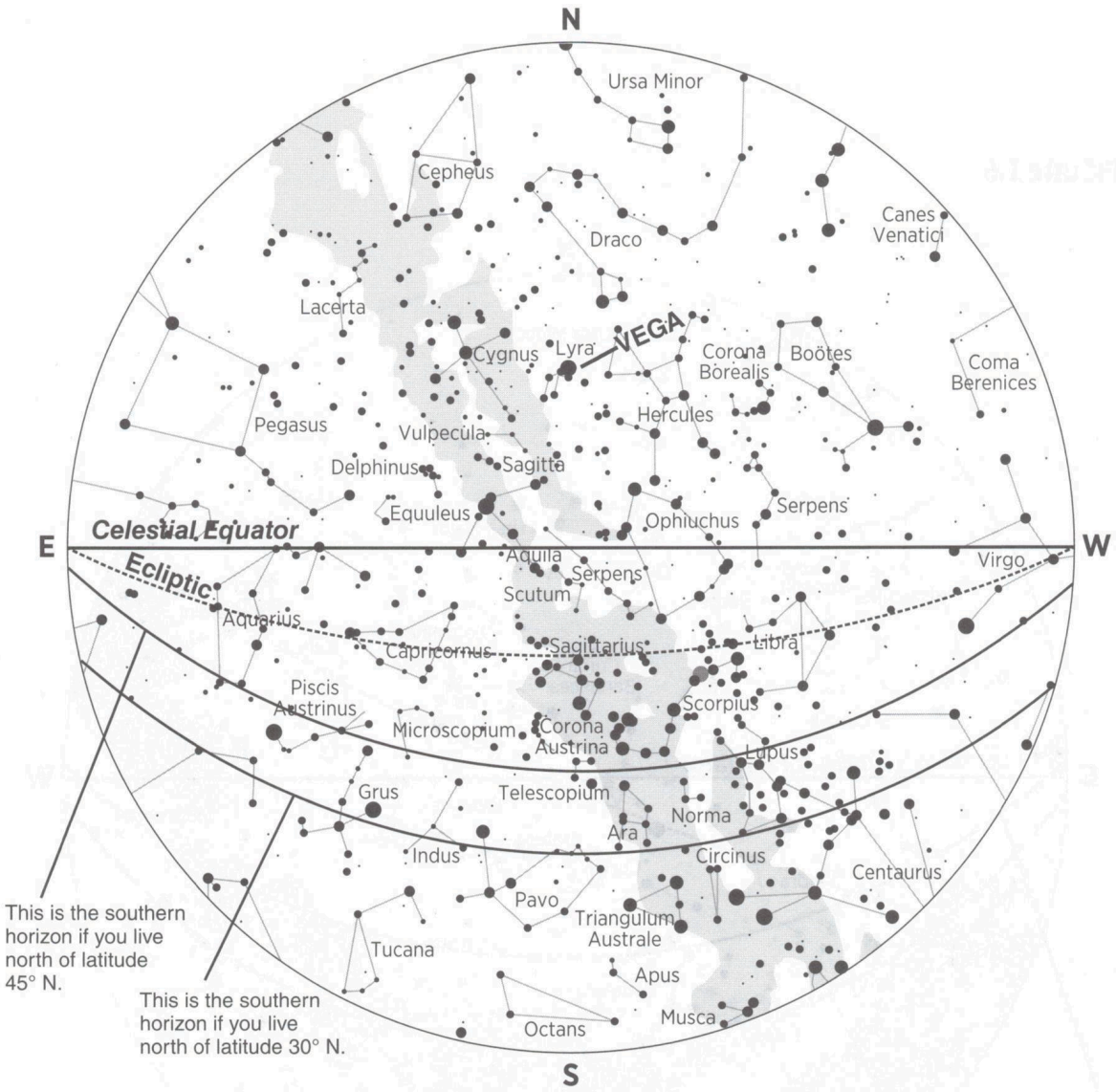


FIGURE 1.8

