1

Your Passport to the Stars

Since before the dawn of history, our ancestors have gazed skyward in awe and wonder. At first, the universe seemed cold, inhospitable, and filled with danger. Was the sky populated by gods of the Moon, the Sun, and planets who ruled mortals and could destroy or spare Earth with a mere wave of their hands? Did our very lives depend on their whimsy? As time evolved, curiosity grew about the exact nature of the Sun, the Moon, and other sky objects. The ancient Babylonians, Assyrians, and Greeks were among the first civilizations to study the sky in an attempt to understand how these objects influenced the course of human events. Their studies gave birth to the pseudoscience of astrology but more importantly also laid the basic foundation for the science of astronomy. Indeed, many of the names for stars and star patterns, called *constellations,* that we still use today trace their origin back to this early epoch.

Perhaps the greatest study of the universe by one of our ancient ancestors was performed by the Greek astronomer Claudius Ptolemaeus, or Ptolemy for short. While living in Egypt in the second century A.D., Ptolemy devised a scheme that predicted the movements of the Sun, the Moon, and planets in our sky with amazing accuracy. Ptolemy's *geocentric* system, which placed Earth at the center of the universe, remained the dominant model for more than a thousand years, until the European Renaissance in the sixteenth and seventeenth centuries.

Today, we know the true order of the universe. No longer populated by fearsome gods and goddesses, our universe plays host to stars and galaxies, planets and moons, and many other wonders that beckon us to stare skyward with the same awe and wonder felt by the first astronomers. We know that Earth is not at the center of the universe, and in fact that the universe really has no center at all. Instead, the universe is populated by millions, if not billions, of *galaxies* (Figure 1.1), each a huge system of stars. With rare exception, all galaxies are seemingly racing away from one another, motions induced by the *Big Bang,* which created the universe some 15 billion years ago. Some are independently traveling through the universe, while others travel in groups and clusters.

Each galaxy, including our own Milky Way, is made up of millions, if not billions, of individual stars. Many stars exist alone, while others formed in pairs, trios, or larger groupings. The largest star groupings are referred to as *star clusters* (Figure 1.2). Depending on the type, a cluster may hold anywhere from a dozen to half a million stars!

Interspersed throughout many galaxies are large clouds of gas and dust called *nebulae* (Figure 1.3). Some nebulae may be thought of as stellar nurseries, marking regions where new stars are forming. Other nebulae are stellar corpses, all that remain of once powerful suns.

Closer to home, our star, the Sun, serves as the focal point of a collection of comparatively small celestial bodies that we collectively call the *solar system.* In addition to the Sun, the solar system includes the nine planets—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto—as well as many moons, asteroids, comets, and meteoroids.

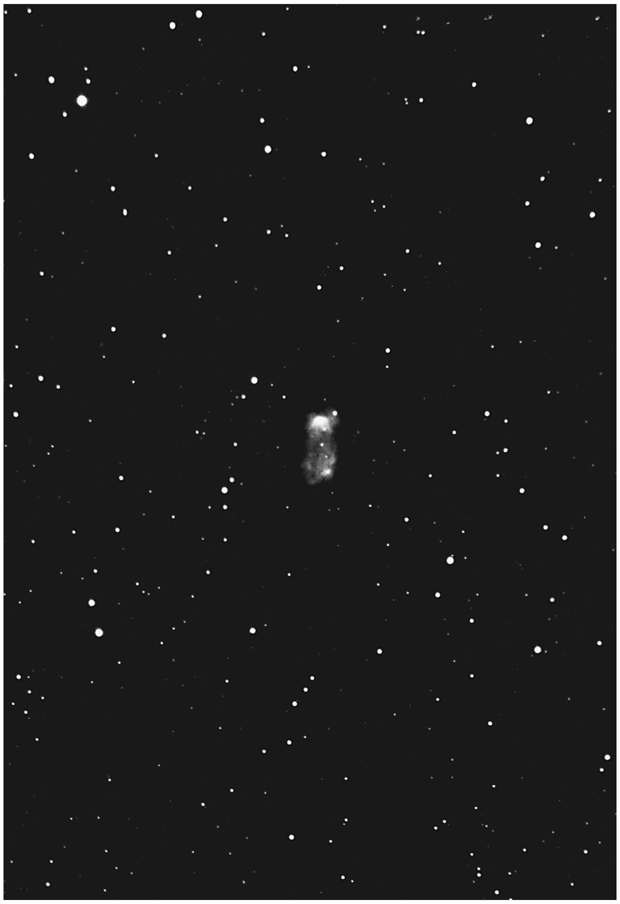
Figure 1.1 *Spiral galaxy M81 in the constellation Ursa Major. This photograph, taken by George Viscome through a 14.5-inch f/6 reflector, is oriented with south toward the top to match the view through most astronomical telescopes.*

a

b

Figure 1.2 *(a) Open star cluster M36 in the winter constellation Auriga. (b) Globular cluster M22 in Sagittarius. South is toward the top of each of these photographs taken by George Viscome through a 14.5-inch f/6 reflector.*

a



b

Figure 1.3 *(a) Bright nebula M16, better known as the Eagle Nebula, in the summer constellation Serpens. (b) Planetary nebula M76 in the autumn constellation Perseus. South is up in each of these photographs taken by George Viscome through a 14.5-inch f/6 reflector.*

All of these objects are waiting for you in the sky. But gazing skyward, trying to identify one from another or simply knowing where to look, can prove to be a daunting task for someone brand-new to the universe! Where is everything? Which star is which? Are there any planets out tonight? I just bought a new telescope; what should I look at first? And how do I use it?

All good questions. Where do you find the answers? I hope you find them here! Think of this book as your passport to places that few of the world's population are even aware exist. You and I are heading off to the farthest depths of space.

The Sky: An Overview

At first glance, the sky appears to be a mishmash of points of light, seemingly scattered at random and impossible to fathom. But the sky isn't as chaotic as it seems at first. It has a clear order that just takes a little time to understand. Let's begin with some basics.

Sky Motions

Watching the stars move silently overhead at night, we can easily see how Ptolemy and other ancient skywatchers came away with the idea that everything circled Earth. Instead, we know that this effect is caused by Earth rotating on its *axis,* an imaginary line that passes through the center of Earth, with the North Pole at one end and the South Pole at the other. This motion, called *daily* or *diurnal motion* (Figure 1.4), causes the Sun, the Moon, planets, and stars to appear as though they rise in the east, move across the sky, and set in the west. Daily motion also opens our sky window toward different stars at different times of the night.

The only stars that do not appear to rise and set are those located near the two *celestial poles,* the projection of Earth's North and South Poles against the sky. Instead, these *circumpolar* stars and constellations rotate above our horizon all night long. Which constellations are circumpolar from your location depends on your *latitude* (the angular distance you are away from the equator, measured in degrees). For most of us who view the sky from midnorthern latitudes (which includes most of the United States, southern Canada, and most of Europe), there are six generally recognized circumpolar constellations: Ursa Major, Ursa Minor, Cassiopeia, Cepheus, Draco, and Camelopardalis. If you live in Hawaii, southern California, and Texas, along the Gulf of Mexico, or in Florida, portions of some of these constellations may dip below the horizon at times, technically disqualifying them as circumpolar. If you live in Alaska, northern Canada, Europe, or Asia, then more constellations will be in your circumpolar zone. Indeed, from the North Pole, all constellations that are visible are circumpolar, since none rise or set (likewise from the South Pole, although the other half of the sky is visible).

