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Stephen James O'Meara
Excerpt
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CHAPTER 1

A Dipper full of wonder

There is no better way to start our journey than by admiring the Big Dipper (also known as the Plough or Wagon), the most famous star pattern in the world. Spending your first nights with this easily seen star pattern is also an excellent way to learn the basics of observational astronomy. Doing so will teach you how to use your binoculars to full advantage; besides, if you're just beginning in this hobby, you'll need to know the basics, which are the building blocks of a strong foundation. I've always been a proponent of learning by doing. So let's get started. But before we do, understand that there's no need to rush. The stars, just like our friends, will always be there for you, night after night, month after month, year after year. It's the beauty of longevity.

Let's start our journey with some understanding. First, the Big Dipper is not a constellation. It is an *asterism* in the constellation Ursa Major, the Great Bear. An asterism is a familiar pattern of stars that forms part of one or more of the 88 officially recognized *constellations* (see Appendix A). The bowl of the Big Dipper lies in the body of the Bear, while the Dipper's handle is the Bear's tail – at least that's how the early Greek and Roman stargazers saw it; other cultures, such as the Cherokee Indians of the southern Appalachian Mountains, saw the three handle stars as three hunters in pursuit of a bear.

How the Bear got its tail

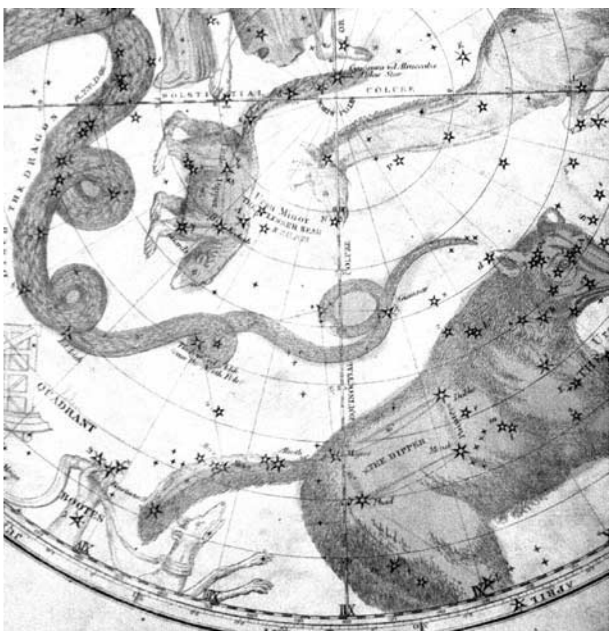
Anyone who has seen a bear knows that its tail is nothing but a short stub. So why is Ursa Major's tail so long? The answer, though a bit of a stretch, comes from the mythological tale of Callisto – one of several chaste maidens who cared for Diana (Artemis),[1] the virgin goddess of the Moon. As fate would have it, Callisto caught the ever-roaming eye of Jupiter (Zeus), the thunderbolt-wielding King of the Gods. After a roll in the hay, the maiden bore Jupiter a son, who she named Arcas (Arctos).

Jupiter never could keep a secret from Juno (Hera), his wife and twin sister, who became enraged with jealousy. When Juno sought out and found Callisto, she grabbed the nymph by her long golden locks and threw her to the ground, screaming, "Curse your beauty! I'll make sure that no one will desire you ever again!" With those words, Juno raised her arms. Lightning flashed, and thunder pealed. Powerless to defend herself, Callisto watched in horror as Juno, red with rage, transformed her into a giant bear. First Callisto's arms turned hairy, then her legs. Her sensitive jaw became crooked. Her gentle lips peeled back to reveal sharp teeth. When the deed was done, Callisto fled into the woods on all fours. She became terrified of her new situation, because, although Callisto looked like a beast, she had retained her human thoughts and heart.

One day, many years later, a young hunter encountered a foraging bear and startled it. Out of surprise, the mighty bear stood on its hind legs, opened wide its paws, and let out a terrifying roar. The hunter jumped back. The bear charged. But just as the hunter raised his spear to lance the beast, Jupiter appeared on the scene in time to stop the killing. Yes, the bear was Callisto, who, forgetting her appearance, was racing toward her long-lost son to embrace him!

