chapter 1

Introduction to the Sky

On a dark night well away from the city, the sky seems to explode with stars. To help orient themselves, ancient skywatchers named the brightest objects—names we still use today. In more modern times, astronomers have cataloged thousands of stars and deep-sky objects, and fixed their positions on a celestial grid.

Scientists have also learned the sizes and distances of most of the objects we observe. Of course, all this knowledge does observers little good if the glow from city lights hides the sky from view. Finding a good viewing site can take some effort, but it's worth it. You'll often find some of the best observing at "star parties" attended by fellow skygazers.

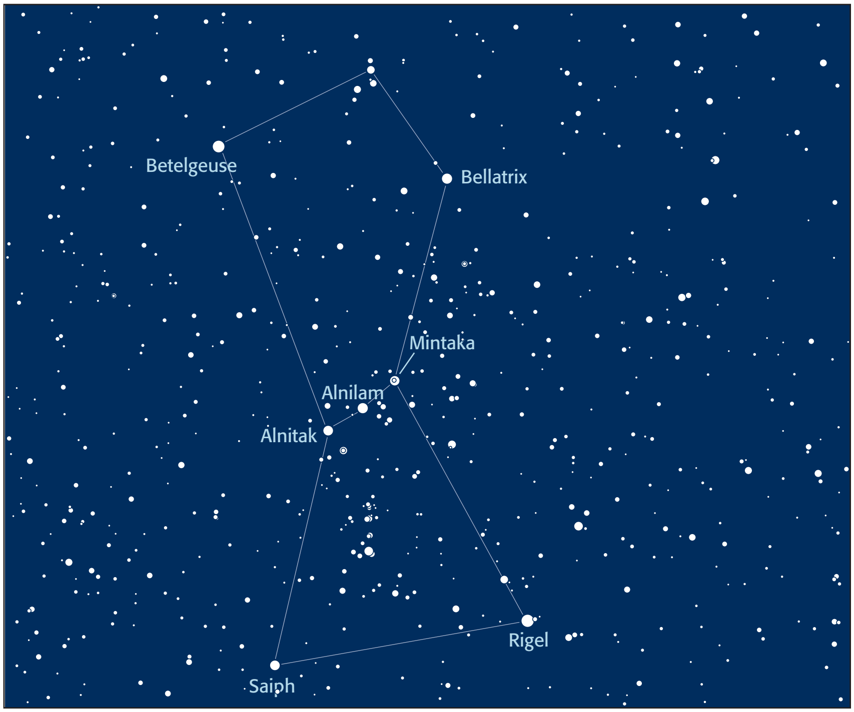
Star Names

What's that bright star over there? If you spend much time observing the night sky, you're bound to hear this question over and over. Once you become familiar with the starry canopy, the answer will come to you almost immediately. "Why, that ruddy star hanging low in the south is Antares, and that gleaming white star overhead is called Vega." Most star names commonly used today came from the Arabic language, although many of these names originated with the ancient Greeks.

Common star names abound throughout the heavens, although most remain far from household names. Orion the Hunter has many outstanding traits, not least among them the fact that all of its bright stars have well-known monikers. Betelgeuse, which marks Orion's upper-left corner, ranks high on most people's list of favorite star names. It appears to be a corruption of the Arabic *yad al-jawza*, meaning "hand of al-jawza." (*Al-jawza* itself means either "the giant" or "the central one.")

In Orion's opposite corner lies the constellation's other luminary, Rigel. Its name derives from the Arabic *rijl al-jawza*, meaning "foot of al-jawza." At the lower left of the Hunter's figure sits Saiph. This star's name has a strange history. It comes from a longer Arabic phrase meaning "sword of the giant." But Saiph has no relation to Orion's sword—a string of stars that descends from Orion's belt—apparently the name got transferred by mistake long ago, and it stuck. Rounding out Orion's four corners is Bellatrix. Unlike its Arabic brethren, Bellatrix is a Latin name that means "Amazon Star."

That leaves us with Orion's three belt stars. At the western (right) end lies Mintaka and at the eastern end Alnitak. Both come from Arabic phrases meaning the "belt of al-jawza." Alnilam, the belt's central star, also gets its name from Arabic. The name means "string of pearls," an apt designation for the three-star belt.



TIP

Directions in the sky can be confusing. Star maps typically show north up and east to the left because that's the way we see the sky. Imagine viewing a constellation that lies due south—the northern part of the pattern then appears at top, but the eastern side faces left.