In addition to rotating on its axis, Earth also revolves around the Sun, taking one year to complete the trip. We call this *annual motion.* It takes Earth 365 days 5 hours 49 minutes to complete a revolution of the Sun, at an

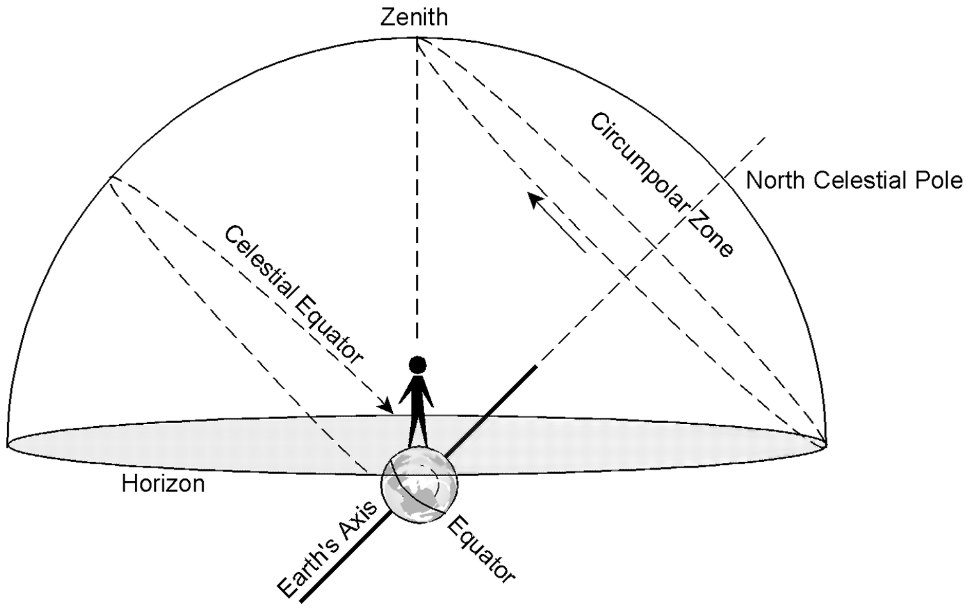


Figure 1.4 *As Earth completes a rotation once each day, celestial objects appear to rise in the eastern part of the sky and set toward the west. Only stars that lie exactly on the celestial equator rise exactly in the east and set exactly west. Stars that are within the circumpolar region appear neither to rise nor set, but instead to remain above the horizon all night along. Centered in the circumpolar zone is the celestial pole, the projection of Earth's axis against the celestial sphere. Right now, the North Celestial Pole is aimed almost exactly at Polaris, the North Star.*

average speed of 66,500 miles (107,000 kilometers) per hour or 18.46 miles (29.73 kilometers) each second!

Annual motion also opens our sky window onto different stars and constellations at different seasons of the year. Those stars and constellations seen on winter evenings, for instance, are called the winter stars, and are completely different from those visible on summer evenings. During the summer and winter months, the night side of Earth is aimed toward different portions of the plane of our galaxy, where the gentle rifts of the Milky Way stretch across the sky to give spectacular views of rich star clouds and subtle nebulae. The spring and fall skies open away from the obscuring dust clouds of our galaxy to reveal a universe that is full of other distant galaxies. Figure 1.5 shows Earth in its annual trek around the Sun as compared with the seasonal constellations.

Finally, Earth also wobbles like a toy top in a motion called *precession*. If you've spun a top, you know that its axis of rotation is usually perpendicular to the surface on which it is spinning. But give it a slight nudge and the top will begin to tip over. Still spinning, the top attempts to right itself, in the process causing its axis of rotation to trace out a circle. The combined effect of Earth slightly bulging at the equator, combined with gravitational nudges from the Sun and the Moon, has nudged Earth enough to set it into a slow

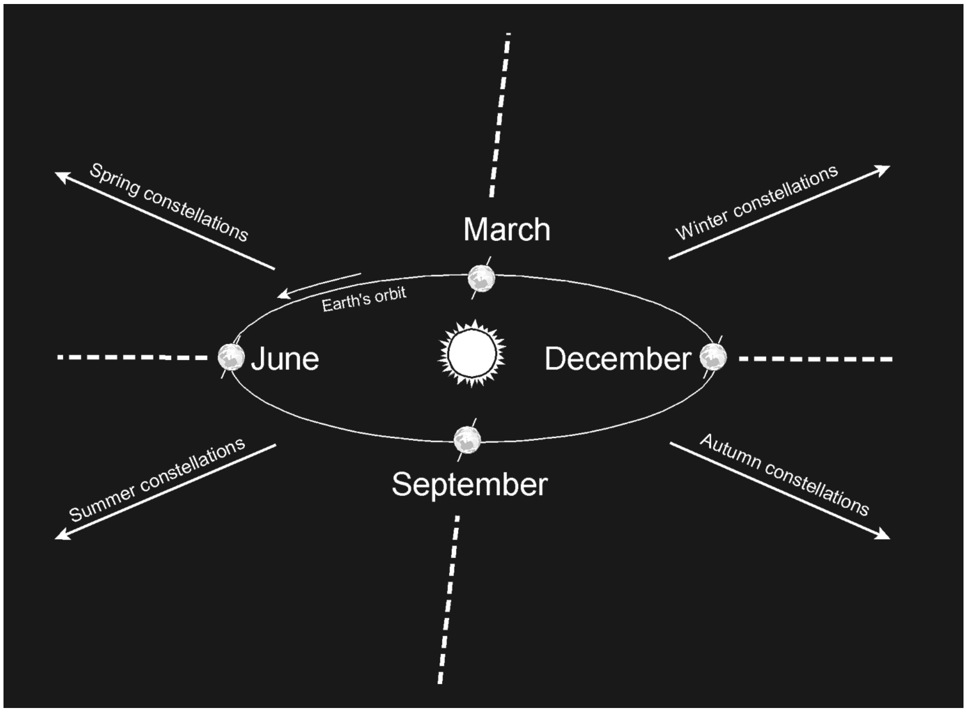


Figure 1.5 *Although Earth's axis remains aimed toward the celestial poles, our planet's revolution around the Sun turns our night sky toward different parts of the universe during different times of the year. This diagram shows Earth's positions relative to the Sun and background constellations at four separate points during its orbit.*

wobble. Precession is barely noticeable compared to our planet's rotation and revolution, taking some 26,000 years for Earth to complete just one twist. While this shift cannot be detected with the naked eye over the brief course of a human lifetime, the change is obvious across the span of human history. Right now, the Earth's North Celestial Pole is aimed almost directly at the star Polaris, also known as the North Star. But back in the time of ancient Egypt, the pharaohs saw the night sky turning about the star Thuban in our constellation Draco the Dragon. In 13,000 years, the star Vega in the constellation Lyra will be closest to the North Celestial Pole.