To prevent any future tragedy, Jupiter turned Arcas into a bear, so he could forever enjoy the company of his mother. The great god then grabbed the two bears by their tails and swirled them high over his head. As he swirled the massive beasts, their tails stretched to great length before Jupiter finally flung them into the heavens. Today we see Callisto and Arcas, as Ursa Major and Ursa Minor, the Great and Little Bear, respectively.

But the story is not over. When Juno discovered what Jupiter had done, she was outraged. How could her husband place that adulteress and her spawn in the night sky



[1] The names in parentheses are the Greek counterparts of the Roman or Latin names.

so near the heavenly pole? Seeking comfort, she went to her foster parents who ruled the seas and complained: "Why should anyone fear offending Jupiter when he rewards them for causing me displeasure?" She beseeched her relatives to grant her one request: that the bears never set foot in her parents' sacred waters, as do the other stars on their nightly courses; instead, she wanted the bears to circle the pole, night after night, without time to rest. And so it is today that observers from mid-northern latitudes never see Ursa Major or Ursa Minor set below the horizon; they are *circumpolar* constellations – ones that circle the north celestial pole without ever setting, which is why finding the Big Dipper is always a good way to start your skywatching experience. Given a low horizon, you can see it at any time of the year or night.

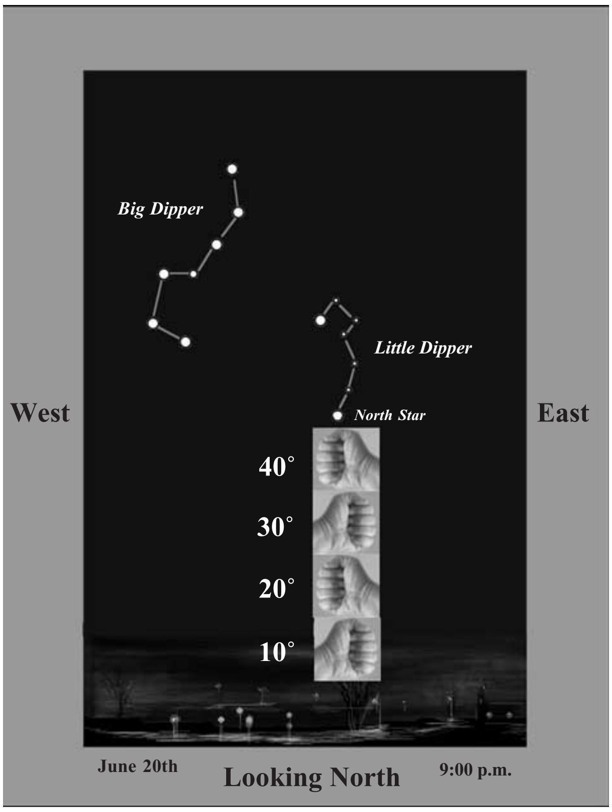
How to find the Big Dipper

To find the Big Dipper, you'll need to get your bearings. Go outside when twilight ends and allow at least 15 minutes for your eyes to adapt to the growing darkness. As you wait, determine which way is north; use a compass or the compass setting on your Global Positioning Service (GPS), if necessary. When you face north, your left arm will point west, your right arm will point east, and south will lie directly behind you. Find a tree, house, or other landmark at these cardinal points, and record them in your observing log. When outside observing, be sure to use a red flashlight to record your notes; the eye's rod cells, which are responsible for our keen night vision, are insensitive to red light.

The landmarks you select will serve as guides to certain stars or constellations mentioned later in this book. For instance, if I were to tell you to look for a bright star halfway up the northeastern sky, you will know how to position your body (say, halfway between an oak tree in the north and a neighbor's house in the east) before looking up. That said, your first challenge is to find Polaris, the North Star, which will serve as your faithful guiding light. Be warned, despite popular myth, the North Star is not the brightest star in the night sky; it ranks 48th. But it is solitary and obvious; it also shines with a yellow light, so it's not difficult to detect.