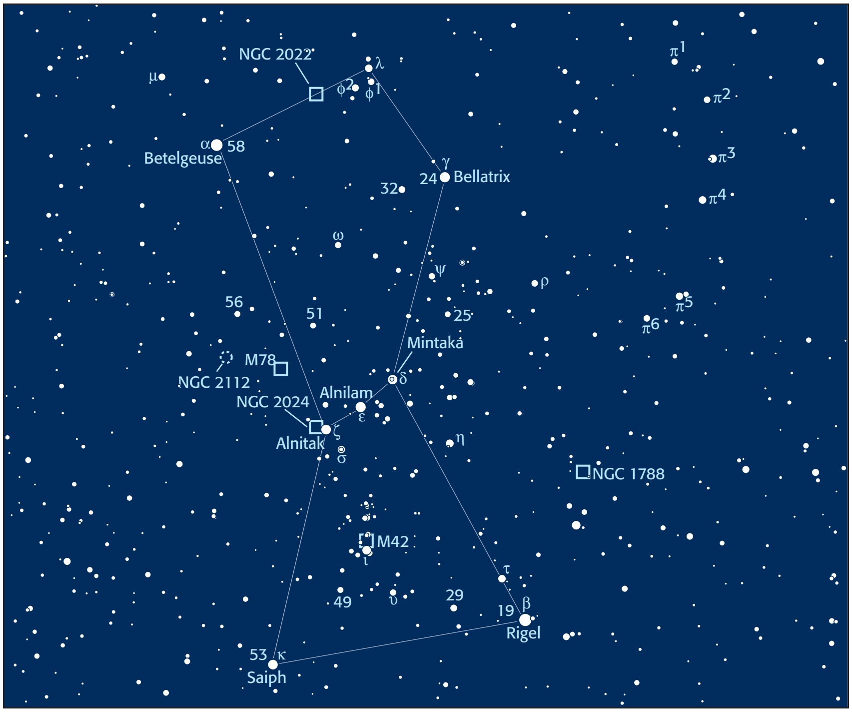
Astronomical Catalogs

Astronomers would be in dire straits if they had to come up with a common name for every star and deep-sky object out there. Smartly, they've devised several classification schemes to tackle the problem. Many of the brighter objects have earned multiple designations, with the first bestowed usually the most common. But you can be sure about one thing: Nearly every object in the sky—even newly discovered ones—has a designation attached to it.

You might think that with perfectly good names like Betelgeuse and Rigel, Orion's brightest stars wouldn't need any other titles. That's not the way astronomers think. In their never-ending quest to catalog objects, scientists have developed more complete and systematic listings, and it really wouldn't work to leave out the brightest objects.

In 1603, German lawyer Johannes Bayer published a star atlas called *Uranometria*. In it, he designated the brightest stars in each constellation by a Greek letter. In most cases, the letters went in order of decreasing brightness, so the brightest star was Alpha (α), the second Beta (β), and so on. In Orion, Betelgeuse received the Alpha designation and Rigel is Beta. In the eighteenth century, a catalog published by British astronomer John Flamsteed numbered the brighter stars in each constellation starting at the western edge and working eastward. So, Betelgeuse is also 58 Orionis and Rigel is 19 Orionis. Still later catalogs, used mostly by professionals, also incorporate Orion's luminaries.

Deep-sky objects are no different. In 1784, French astronomer Charles Messier compiled the first such catalog. The famed Orion Nebula earned the designation M42. In the nineteenth century, Danish astronomer John Dreyer compiled the *New General Catalogue*, a compendium of several thousand objects (Messier's barely surpasses 100). The Orion Nebula is the 1,976th object in this catalog.



Understanding Magnitudes

Few subjects confuse beginners more than the magnitude system astronomers use to describe the brightnesses of celestial objects. The problem is that the system is counter-intuitive, with bigger numbers corresponding to fainter objects. Once you know how the system is set up, however, you shouldn't have any trouble.

The story of magnitudes dates to the Greek astronomer Hipparchus. In the 2nd century B.C.E., he cataloged the stars he could see from his home. He called the brightest stars *1st magnitude,* the next group *2nd magnitude,* and so on to the faintest stars at *6th magnitude.* Later astronomers quantified this magnitude system, keeping lower numbers for brighter objects and extending it into negative magnitudes for the very brightest.

Magnitudes of Celestial Objects

Magnitude	*Object or Limit*
–26.7	Sun
–12	Full Moon
–4.5	Venus at its brightest
–3.9	Venus at its faintest
–2.9	Mars at its brightest
–1.47	Sirius (the brightest star)
–0.72	Canopus
–0.29	Alpha Centauri
–0.04	Arcturus
0.03	Vega
6.5	Naked-eye limit
9	Binoculars limit
13	8-inch telescope limit
18	Approximate large scope limit
30	Hubble Space Telescope limit

In quantifying the magnitude system of Hipparchus, astronomers realized the Greek scientist's 1st-magnitude stars were about 100 times brighter than his 6th-magnitude stars. So, they devised a system with a logarithmic scale wherein a 5-magnitude difference would equal a factor of 100 in brightness. This table gives brightness ratios for several magnitude differences.

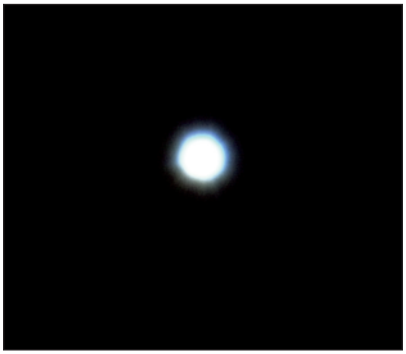
The Magnitude System

Magnitude Difference	*Brightness Ratio*
0.5	1.58
1.0	2.51
1.5	3.98
2.0	6.31
2.5	10.0
3.0	15.8
4.0	39.8
5.0	100
10.0	10,000
15.0	1,000,000

Seeing Color in the Sky

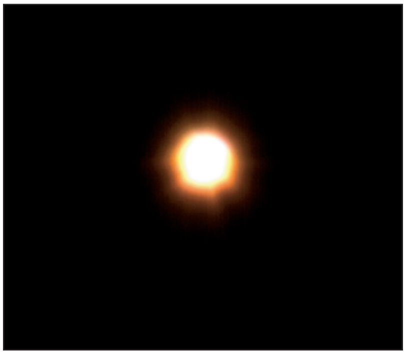
To see color, the eye needs a fair amount of light to reach the retina. Bright stars and auroras are up to the task for naked-eye observers. Use the light-gathering power of binoculars or a telescope, and you'll see colors in many more stars. Although the beautiful reds and blues you see in photographs of deep-sky objects are real, an observer staring through an eyepiece has no hope of seeing them.