Star Brightness

When astronomers talk about how bright something appears in the sky, they are referring to that object's *magnitude*. The magnitude system dates back over 2,000 years to the Greek astronomer Hipparchus, who was first to survey the night sky and devise a system for categorizing stars according to their brightness. His method was quite simple. The brightest stars visible to the eye were labeled 1st magnitude, while the faintest stars were 6th magnitude. The remaining stars fell somewhere in between. In the Hipparchus magnitude system, the larger the magnitude number, the fainter the star. The magnitude system in place today is far more precise but still strongly reminiscent of Hipparchus's. We still use the basic 1st-through-6th magnitude designations, but we now specify that a 1-magnitude jump (say from 1st to 2nd, or 2nd to 3rd) corresponds to a change in brightness of 2.5 times. Therefore a 1st-magnitude star is 2.5 times brighter than a 2nd-magnitude star, while a 2nd-magnitude star is 2.512 times brighter than a 3rd-magnitude star. By this method, a 1st-magnitude star is about 6.3 times brighter than a 3rd-magnitude star ($2.512 \times 2.512 = 6.310$), about 15.8 times brighter than a 4th-magnitude star ($2.512 \times 2.512 \times 2.512 = 15.85$), about 40 times brighter than a 5th-magnitude star ($2.512 \times 2.512 \times 2.512 \times 2.512 = 39.81$), and so on. A 5-magnitude jump, say from 1st to 6th magnitude, equals a change in brightness of exactly 100 times.

Astronomers of the nineteenth century refined and expanded Hipparchus's magnitude system to include the very brightest and very faintest celestial objects, so the scale doesn't stop at 1st or 6th magnitude. A zero-magnitude object is 2.512 times brighter than a 1st-magnitude object, while negative-value objects are brighter still. The Sun, for instance, is magnitude −26. At the same time, stars that are too faint to be seen with the naked eye have magnitude values greater than 6th magnitude. As you can see from Figure 1.6,

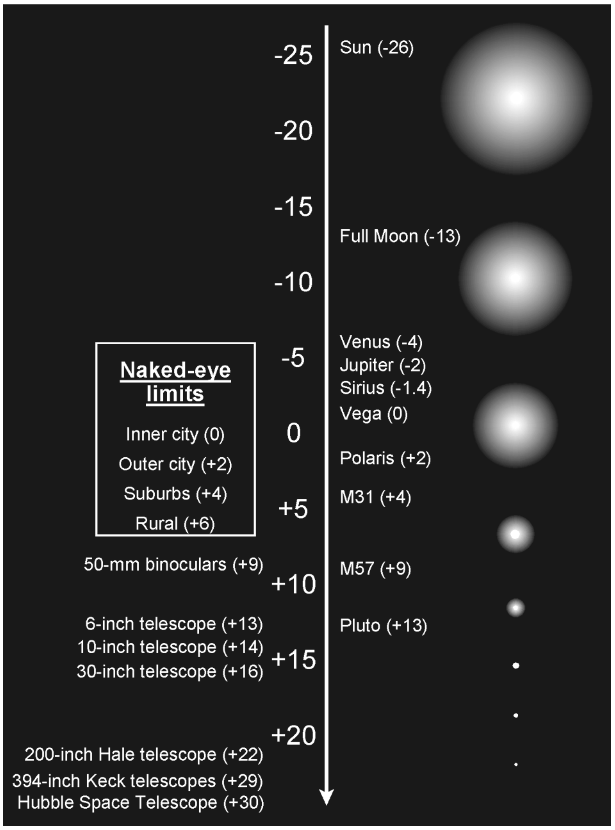


Figure 1.6 *The magnitude scale. The Sun, the brightest object in the sky, rates magnitude −26, while the faintest stars ever photographed through the Hubble Space Telescope are rated magnitude +30. Out in the countryside, the human eye can detect stars as faint as magnitude +6 (possibly fainter under extraordinary conditions) but may only see stars to magnitude 0 or +1 from cities because of light pollution.*

binoculars reveal stars to about 9th magnitude, a 6-inch (15-cm) telescope to 13th magnitude, and larger telescopes deeper still. The Hubble Space Telescope can record stars as faint as 30th magnitude, about 19 billion times fainter than the Sun!

Magnitudes only refer to how bright objects appear in our sky. Just because a star looks bright in the sky doesn't mean that it is big, of course. For example, the Sun is the brightest object in our sky, but pull back an appreciable distance and it quickly disappears into the crowd. The Sun is only bright because it is so close. A star's apparent brightness, or magnitude, depends on two factors: its intrinsic luminosity and distance. To express a star's true brightness, astronomers use the term *luminosity.* The luminosity scale uses the Sun as its baseline value of 1.0. Stars with luminosities greater than 1.0 are intrinsically brighter than the Sun, while those less than 1.0 are dimmer. Sirius, the brightest star in the sky, has a luminosity of 24, meaning that it is 24 times more luminous than the Sun, while the star Deneb in Cygnus has a luminosity of 24,000. So why does Sirius look brighter in our sky than Deneb? Measurements show that Sirius lies only 9 light-years away, while Deneb is more than 3,200 light-years from us.

Star Sizes and Distances

The sizes of stars, planets, and other objects are referred to in two different ways. One is a measure of their actual size. The Moon, for instance, measures 2,159 miles across (3,476 kilometers), while the Sun is 864,400 miles (1,392,000 kilometers) in diameter, and so on.

Apparent size, or how large something appears in the sky, is expressed in angular degrees, which can be further divided into arc-minutes and arc-seconds. Figure 1.7 offers an example. The Andromeda Galaxy apparently spans 5° in length in photographs. This is considerably more than the Moon or Sun, each of which measures half a degree, or 30 arc-minutes (abbreviated 30'). Sky objects that are even smaller than 1 arc-minute are measured in arc-seconds. There are 60 arc-minutes (60') in 1 degree and 60 arc-seconds in 1 arc-minute.

Values in miles and kilometers quickly become too cumbersome to use when talking about the actual distances to the stars, so astronomers refer to distances in *light-years*. One light-year is equal to the distance that a beam of light would travel in space in one Earth year, more than 5.87 trillion miles (9.45 trillion kilometers), or 186,000 miles per second (300,000 kilometers per second)! The Andromeda Galaxy, usually regarded as the most distant object visible to the naked eye, lies about 2.9 million light-years away. That means the light we would see from it tonight, traveling at 186,000 miles every second, took 2.9 million years to get here! That translates to a distance of 17 billion miles (27.4 billion kilometers)!

Astronomers use very precise tools to measure apparent sizes of and distances between objects in the sky with great accuracy, but you and I were born with a handy tool that we can use to approximate those same values. It's your hand! Take a look at Figure 1.8. It turns out that the ratio of the size of the human hand to the length of the arm is proportional for everyone,