The height of the North Star above your horizon (its *altitude*) is the same as your latitude on Earth. (Latitude is measured from 0° at the equator to 90° at the pole.) If you lived on the North Pole (latitude 90°), the North Star would be at the *zenith* (the point in the sky directly overhead; altitude 90°). The reason for this coincidence is that the North Star happens to be within 1° of the point where Earth's imaginary axis of rotation intersects the dome of the sky.[2]

If you lived on the equator (latitude 0°), the North Star would sit on the north horizon (altitude 0°). Likewise, if, you live in New York City (40° latitude), the North Star is 40° above the north horizon (40° altitude). How high is 40°? Draw an imaginary line from the north horizon to the point overhead (the sky's *zenith*). That line spans an angular distance of 90°. Forty degrees is almost one-half of the way from the horizon to the zenith. Now hold an upright fist at arm's length and look at it with one eye closed. The amount of sky covered by the fist is about 10°.



For an observer living in New York City to find the North Star, he or she would face north, place the base of their upright fist on the horizon line, make a fist with his or her other hand, and place it on top of the first fist (like one potato, two potato). Four fists equals about 40°. The North Star should be sitting on the top fist.

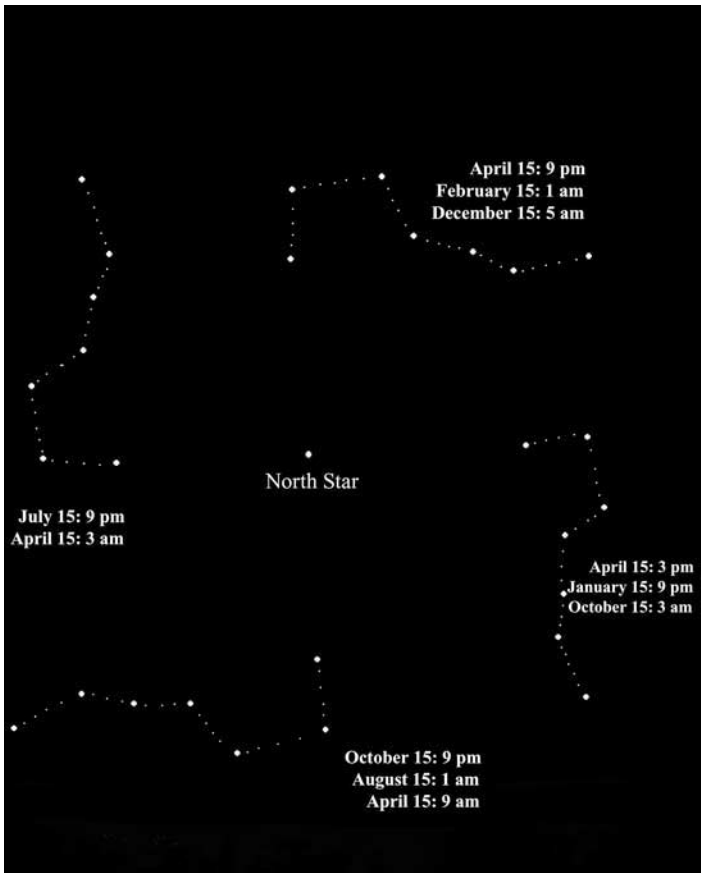
Now let's look for the Big Dipper. Since the Dipper is circumpolar, you can go out at any time of the night, at any time of the year to find it. If you go outside and observe the Big Dipper and the North Star at, say, 9:00 pm on April 1, then observe them again on the same night three hours later, you will see that the Dipper has rotated counterclockwise around the north celestial pole

[2] It is only by chance that Polaris is so close to the north celestial pole. It was not always our pole star and it will not always be our pole star. As the Earth spins on its axis, gravitational tugs by the Sun and Moon cause our planet to wobble like a top. Since one wobble takes 26,000 years to complete, Earth's imaginary axis slowly precesses over the years, transcribing an invisible circular path in the northern sky. Right now, that point on the circle just happens to bring it close to Polaris, our present day North Star. In AD 14,000, the bright star Vega will be our pole star. This polar precession is also responsible for the dawning of new zodiacal ages, such as the Age of Aquarius.

(from east to west). The pole star will not have moved perceptibly. That's because the Earth spins on its axis once every 24 hours, which causes us to see the entire sky turn like a giant wheel at a speed of about 15° per hour. Just as the Sun rises and sets each day so too do the stars (except for the circumpolar constellations). Since the North Star is very close to the point where Earth's imaginary axis intercepts the celestial sphere, it stays relatively fixed as all the other stars rotate around it. Imagine an umbrella dappled with dots representing the stars. If you spin the axis of the umbrella, the axis will remain fixed while all the "stars" on the umbrella turn around the axis. This eternal parade happens in the sky night after night, year after year.