Color shows up best in bright stars. Leo's 1st-magnitude luminary, Regulus, sports a distinct bluish hue. This reflects the star's high surface temperature. (In astronomy, blue is a hot color and red is a cool color.)



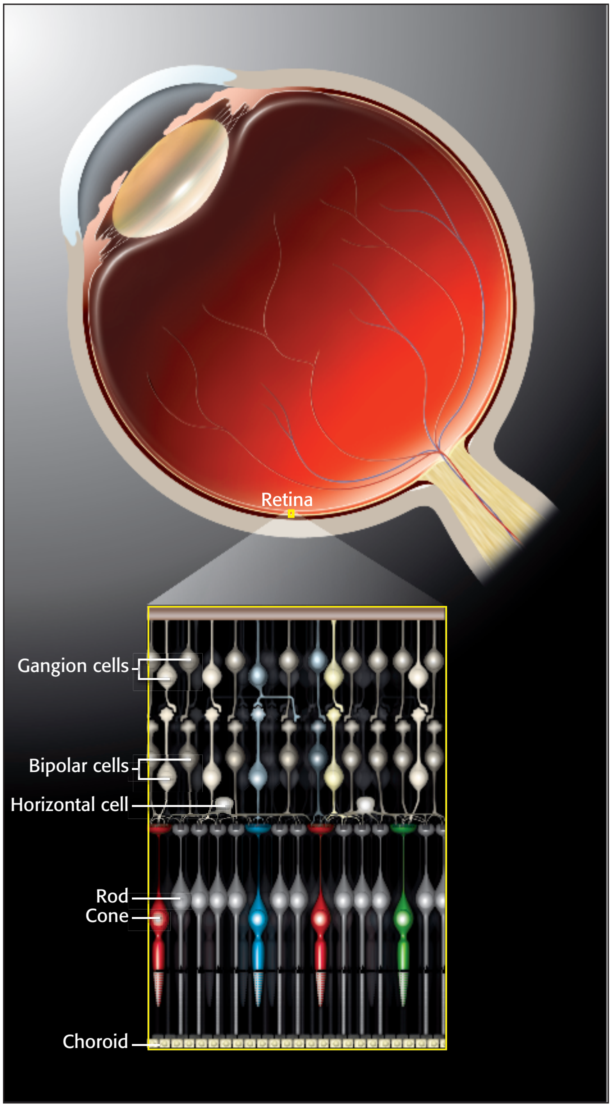
Oddly enough, the brightest star in the sky shows no natural color. Sirius has just the right surface temperature so that it emits equal amounts of light at all wavelengths—what we perceive as white. When Sirius lies low in the winter sky, however, it often looks colorful. The rapidly changing colors appear because the star's light passes through our turbulent atmosphere. This phenomenon is called "twinkling."

Colorful shades of red also show up in stars. With 1st-magnitude Antares (near right), the color tends toward orange, reflecting the star's modest surface temperature. But in the comparatively cool atmosphere of R Leporis (far right), almost all the light radiated lies at the red end of the spectrum. Colors like this show up in the eyepiece when you have a large enough scope operating at a fairly high magnification.



Dark Adaptation

The human eye is a phenomenal organ, but it does have its limitations. Walk from bright sunshine into a darkened room, and it takes a few minutes before your eyes can adjust. Similarly, if you're in a brightly lit room at night and then step outside, you won't see clearly for quite a while. To get the most out of an observing session, you need to be dark adapted. It's easy to do, and will make a world of difference in what you see.