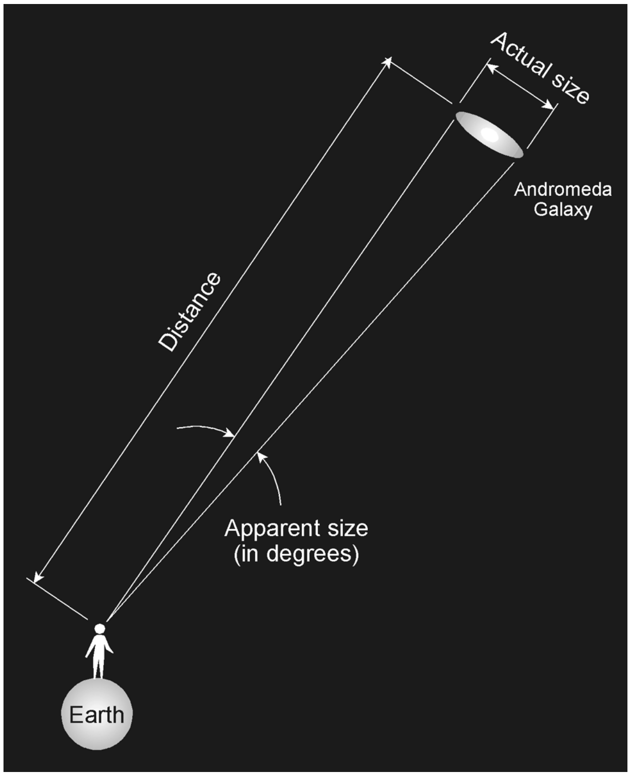


Figure 1.7 *How large an object appears in our sky, called its apparent size, depends on two factors: its actual size and its distance away. Despite its great distance, the Andromeda Galaxy M31 spans close to 5° in our sky because it is physically very large.*

regardless of age or gender. For instance, at arm's length, your fist covers 10°. Your middle three fingers extended as in a Scout salute cover 5° of sky, the same span as the pointer stars at the end of the bowl of the Big Dipper. The span between your pinky finger and forefinger equals 15°, while the span between your thumb and pinky equals 25°. (Note that some people can stretch their hands more than others, which may throw this last measurement off a bit. To find out your hand span, hold it up against the Big Dipper. If your finger and thumb can cover its length fully, your span is 25°; a little less, and it's probably closer to 20°.)

When you get to the later chapters that discuss each seasonal sky, remember this "handy" method for finding distances between stars and constellations. It makes getting around the sky much easier.

Star Positions

If you were to give me directions to your home, you might take me from a major highway or thoroughfare to a secondary road, and finally to your street and house number. That is pretty much how most amateur astronomers find objects in the sky. They begin at a major constellation, travel to a particular star in the pattern, then follow fainter stars to the target itself. This technique, called *star hopping,* is discussed later in this chapter.

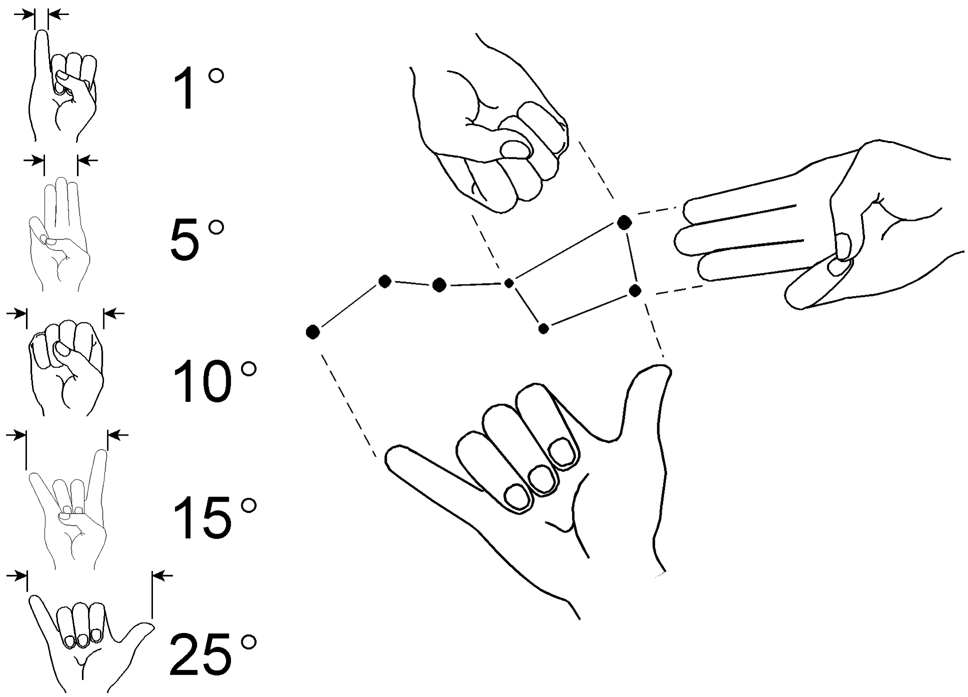


Figure 1.8 *The human hand is a useful tool for estimating distances in the sky.*

While these methods work fine out in the field, they can be cumbersome when trying to list either an earthly location or celestial object in a data catalog. Instead, geographers have divided up Earth into a north-south and east-west coordinate system called latitude and longitude, respectively. Astronomers have similarly divided up the sky into a north-south, east-west coordinate system. Rather than use longitude and latitude, celestial coordinates refer to *right ascension* and *declination*.

Let's look at declination first. Just as latitude is the measure of angular distance north or south of the Earth's equator, declination (abbreviated Dec.) specifies the angular distance north or south of the *celestial equator*. The celestial equator is simply the projection of Earth's equator up into the sky. If we were positioned at 0° latitude on Earth (the equator), we would see 0° declination pass directly through the zenith, while 90° north declination (the North Celestial Pole) would be overhead from the Earth's North Pole. From our South Pole, 90° south declination (the South Celestial Pole) is at the zenith.

As with any angular measurement, the accuracy of a star's declination position may be increased by expressing it to within a small fraction of a degree using arc-minutes and arc-seconds:

$$
\begin{aligned}
1 \text{ degree } (1^\circ) &= 60 \text{ arc-minutes } (60') \\
&= 3{,}600 \text{ arc-seconds } (3{,}600'')
\end{aligned}
$$

Right ascension (abbreviated R.A.) is the sky's equivalent of longitude. The big difference is that while longitude is expressed in degrees, right ascension divides the sky into twenty-four equal east-west slices called "hours." Quite arbitrarily, astronomers chose as the beginning or zero-mark of right ascension the point in the sky where the Sun crosses the celestial equator on the first day of the Northern Hemisphere's spring. A line drawn from the North Celestial Pole through this point (the vernal equinox) to the South Celestial Pole represents 0 hours right ascension. Therefore, any star that falls exactly on that line has a right ascension coordinate of 0 hours. Values of right ascension increase toward the east by 1 hour for every 15° of sky crossed at the celestial equator.

To increase precision, each hour of right ascension may be subdivided into 60 minutes, and each minute into 60 seconds. In other words:

$$\begin{aligned} \text{1 hour R.A. (1 h)} &= \text{60 minutes R.A. (60 m)} \\ &= \text{3,600 seconds R.A. (3,600 s)} \end{aligned}$$

Unlike declination, where a minute of arc does not equal a minute of time, a minute of R.A. does.

A star's celestial coordinates do not remain fixed forever. Recall that Earth wobbles in a 26,000-year cycle called precession. Throughout the cycle, the entire sky floats behind the celestial coordinate grid. While this shifting is insignificant from one year to the next, astronomers find it necessary to update the stars' positions every fifty years or so. That is why you will notice that all right ascension and declination coordinates are referred to as "epoch 2000.0" in this book and most other contemporary volumes. These indicate their exact locations at the beginning of the year 2000, but they will remain accurate enough for most purposes for several decades to come.

A Survey of the Sky

Many sky objects are perfect targets for binoculars and backyard telescopes. Some are better seen through telescopes, others through binoculars, but all have intrinsic beauty and interest.

When describing objects in the following chapters, I've attempted to answer five fundamental questions we all have when looking through a telescope:

1. What can I see?
2. When and where should I look?
3. How can I find it?
4. What does it look like?
5. What am I looking at?