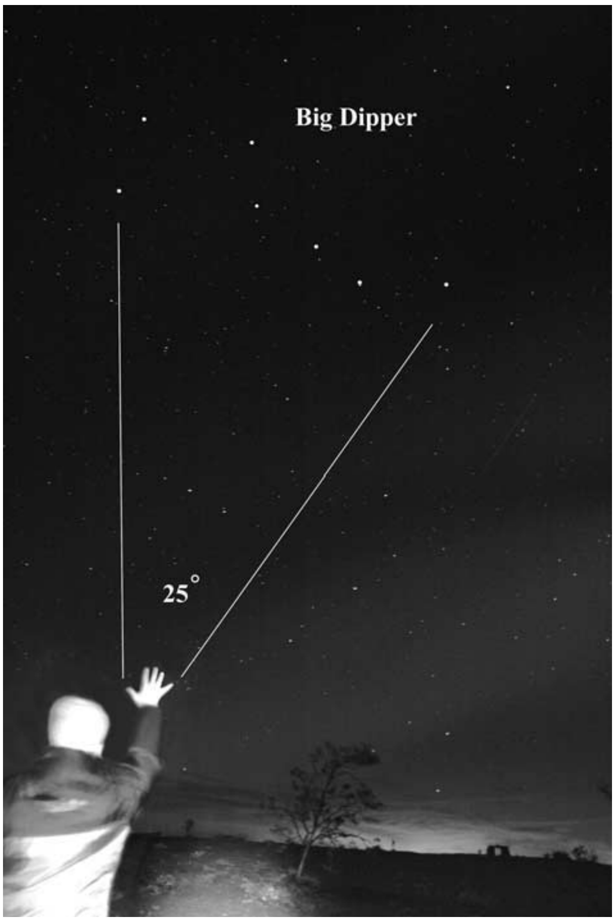
If you were standing at the North Pole, Earth's axis would intersect the sky at a point directly overhead (a point we call the north celestial pole). No stars would rise and set because they are moving parallel to the horizon. If you were at the equator, the north celestial pole would be on the horizon, so all the stars would rise and set. For an observer halfway between the pole and the equator, the north celestial pole is halfway (45°) above the horizon. Therefore, any star within 45° of the north celestial pole is circumpolar, meaning that as the Earth turns, it will remain in view all night and never set.

If the Earth did not orbit the Sun, this eternal parade would always start and end at the same point in the sky. In other words, the Big Dipper would be in the same position in the sky on April 1 at 9:00 pm as it would be on December 1 at 9:00 pm. But the Earth does orbit the Sun – once every $365\frac{1}{4}$ days. As a result, the part of the sky that we see each night changes. Each night any given star will rise four minutes earlier than it did on the previous night. The change adds up. A star that rises in the east at 9:00 pm on April 1 will be high in the south at 9:00 pm on July 1. At 9:00 pm on October 1, the star will be setting in the west. Although the circumpolar constellations never rise or set, we still see them perform a yearly, counterclockwise march around the north celestial pole. Look at the chart on this page. The Big Dipper is almost directly above the North Star on April 15 at 9:00 pm but almost directly below it on October 15 at 9:00 pm.



Unless it's spring, you'll need to observe from a location that offers a clear, low horizon. Otherwise, the Big Dipper may be obstructed by houses or trees. Let's assume it is April 1 at 9:00 pm. Go outside, face north, then look high overhead – high enough to get a crick in the neck. The seven stars of the Big Dipper should be prominently placed with the Dipper's bowl "pouring" its celestial waters down to the thirsty Earth (April showers bring May flowers). To confirm you have the right star pattern, hold out your hand at arm's length, close one eye, and spread your fingers; the Big Dipper should stretch fully from the tip of your thumb to the tip of your pinky. The photo on the next page illustrates this technique.

Once you're certain you have found these stars, turn your attention to Dubhe and Merak, the two stars at the end of the Big Dipper's bowl. These are the famous Pointer stars, because if you extend an imaginary line from Merak, through Dubhe away from the Bowl, they will point to the North Star. Extend your hand once again and spread your fingers. If you place the pinky of your right hand at the position of Dubhe, and twist your thumb toward the horizon, the North Star should be a short distance beyond your thumb. The North Star marks the tip of the Little Bear's tail, but we will not concern ourselves with the rest of that dim constellation right now, because it is best seen in the autumn.