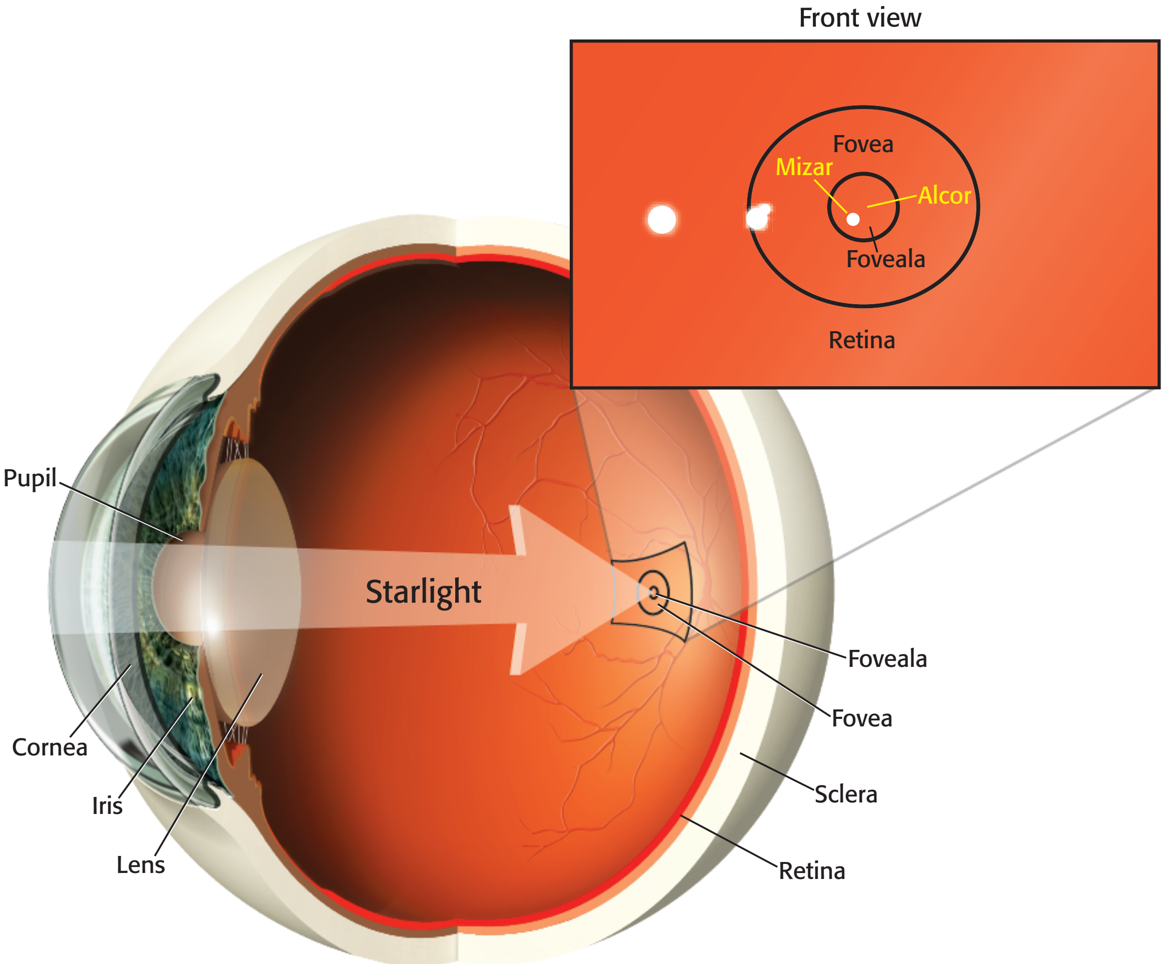
Go from bright light to dark, and your eye will do two things. First, your pupils will dilate to let in more light. In daylight, the pupil may open only 1 to 2 millimeters, but that can jump to 5 to 7 millimeters in darkness. Second, the eye's rod cells produce more rhodopsin, which increases their light sensitivity. It can take up to 30 minutes before the eye fully dark adapts and can see the most detail. When observing, avoid bright lights if at all possible.

The eye's rod cells are affected less by red light than by blue light. So, if you need some illumination to see telescope or camera controls, or to avoid objects on the ground, use a red flashlight. (You can either buy one or make one by taping red cellophane over the flashlight's front.) If you can, adjust the flashlight's light level so it illuminates just what you need to see.

Averted versus Direct Vision

It sounds odd to most beginners, but it's true: You can see fainter objects by not looking right at them. If you want to see detail in an object, then certainly look directly at it. But if you want to detect a dim object that seems just out of reach, avert your gaze slightly. You'll be amazed at what pops into view.

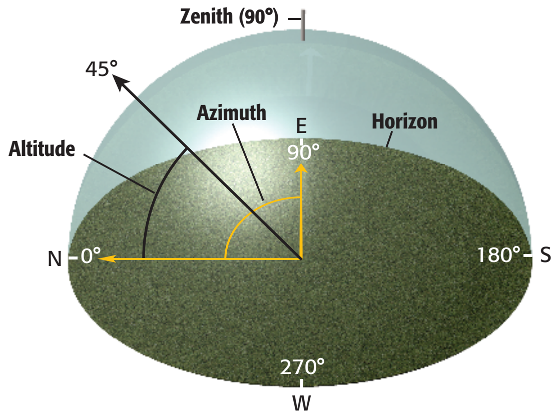
If you want to see detail along the Moon's terminator, or in the cloud tops of Jupiter's atmosphere, you need to let the light fall on the eye's central *fovea*. This area is lined with day-sensitive cone cells, which let you see fine details in bright lighting conditions. But many of the sights observers want to target are dim, and averted vision can add half a magnitude to what you see. When using a telescope, try to look about halfway from the center of the field (presumably where you placed the object) to the edge. Averted vision will also deliver the clearest view of stars in close proximity, such as Ursa Major's Mizar and Alcor.



Finding Your Way around the Sky

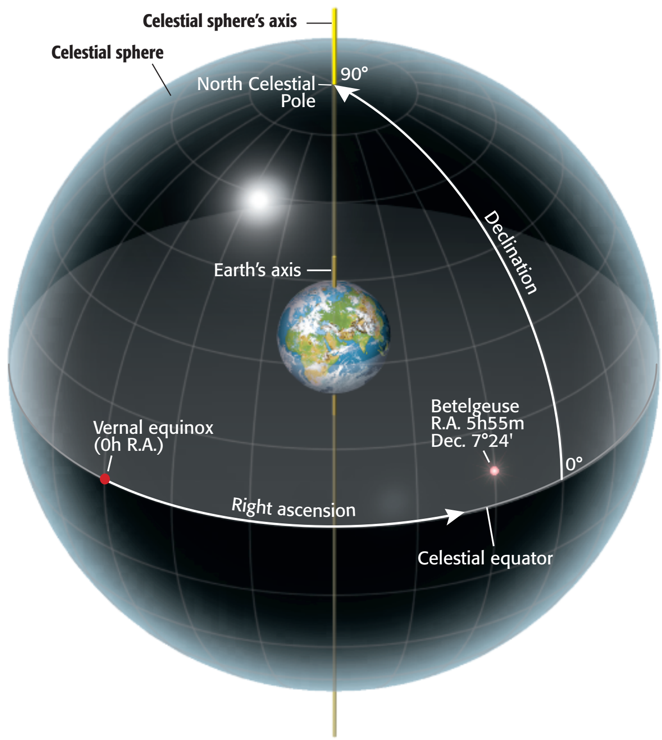
If you want to pinpoint a place on Earth, all you need to know is its latitude and longitude. The same technique works in the sky, where astronomers have established similar coordinate systems. Once you know where an object is, you can center it in your telescope either by moving it by hand or by having a computer slew it for you. You'll find that observers hold strong views about which is the better method.