What Can I See?

The first question most new telescope owners ask is: "Okay, so what can I see through my telescope?" The short answer is "Plenty!" We begin by venturing into our immediate neighborhood, the solar system, with the first stop at

Earth's nearest neighbor in space, the Moon. Whether you use a telescope, binoculars, or gaze skyward with your eyes alone, the Moon is a familiar part of the night sky. It is the only object in the night sky that reveals surface details to the naked eye. Binoculars and telescopes expand on this to show a spectacular sight, with literally hundreds of lunar features coming into view as the Moon progresses through its phases. Witnessing for yourself the stark beauty of the Moon up close is an overwhelming experience.

Next, we will explore our solar system. Each of the five naked-eye planets—Mercury, Venus, Mars, Jupiter, and Saturn—has something to offer. Even if you only have a 2-inch (5-cm) telescope, you can see the phases of Venus, the moons and cloud belts of Jupiter, the rings of Saturn, the Martian polar caps, and even the distant disks of Uranus and Neptune. Only lonely Pluto is missed; for that, you will need at least a 6-inch (15-cm) telescope.

Our survey of the solar system would hardly be complete without a visit to our star, the Sun. But always be careful when viewing the Sun, since it is the only celestial object that can actually cause you physical harm. Without proper precautions, its intense radiation can burn your eyes' retinas just as it can burn your skin, but much more quickly. There are many ways to view the Sun safely, as described in chapter 4.

Finally, we leave the confines of our solar system to explore the seemingly limitless boundaries of the universe. Even the smallest binoculars and telescopes can show dozens of deep-sky objects, including binary and variable stars, star clusters, nebulae, and galaxies. And this book will get you to them!

Star Identification

It's an awfully big universe, so before venturing out, let's look at how sky objects are identified. For thousands of years, stars have been grouped into large patterns that we call constellations. There are eighty-eight constellations in all, listed alphabetically in Appendix A. Our ancient ancestors created most of these fanciful star pictures as they gathered their families at night to tell exciting myths and legends about some amazing creatures and beings. Storytellers would illustrate their narratives using figures drawn among the stars. In reality, the stars that make up a constellation have no real relationship to one another and are more than likely tens or hundreds of light-years away from one another in space. Nobody knows who described the first constellation, but most come to us from ancient Greece, Rome, Egypt, Persia, and Babylonia. Other cultures, such as Native Americans and those of the Orient, also made up constellations, but they were quite different from the more familiar, western ones.

Astronomers use the traditional constellations as helpful guides for locating and naming stars and other sky objects. Every object has been assigned to a home constellation, even though it may not contribute to the constellation's figure. Picture the night sky as a community divided into plots of land. The owner of each plot then builds a house on his or her land. In this analogy, the house refers to a constellation's recognizable figure, while the property that surrounds the house can be thought of as each constellation's boundaries.

In 1603, only a few short years before the invention of the telescope, the astronomer Johannes Bayer created that era's most detailed atlas of the night sky, which he called *Uranometria.* He chose to identify the brightest stars in each constellation by lowercase letters from the Greek alphabet. He usually labeled a constellation's brightest star alpha, then, working his way through the traditional constellation pattern from head to toe, labeled succeeding stars beta, gamma, and so on. Once completed, he repeated the head-to-toe sequence for any fainter stars that remained, sometimes until all twenty-four letters of the Greek alphabet were used. There are many exceptions to this pattern, but it holds true for the most part. Bayer's Greek letters stuck and are still in use today. Table 1.1 lists the Greek alphabet by name and corresponding letter.

In order to extend the Greek alphabet system, the British astronomer John Flamsteed assigned numbers to all stars of about 5th magnitude and brighter in each constellation. These Flamsteed numbers begin at 1 in each constellation and increase from west to east. Fainter stars have subsequently been inventoried in other lists.

Many of the brightest stars in the night sky also have beautiful and mysterious-sounding names, such as Betelgeuse, Capella, Aldebaran, and Vega, which come to us from antiquity.

So some stars have three names. The bright star Vega is called Alpha Lyrae in Bayer's system and 3 Lyrae in Flamsteed's catalog, while nearby Albireo is also known as Beta Cygni and 6 Cygni. ("Lyrae" and "Cygni" are the genitive forms of the constellation names Lyra and Cygnus, respectively.)

Nonstellar deep-sky objects are cataloged numerically. While some of the more spectacular examples have unofficial nicknames (such as the Orion Nebula or the Andromeda Galaxy), most do not. The most famous deep-sky index of all is the Messier catalog, compiled by Charles Messier, the eighteenth-century French comet hunter, shown in Figure 1.9. Among the more celebrated members of the Messier catalog are M1, the Crab Nebula; M8, the Lagoon Nebula; M13, the Great Hercules Globular Cluster; M31, the Andromeda Galaxy; M42, the Orion Nebula; M45, the Pleiades; and M57, the Ring Nebula. The Messier catalog lists 109 of the finest nonstellar objects in the sky. Although Messier did not discover all of "his" objects (many were first spotted by his contemporary Pierre Mechain), he is credited with creating the catalog that bears his name. He numbered the objects consecutively, starting with M1, based on the order in which they were added to the catalog. (The list

Table 1.1 ***The Greek Alphabet***

alpha	α	eta	η	nu	ν	tau	τ
beta	β	theta	θ	xi	ξ	upsilon	υ
gamma	γ	iota	ι	omicron	o	phi	φ
delta	δ	kappa	κ	pi	π	chi	χ
epsilon	ϵ	lambda	λ	rho	ρ	psi	ψ
zeta	ζ	mu	μ	sigma	σ	omega	ω

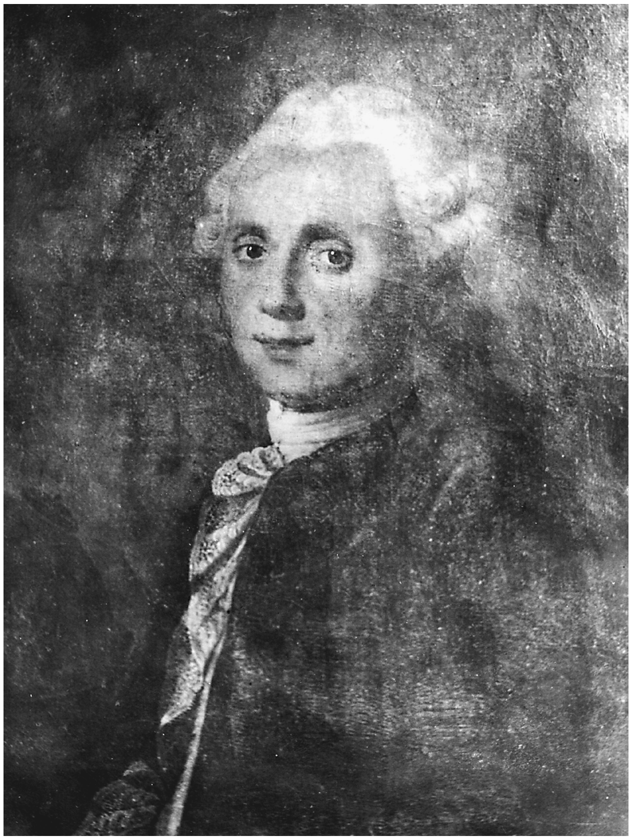


Figure 1.9 *Portrait of Charles Messier (June 1730–April 1817), as painted by Desportes in March 1771. Of this portrait, Messier wrote, "This is a good likeness, except that I appear younger than I am, and I have a better expression than I have." Courtesy of Owen Gingerich.*

actually goes up to M110, but it is now generally agreed that M102 was a mistaken repeat observation of M101.)