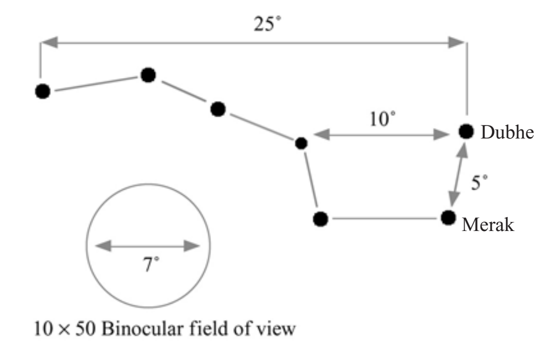


Sky measures

The Big Dipper should also be three fists above the North Star. Of course, the amount of sky your fist covers will depend on the size of your hand and the length of your arm. For instance, I find my fist covers a little more than 10°, and that I'm more comfortable using just my four fingers.

You can determine more precisely how your fingers and hands measure up by using the stars of the Big Dipper to help you visualize apparent sky distances. Hold up a fist against the bowl of the Big Dipper. It should fit conveniently inside the stars that mark the open part of the bowl, which are separated by 10°. Your hand with outstretched fingers spans about 22°, which, again, is nearly the full length of the Big Dipper – from tip of the bowl to tip of the handle. To make life easier, most sources round that number off to 20° (which I've done in this book), though I find my outstretched hand covers about 25° (see the photo at above). So measuring sky distances with your hands is a rough sport but one that at least gets you in the ballpark. That said, the distance between Dubhe and Merak is only 5° – about the width of two or three fingers held at arm's length; you decide. Now take your binoculars and hold them up to the Pointer stars in the Big Dipper's bowl. Most binoculars give a field of view around 7°, so the pointer stars should fit nicely in the binocular field, being near opposite edges. Throughout this book I have adopted a binocular field of view of 7° to help you find objects in the sky.

Use the Big Dipper to calibrate your hand measurements



Name those stars

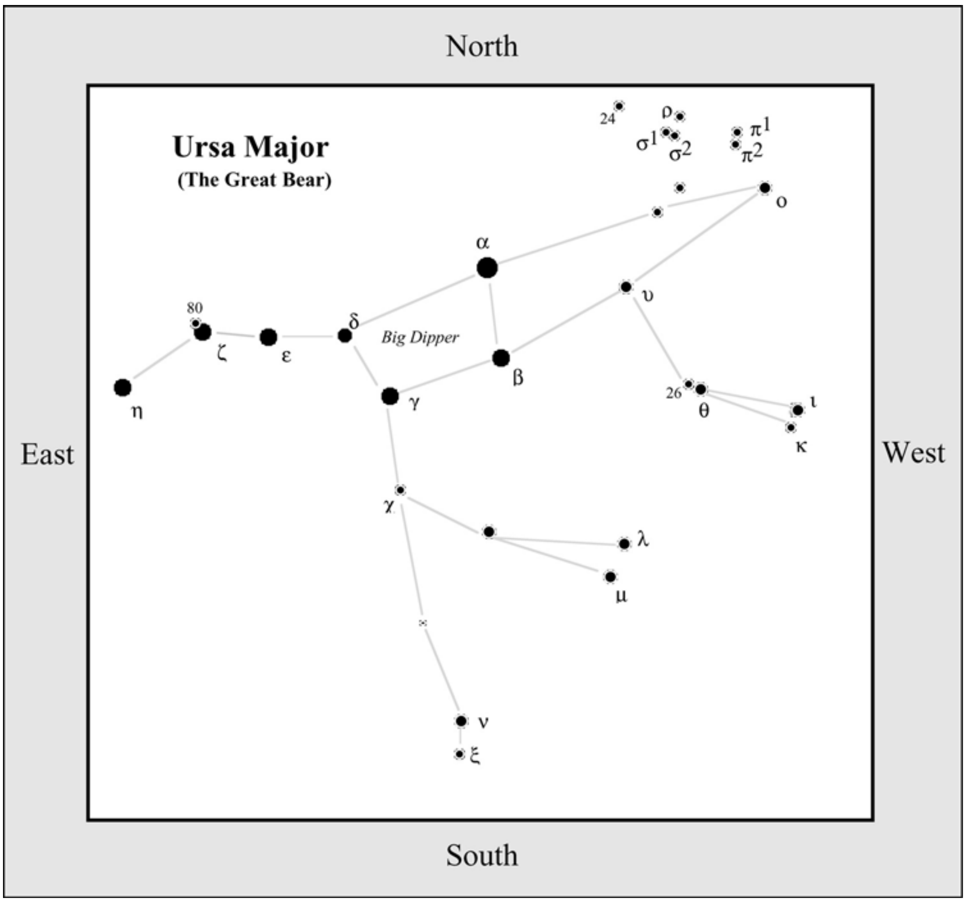
The chart on the next page shows the constellation of Ursa Major labeled with lower-case Greek letters and numbers. The Greek letters are a system of stellar nomenclature introduced in 1603 by Bavarian astronomer Johann Bayer, who labeled stars in each constellation according to their brightness. The most prominent star was given the letter Alpha (α); the faintest became Omega (ω).