The most intuitive approach to finding your way around the sky is by using the *horizon coordinate system*. Here, you measure how far above the horizon an object lies (its *altitude*) and how far east of due north it lies (its *azimuth*). More often than not, you'll read or hear directions given in this system. For example: "Venus lies 15° high in the west an hour after sunset."

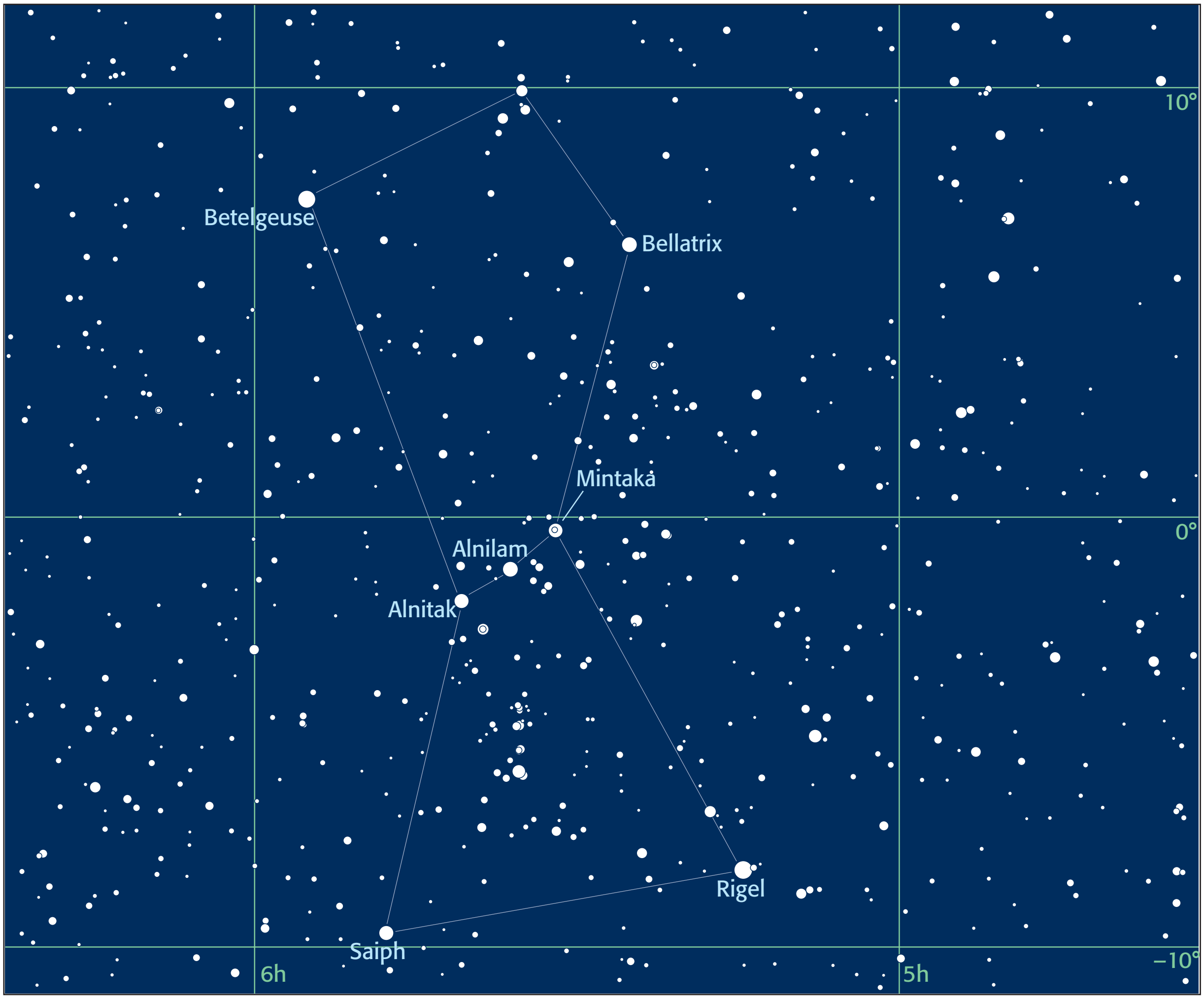


The *equatorial coordinate system* closely matches the latitude and longitude we use on Earth. Imagine all celestial objects lying on the surface of an infinitely large celestial sphere centered on Earth. The celestial equator is an extension of Earth's equator into the sky, and the celestial poles mark where Earth's axis of rotation intersects the celestial sphere.

Astronomers measure how far north or south of the celestial equator an object lies (its *declination*) and how far east of the vernal equinox an object lies (its *right ascension*). The advantage of the equatorial coordinate system is that it remains essentially fixed relative to the stars. So, if you know the right ascension and declination of the star Betelgeuse tonight, it will be in the same position next week, next year, and even next decade. In the horizon system, an object doesn't stay in the same place from one hour to the next.