Oddly enough, Messier assembled his listing not in an effort to record the locations of deep-sky objects, but rather to record the locations of annoying cometlike objects that hindered his comet-hunting efforts. Ironically, while all of the comets discovered by Messier have long since faded into oblivion, his catalog of 109 "nuisance" objects was what became famous, and it continues to challenge amateur astronomers to this day.

Finding all of the Messier objects is a great first observing project for new amateur astronomers. All 109 Messier objects are included in the seasonal chapters of this book. You and I are about to go Messier hunting! Now, before you say "wait a minute, I only have a small telescope," let me assure you that finding all of the Messier objects can be done with small amateur telescopes used in suburban backyards. If you live in a city, I'm afraid that you might have to travel to darker skies to see some of them, although Messier actually spotted each from a hotel rooftop in downtown Paris (but before light pollution) through telescopes no greater than 6 inches (15 cm) in aperture. Today, some amateurs complete the project with telescopes half that size.

The most comprehensive digest of deep-sky objects is the *New General Catalog of Nebulae and Clusters,* abbreviated NGC and compiled by John L. E. Dreyer in 1888. The NGC lists more than 7,800 star clusters, nebulae, and galaxies covering the entire celestial sphere. All entries are ordered by increasing right ascension. With few exceptions, all of the Messier objects are also included in the NGC. The Orion Nebula M42, for instance, is also known as NGC 1976. Dreyer subsequently assembled a pair of supplementary *Index Catalogs* (IC) that included new objects discovered after the NGC was published. Many other deep-sky inventories have been compiled since the NGC and IC listings. While the Messier, NGC, and IC listings are general compilations, most newer catalogs are segregated by object type.

When and Where Should I Look?

The combined motions of Earth rotating on its axis and revolving about the Sun opens for us a different sky window hour by hour, as well as season by season. At the same time, the other members of the solar system are also on the move. The Moon takes about a month (actually 29.5 days) to go through its sequence of phases as it orbits Earth. Each planet orbiting the Sun can also be seen to move slowly through the sky. Mercury, the fastest, takes 88 days to orbit the Sun, and so it quickly transfers from the evening sky to the early morning sky, and back again, over a period of less than three months. At the opposite end of the scale, Pluto takes more than 248 years to revolve around the Sun. To find out which, if any, planets are visible in tonight's sky, consult Appendix B, which lists the planets' positions to the year 2015. A planetary conjunction (Figure 1.10) occurs when either two planets or a planet and the Moon appear very near each other in our sky. Conjunctions can be quite striking, whether seen through binoculars or just with the naked eye.

Beyond our solar system, each seasonal sky contains its own stars, constellations, and hidden treasures. The sky show that we enjoy on a warm summer evening, for instance, is totally different from that adorning frigid winter nights. The seasonal charts in chapters 6 through 9 will help you find out which stars will be visible in tonight's sky. Each begins with an introduction to the naked-eye sky of that season, pointing out the more prominent stars and constellations, which are also plotted on an accompanying star map. A timetable at the bottom of each map shows the hour of night depicted. For those who prefer to do their stargazing in the early morning hours instead (since that is when lower levels of light pollution often make the sky darker), each key includes times well into the early morning. A general rule to remember is that a star or constellation rises two hours earlier every month. For instance, the spring seasonal map shows the sky as it appears on June 1 at 8 P.M., as well as December 1 at 4 A.M., and several points in between. At the same time, the stars of summer are seen on May 1 at midnight.

From here, the four chapters break the seasonal skies into several detailed "sky windows." Each window is an enlarged area of the sky that plots selected deep-sky targets as well as stars to 7th magnitude. Although that's too faint to be visible to the eye alone, these stars are readily visible with binocu-

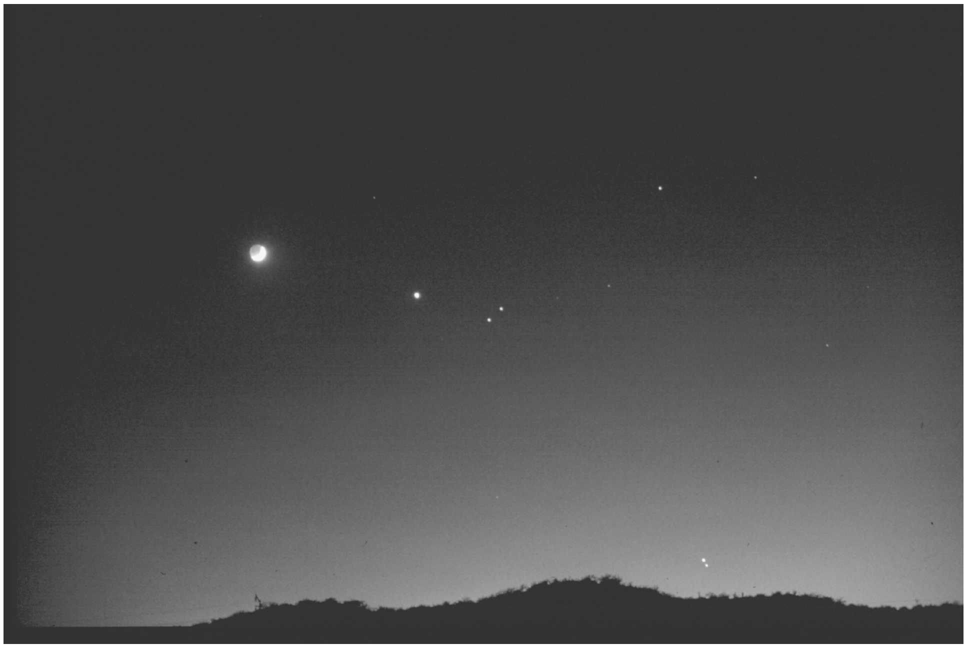


Figure 1.10 *Mercury is but one of four planets in this photograph. On the bottom are Mercury* (right) *and Jupiter* (left), *in the middle is Mars* (right) *and the star Regulus* (left). *Finally, in between Regulus and the crescent moon is brilliant Venus. Photograph by Brian Kennedy.*

lars and finderscopes (small, low-power, spotting scopes mounted piggyback on telescopes that help the observer aim toward a target). A key map is included in each of the chapters to show where the sky windows are located with respect to each other as well as relative to the entire night sky.

How Can I Find It?

To those new to stargazing, the naked-eye sky is tough enough to sort out. How can someone find a small, faint object buried in among all of those stars? To give you beforehand an idea of how easy or difficult an object might be to see through your telescope, I have assigned each target a "Finding Factor" to indicate just how difficult each object is to find through a small, manually operated telescope. If an object has a Finding Factor of one star, then locating it is a piece of cake. The more stars listed under the heading Finding Factor, the tougher the hunt. A target rated at a Finding Factor of five stars will probably require some fairly intense searching. Leave those until you have already bagged easier prey and developed some experience with star hopping.