The Greek alphabet (lower case)

α	Alpha	ι	Iota	ρ	Rho
β	Beta	κ	Kappa	σ	Sigma
γ	Gamma	λ	Lambda	τ	Tau
δ	Delta	μ	Mu	υ	Upsilon
ε	Epsilon	ν	Nu	φ	Phi
ζ	Zeta	ξ	Xi	χ	Chi
η	Eta	ο	Omicron	ψ	Psi
θ	Theta	π	Pi	ω	Omega

There are exceptions, though, such as with the stars in the Big Dipper, which are labeled in order of celestial longitude (as measured from west to east), not by brightness. So Dubhe is the Alpha (α) star of Ursa Major. Astronomers condense it all by saying that Dubhe is Alpha (α) Ursae Majoris, which is the Greek letter followed by the Latin genitive of the constellation name (see Appendix A).

Other stars have number identifications. These are *Flamsteed numbers*. Like the Greek letters, a Flamsteed number precedes the Latin genitive of the constellation: 80 Ursae Majoris (Alcor), for example. John Flamsteed was



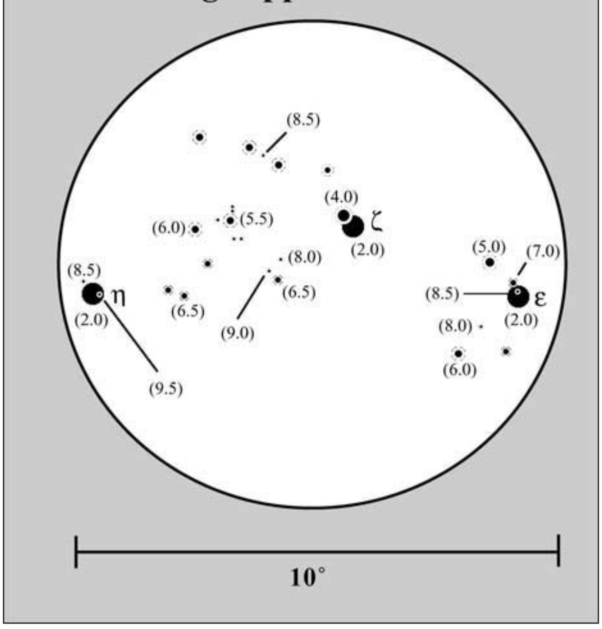
a prodigious eighteenth-century observer who dedicated 30 years of his life to measuring star positions, which he dutifully cataloged in his *Historia Coelestis Britannica* (1725) in order of their celestial longitude, again from west to east. Note that, on occasion, I have also added to the charts some stars that have an italicized lowercase letter, like *a* or *b*; these are additional guide stars (those with no Greek letter or Flamsteed designations), which you'll find described in the text as Star *a* or Star *b*, etc.

Star brightness

Look carefully at the seven stars of the Big Dipper with your unaided eyes. At first glance all of the Dipper's stars will appear to shine at about the same brightness. But notice how Delta (δ) Ursae Majoris, the star in the bowl closest to the handle, is slightly dimmer than the rest. Astronomers refer to an object's apparent brightness as its *magnitude*. The brighter an object appears, the smaller the numerical value of its apparent magnitude. On the brighter side of the magnitude scale, the values soar into the negative numbers; Sirius, for example, the brightest star in the night sky, shines at magnitude −1.5. The faintest stars visible at a glance to the unaided eye hover around 6th magnitude. The faintest stars visible *at a glance* in 10 × 50 binoculars shine at about 9th magnitude. Limiting magnitude is a *very* conservative number; your visual limit will vary depending on your location, the clarity of the atmosphere, the degree of light pollution, your binoculars, your visual acuity, the time you spend looking, and your expertise.