Our winter friend Orion stands astride the celestial equator (the line of 0° declination). Betelgeuse lies nearly 10° of declination north of the equator and Rigel appears about the same distance south. The main body of Orion falls between 5 hours and 6 hours of right ascension, placing it about one-quarter of the way around the sky from the vernal equinox.



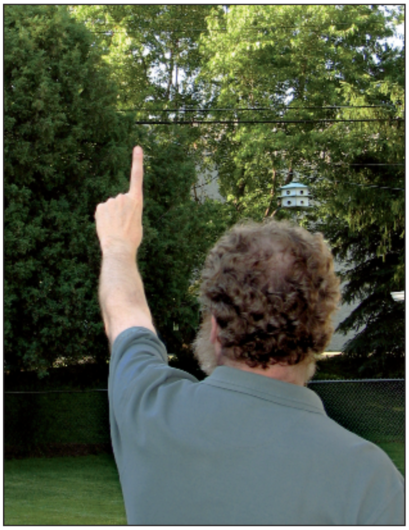
TIP

To Star Hop or Go-to

How do you point your telescope to the Orion Nebula? If you're a traditionalist, you first find Orion's belt, and then follow a line of stars southward until you reach the glowing gas cloud. These people claim you won't learn the sky well until you learn to hop from star to star. If you're a technology freak, you tell your telescope's computer to find M42, and it slews there automatically. These people claim they see far more objects through their go-to telescopes because they don't "waste" time searching. Both groups are right, at least to some extent.

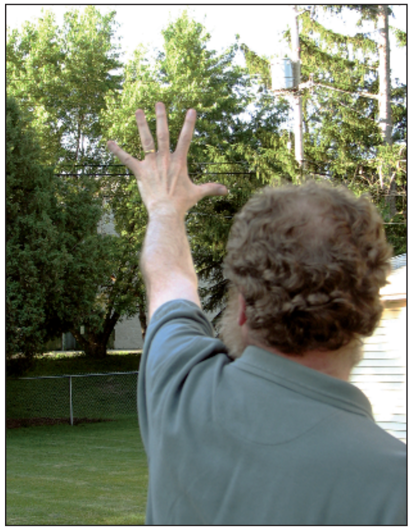
Apparent Sizes and Distances

It's fairly easy to get confused about the sizes of celestial objects. The Moon looks bigger near the horizon than when it's up higher. But many people think the Moon is nearly as large as the Big Dipper, and must certainly span a greater diameter than the Pleiades star cluster. With a few handy methods to measure the sizes of sky objects, you won't be making these mistakes.



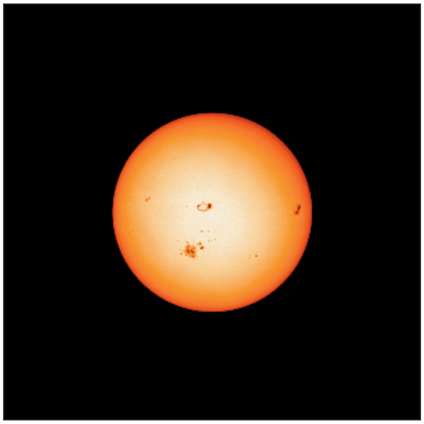
If you hold a finger at arm's length, it will span an angle of approximately 2°. That's more than enough to totally block the Moon, but it's not enough to completely cover the Andromeda Galaxy. And most constellations extend much farther than your finger could hope to block.

If you make a fist and hold it at arm's length, you'll be covering approximately 10° of sky. This handy reference matches the size of the Big Dipper's bowl, but it's smaller than the Great Square of Pegasus.



Open your hand wide and hold it at arm's length, and you're now spanning some 25° from the tip of your thumb to the tip of your pinkie. This larger unit makes a good way to gauge the separation of objects in the sky, say the distances between the stars of the Summer Triangle.

The Sun spans a whopping 865,000 miles and lies an average of 93 million miles from Earth. If you divide the Sun's diameter by its distance, you get a measure of how big it appears in the sky. The result: about 0.5°, or 30 arcminutes, across. All three photographs on this page are shown to the same scale.

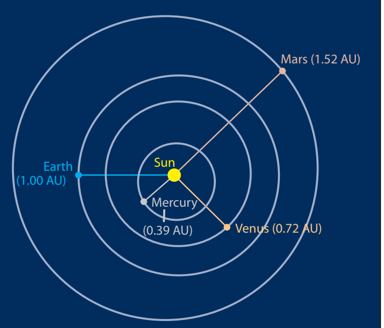


Our Moon is much smaller than the Sun (only 2,160 miles across) but also much closer to Earth (239,000 miles away). Combine these two numbers, and you'll find that the Moon spans the same 0.5° angle as the Sun does. The uncanny coincidence leads to exquisite solar eclipses over a narrow path on Earth's surface.

The Pleiades star cluster lies some 440 light-years from Earth, but its stars spread out across nearly 10 light-years. This makes the Pleiades appear significantly larger in our sky than either the Sun or Moon.

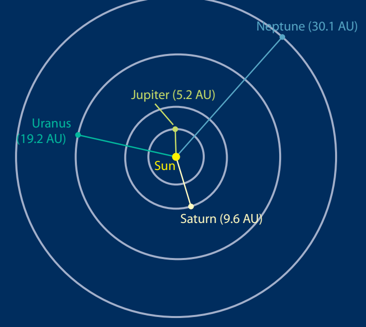
Astronomical Distances

To those of us used to hopping in the car to go grocery shopping, distances in the universe seem astounding. The nearest celestial object, the Moon, lies 239,000 miles away. But that's just the tip of the iceberg. In the solar system, distances climb to millions and billions of miles, and the nearest star system beyond the Sun lies many trillions of miles away. It's no wonder even nearby stars appear as mere points of light.