"Where Am I" gives both written directions as well as matching sky windows. While some telescopes have computerized aiming systems, most readers will probably use the old tried-and-true method of star hopping. Star hopping involves going from a naked-eye jumping-off point, such as a bright star, to a faint target in a series of hops from one star or star pattern to the next. It's a great way to get to know the sky and your telescope at the same time.

Here on Earth, we are used to giving directions like left, right, up, and down, but these directions are of little use in the sky. One of the most confusing parts of viewing the sky is trying to orient star charts to agree with the stars. Which way is up? That all depends on where you are facing. Figure 1.11 shows that, depending on what direction you are facing, you will need to rotate star charts, such as those found later in this book, either clockwise, counterclockwise, or upside down. (Note that this is common to all star charts, not just those found in this book.)

To add to the confusion, most telescopes and finderscopes flip the view around, sometimes turning it upside down, other times flipping it left-to-right. Take a look at Figure 1.12 and see which view corresponds with your telescope. Remember that orientation will also depend on where you are relative to the eyepiece. If you are standing to the right side of the telescope, the view will be upside down compared to how it looks on the left side of the telescope, regardless of its design.

Once you have aligned the finder to the telescope and oriented yourself to the sky, the fun can begin. The Moon and the planets should be easy to find, if any are visible in the night sky. To help you plan your observing sessions,

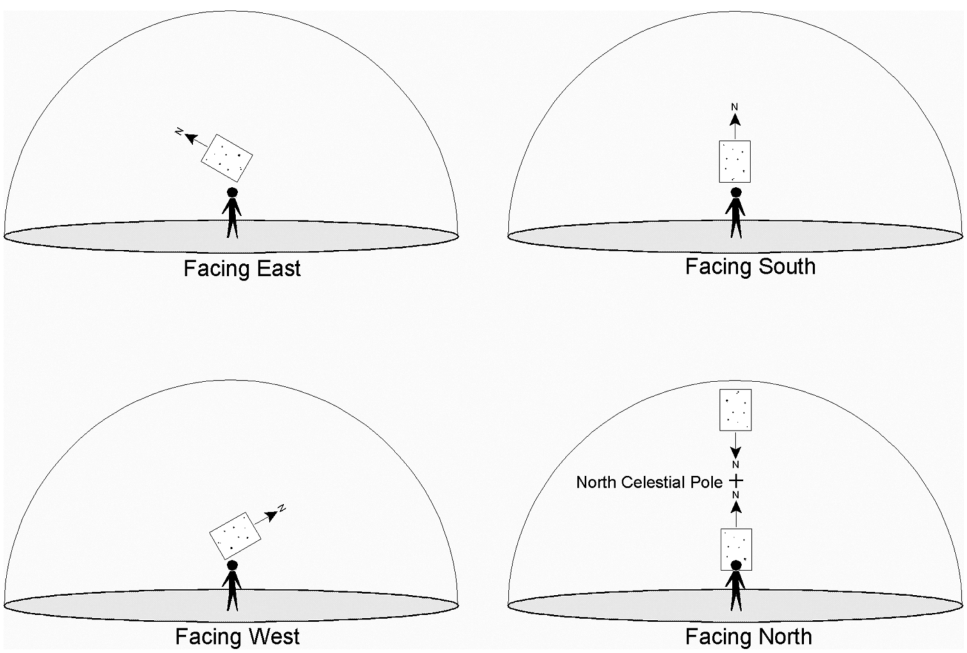


Figure 1.11 *To use a star chart correctly, it must be turned to agree with the direction that the observer is facing.*

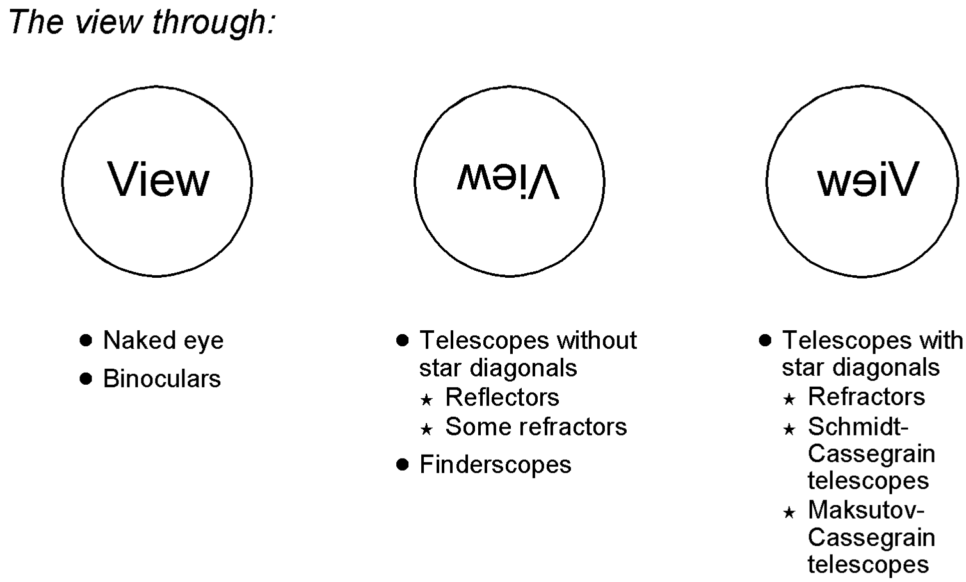


Figure 1.12 *While binoculars orient their views to agree with what our eyes actually see, all astronomical telescopes flip images around in one manner or another. Depending on the design, the image may be turned upside down or flipped left to right.*

the appendices include lists of the Moon's phases and positions of the five naked-eye planets through the year 2015.

What about locating fainter deep-sky objects? Each of the sky windows in the later chapters, as well as each object description, features a suggested star-hopping path to follow. Each star-hop casts off from a naked-eye star, constellation, or pattern, then proceeds across a portion of the sky toward the target. Along the way, star patterns such as triangles, arcs, and rectangles serve as signposts to tell you that you are on the right track. By switching back and forth between your finderscope and the sky window, you can hop from one star or star pattern to the next across the gap toward the intended target. Don't worry if you get lost along the way. Just return to the starting point and try again.

Here's an example. Let's go hunting for M1, the famous Crab Nebula in Taurus the Bull. It was Messier's first object in his list, so let's let it be ours as well. Insert your lowest-power eyepiece (remember, the longer the eyepiece's focal length, the lower its magnification), since it also has the widest field of view, which is what is needed when searching for a new target. Next, take a look at Figure 1.13. M1 is in Taurus the Bull, so the first thing to do is to find that constellation. Figure 1.13a shows M1 lies just to the west-northwest of the star Zeta Tauri, which marks one of the Bull's two horns. Step two is to aim your telescope toward that star in the sky, as shown in Figure 1.13b. Chances are your finderscope flipped the view upside down compared with what your eye alone sees. Remember to orient your finder chart to match the view.