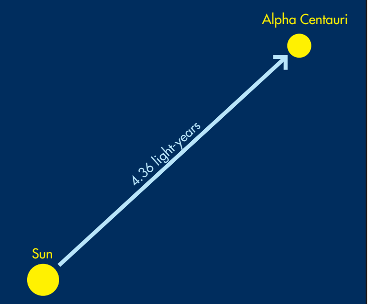
One astronomical unit (AU) equals the average distance between the Sun and Earth — about 93 million miles.

On average, the Sun lies about 93 million miles from Earth. To avoid using such huge numbers all the time, astronomers defined a new measuring stick called the *astronomical unit* (AU), which is equal to the Sun–Earth distance.



One astronomical unit (AU) equals the average distance between the Sun and Earth — about 93 million miles.

By the time you reach the outer solar system, the distances in miles climb to well over a billion. With the more appropriate AU, however, the numbers stay far more reasonable.

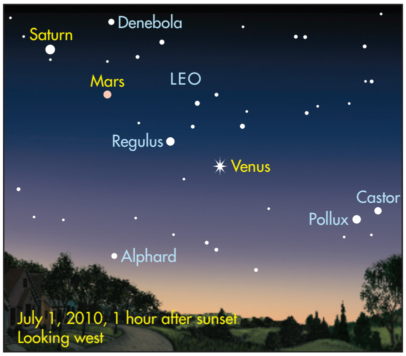


The closest star to the Sun — Alpha Centauri — lies 4.36 light-years distant. One light-year equals some 63,250 astronomical units, or 5.9 trillion miles.

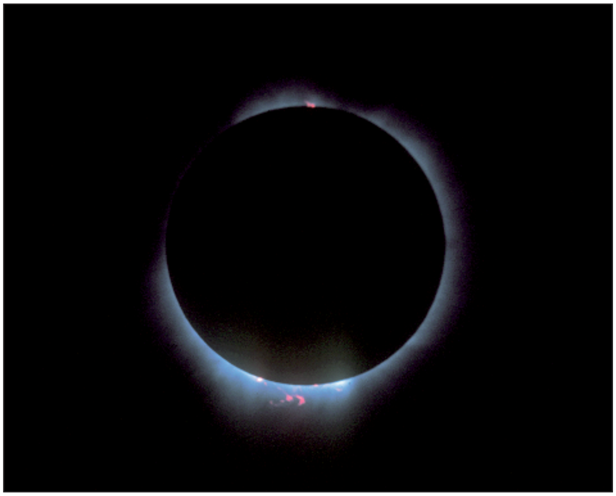
The leap out to the nearest star puts the astronomical unit to shame. Alpha Centauri lies some 275,000 AU from Earth, or 25 trillion miles. For such vast distances, astronomers turn to the *light-year*, the distance light (moving at a speed of 186,000 miles per second) travels in a year. Still, Alpha Centauri lies 4.36 light-years away.

Laws that make commerce run more smoothly push us away from the natural rhythms that form the basis of timekeeping. Instead of defining noon as the moment when the Sun lies due south in the sky, our clocks tell us noon happens at the same time in cities hundreds of miles to the east or west. And during summer, the discrepancy grows larger. All this makes it harder to figure out when a celestial event will occur.

When you read about an event happening in the early evening sky, the time will usually be quoted as being half an hour or an hour after sunset. If you want to know the clock time of this event, you'll need to look up when your local sunset occurs. There's simply no way to be precise because sunset occurs at different times in different locales. The good news: In most cases, the event will look the same regardless of where you live.



Timing is precise when it comes to eclipses of the Sun and Moon. The alignments that produce these events happen at certain times, and all you need to do to calculate when the eclipse begins, for example, is to correct for your time zone. The phases of the Moon operate in the same way.



TIP

Universal Time

To get around some of the problems associated with time zones, astronomers developed an unambiguous time standard known as *Universal Time* (UT). Observers anywhere in the world can coordinate their observations by using UT. UT runs five hours ahead of Eastern Standard Time, for example, and 4 hours ahead of Eastern Daylight Time.

How Dark Is Your Sky?

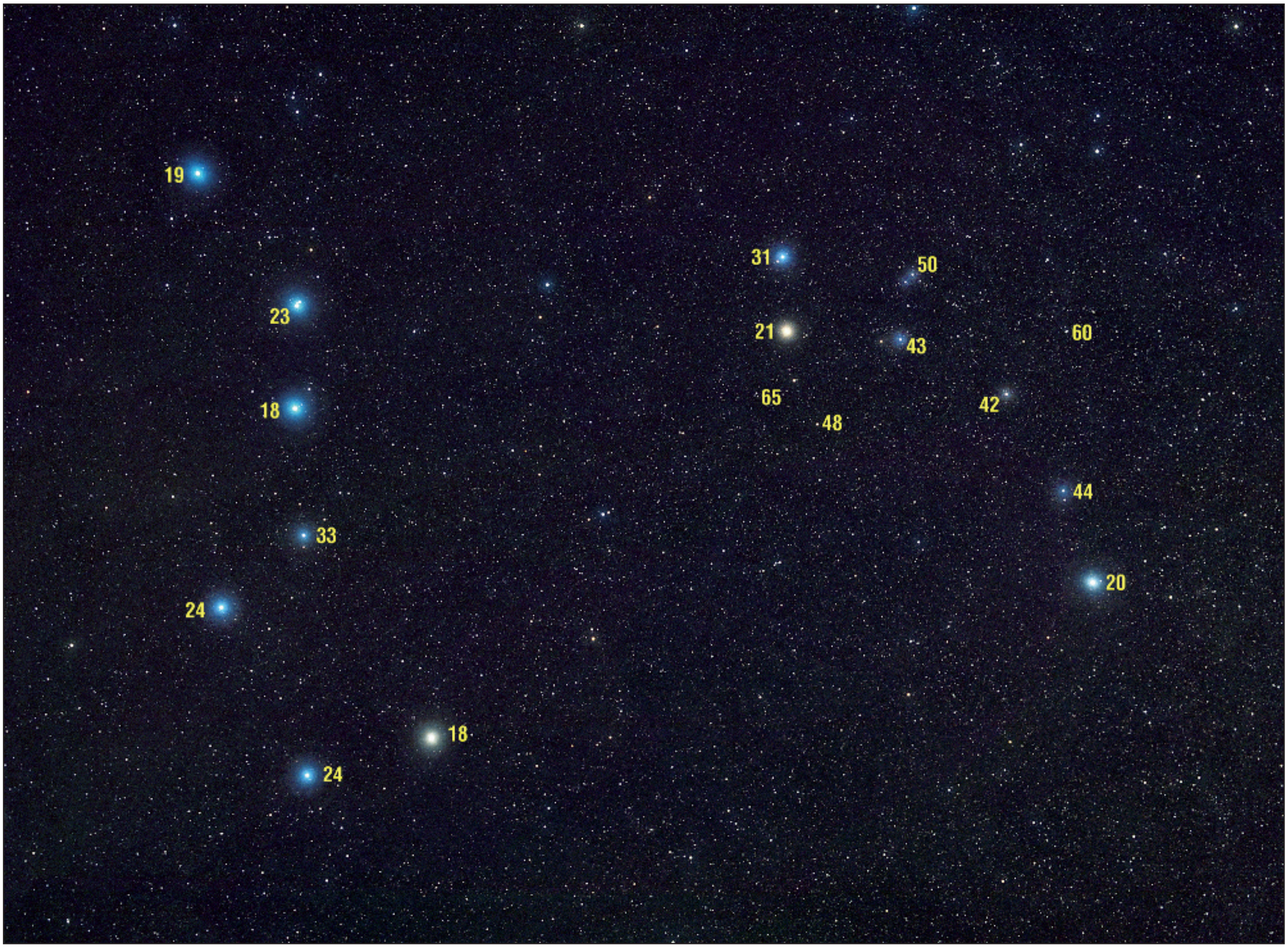
All other things being equal, the darker your sky, the more you can see. But the number of truly dark places in the world is dwindling as population increases. In large parts of North America and Europe, you have to travel hundreds of miles to escape the pall of urban skyglow. How can you tell if you've found a good site? Spend a few minutes calculating the limiting magnitude.

Europe blazes with civilization's lights. The problem: A lot of this light goes up into the sky, where it harms our view of the night sky, and not toward the ground, where it would do the most good. Europeans in search of dark skies usually have a long way to travel.

North America spreads out a lot more than Europe and has a lower population density, so it's no wonder some good observing remains. Still, the lights seemingly keep expanding, except in some parts of the western American deserts and mountains, and in northern Canada. A close look toward the eastern seaboard reveals only a few oases of darkness.

You can use the region of the Big and Little Dippers to determine the darkness of your observing site. Under a dark sky and good observing conditions, an average person can see stars down to about magnitude 6.5. Exceptionally sharp-eyed observers under outstanding conditions can get down to magnitude 7.0 or a bit fainter.

Under the less-than-ideal conditions we more typically experience, the numbers won't be so high. A good way to judge is to look toward the Dippers. The Big Dipper, of course, contains a lot of bright stars, and you should see them easily unless the Moon's shining brightly or haze abounds. The Little Dipper offers a better test. On this photograph, we've marked the magnitudes of several stars (the decimal points have been dropped to avoid confusion with stars). When you're under the sky at night, establish which is the faintest star you can see. That is your *limiting magnitude.*



Party under the Stars

To some, observing the night sky is a solitary pursuit. But most people enjoy the camaraderie of their fellow enthusiasts. Some join together to witness the spectacle of a solar eclipse. Others simply gather at a good dark-sky site for a few nights under the stars. And don't think such star parties are only the domain of experts. Beginners can learn a lot about the sky—and about the telescope they might want to purchase—by attending a star party.

Few events draw people together more than a total solar eclipse. Perhaps it's the exotic locales, and people prefer company when they explore uncharted regions. Or maybe it's the expense and hassle of trying to book an entire tour by yourself. But there's no question that a group of people bring excitement to eclipse viewing. You'll never forget the whoops and hollers that come from people as the Sun winks out and totality commences.

Aurora watching also gains by having other people around. During a bright display, things happen quickly, and having several sets of eyes on the sky almost guarantees you won't miss anything. And if you're photographing an aurora, it's easy to get caught up in the picture taking and not take in the grand sweep.

The South Pacific Star Party features dark skies and friendly people—a grand combination. In this long-exposure shot, big telescopes stand watch as stars trail in the distance. The red lights belong to observers protecting their night vision. Most beginners benefit by going to a local star party, whether it's at a dark-sky site or a planetarium or science center. You can pick up a lot of helpful hints, see what the universe looks like through a big scope, and perhaps even test-drive a telescope you're thinking about buying.