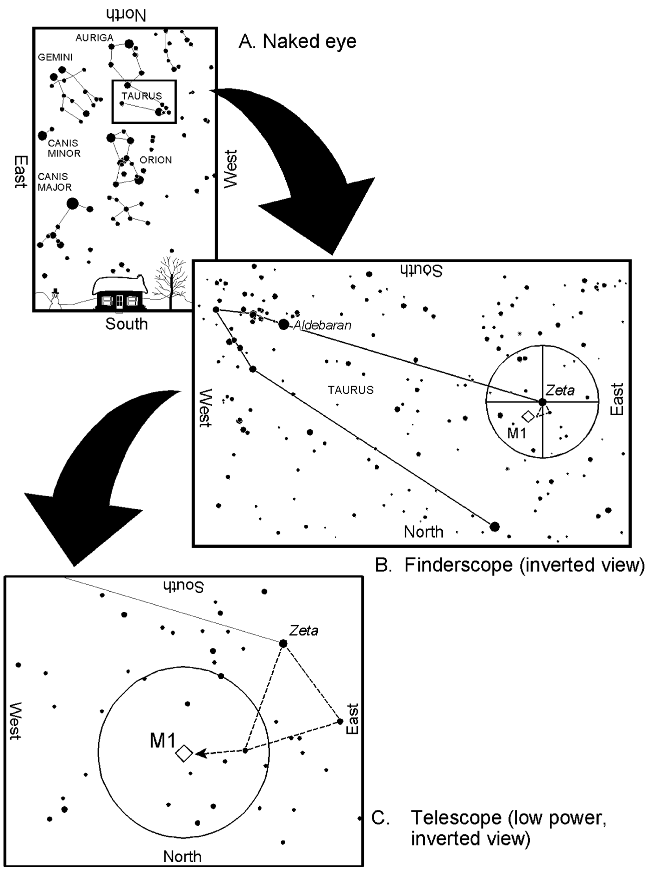


Figure 1.13 *Star hopping is the preferred way of locating sky objects that are too faint to be seen with the eye directly. Here is the three-step approach for finding M1, the Crab Nebula in Taurus the Bull. (a) Locate the constellation or nearby naked-eye star pattern. (b) Aim your finderscope toward a known star, then star hop to fainter stars that are closer to the target. (c) Finally, look through your telescope for the target.*

Figure 1.13b is flipped around for you to illustrate the change, but you may still need to rotate it left or right to match what you are seeing exactly.

Once Zeta is centered in the finderscope, check to see that it is also in your telescope's field of view. If it isn't in there, your finderscope is probably misaligned. Double-check the finder's alignment, then try again. With Zeta in the finder, look to its north for two faint stars that join with it to form a small right triangle. See them? Good. M1 lies just to their west.

Time to switch to your telescope. Use your lowest-power eyepiece to match Figure 1.13c. Find Zeta and those two stars that form the right triangle. Slide slightly to their west. Which way is west? Look at the chart and notice the directions along its edges. Remember, the view is probably upside down, so take a moment to orient yourself. Looking through a telescope, you should see a faint smudge of light in the position marked by the diamond in the figure. That's M1. If you don't see it, move the telescope back and forth, and up and down *just a little* to see if it's nearby. If it still isn't, check the finder to make sure you have aimed it toward the correct star.

What Does It Look Like?

I have also given each target a "WOW!" Factor to provide an indication of how spectacular an object will appear through binoculars or a telescope. Here I have chosen to rate objects not just through one, but rather through three different instruments: binoculars, small telescopes, and medium telescopes. Binoculars refer to typical 50-mm units, such as 7 × 50s and 10 × 50s. Small telescopes are defined as apertures between 3 inches (7.5 cm) and 5 inches (12.5 cm), while medium telescopes range from 6 inches (15 cm) to 8 inches (20 cm) in aperture. Telescopes larger than 8 inches (20 cm) in aperture, usually owned by intermediate and advanced amateurs, will give wonderful views of all the objects described in this book. The "WOW!" Factor uses a one-to-four-star grading system to judge an object's beauty and interest. The more stars, the more visually appealing the object. Objects noted as not resolvable are not visible through that particular instrument.

Each object is described as you would see it through binoculars and telescopes. Many new stargazers are disheartened to learn that their telescopes will not show sky objects as they are depicted in the brilliant color photographs that often adorn the outsides of their telescope boxes. Sorry, that is the sad reality. But just because the view doesn't look like the backdrop of a space science-fiction movie doesn't mean that astronomy is not for you. Quite the contrary. You will find, as I did over the years, that what appears to be a vague, formless mass at first will often transform into a striking sight after concentrated study. So, take heart. If an object appears uninteresting at first, give it some time. If you study each object carefully, using some of the tricks and techniques described in this book, then you will be amazed at what you can see. Best of all, you are seeing it live through your own telescope or binoculars, not in some sanitized photograph. That thrill and sense of accomplishment can never be captured in a photograph.

All observers have had those moments, however, when, even after great care has been taken to aim toward an intended target, it simply isn't there. No matter how often you go back and forth to one of the charts, the object just isn't there. It can drive you nuts! But just because something isn't there at first pass doesn't mean that it is time to move on to another object. Here are a few secrets that may help render an invisible object visible.

Many observers overlook the simple need to let their eyes become accustomed to darkness before searching for faint objects. While most people's eyes partially adapt in about 20 to 30 minutes, the entire process can take an hour or more to complete. Plan your night's observing program so that brighter objects are viewed first. Wait at least an hour before you begin to search out those faint fuzzies that are just on the brink of visibility.

Next comes patience. Take a deep breath and slow down! Just because an object doesn't reveal itself immediately doesn't mean that it won't after a few minutes of concentrated searching. If eye fatigue sets in, move away from the eyepiece and take a short break.

If a faint object refuses to be seen when stared at directly, try looking at it with your peripheral vision. This technique, called *averted vision,* can be very successful for spotting deep-sky objects. With peripheral vision (that is, looking to one side or the other of the target being observed), light falls on a more sensitive part of the eye's retina. Frequently, objects that are invisible when viewed directly will be seen with averted vision.

Of course, even averted vision won't make much difference if the sky isn't clear and dark. Nothing short of clouds can ruin the sky more than *light pollution,* the curse of the modern astronomer!

There are two kinds of light pollution: sky glow and local light pollution. Sky glow is general light pollution that comes from buildings, streetlights, roadside billboards, floodlights, and civilization in general. It can turn a beautifully clear day into a soupy, grayish night. Can anything be done to combat sky glow? The good news is yes, but progress is slow. In an attempt to recapture one of our greatest natural wonders, the night sky, some municipalities have enacted legislation against overlighting. Connecticut became the first state to pass statewide parameters restricting nighttime lighting. Similar legislation has been advanced in other states as well. Will these light-pollution laws make a difference in our view of the night sky? Only time will tell, but it is a step in the right direction.

Localized light pollution, such as from a streetlight or porch light, is a little easier to deal with. To help combat this distraction, use a personal cloaking device, which is nothing more than a piece of dark cloth placed over your head and eyepiece, like an old-time photographer's shroud. The only drawback to the cloaking device is that in damp weather it tends to accelerate eyepiece fogging.

What Am I Looking At?

Astronomers have been asking this all-important question since the dawn of time. What exactly are we looking at when we view these objects? Each of the chapters to come includes a discussion of the latest findings about each target. But it seems at times that the more we learn about these celestial objects, the more questions we need to ask. That is perhaps the most compelling part of astronomy.

The night sky holds a lifetime's worth of fascination for stargazers. Whether you own binoculars or a telescope, or if you live in the city, the suburbs, or the country, there is always something new to look at. Before dashing off to your telescope, however, review the chapters to come, especially the one that covers the night sky as it will appear tonight. Take a look at the sky objects on tonight's menu and start with the brighter offerings. If the Moon or a planet is visible, that's an excellent beginning. Then, work your way through the deep-sky objects. Take your time and enjoy the view.