Mathematically, a 1st-magnitude star is 2.512 times brighter than a 2nd-magnitude star, which is 2.512 times brighter than a 3rd-magnitude star, and so on. The math works out nicely so that a star of 1st magnitude is exactly 100 times brighter than a star of 6th magnitude. Since Delta Ursae Majoris shines at 3rd magnitude, it appears about $2\frac{1}{2}$ times fainter than the other stars in the Big Dipper, which are all 2nd magnitude. (Think of magnitude as "class," where a first-class star is brighter than a second-class star, and so on.)

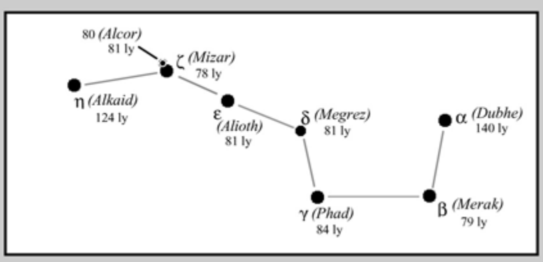
The chart on the next page shows some star magnitudes (placed in parentheses) in and around the Big Dipper's handle. The magnitudes have been rounded off. Learn to discern the difference between these magnitudes, because throughout the book I will refer to stars by their rounded-off magnitudes, telling you to look, say, for a 4th-magnitude, or an 8th-magnitude, star. Having a clear idea of how bright or faint a star will appear with your unaided eyes or through binoculars will help you in your searches.



Stellar magnitudes in the Big Dipper's handle

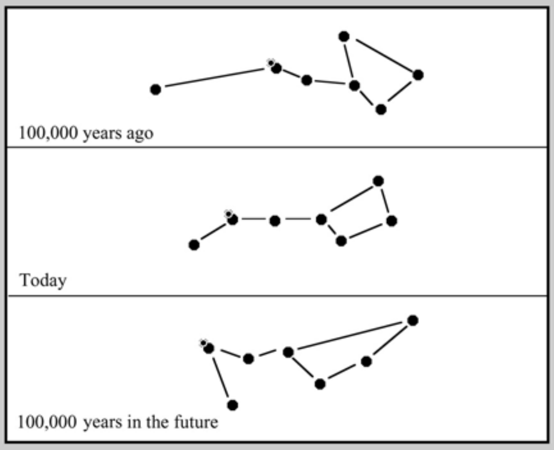
Distance and depth perception

Look at the chart below. It gives the distances to the stars in the Big Dipper as measured in *light years (ly)*. A light year is the distance light will travel in one year. At a rate of 186,000 miles per second, light will travel 6 trillion miles in a year, so 1 light year equals 6 trillion miles. Notice how the five central stars of the Big Dipper – Beta (β), Gamma (γ), Delta (δ), Epsilon (ε), and Zeta (ζ) – all lie at similar distances (roughly 80 ly). That's because they are the brightest members of the Ursa Major Moving Group – a loosely bound *open star cluster* that has, in addition to the five stars of the Big Dipper mentioned above, about a half dozen fainter members splashed across a volume of space that measures 18 by 30 light years.



Distances of the Big Dipper's stars measured in light years (ly)

Alpha (α) Ursae Majoris (Dubhe) and Eta (η) Ursae Majoris (Alkaid) are not members of the Moving Group, being 140 and 124 light years distant, respectively. They are moving in their own separate paths. Take a moment now and try to perceive these different distances. It's hard to do because we see the sky as a two-dimensional sphere, but the night sky really is a vast and deep sea of space. (Try to imagine the stars, as bioluminescent deep-sea creatures, at different depths.) Come back to Earth 100,000 years from now, and the Big Dipper will no longer appear as it does today. As Dubhe and Alkaid move on their own separate ways, the familiar Dipper pattern will change to what looks more like a scoop than the Plough so familiar to British observers.



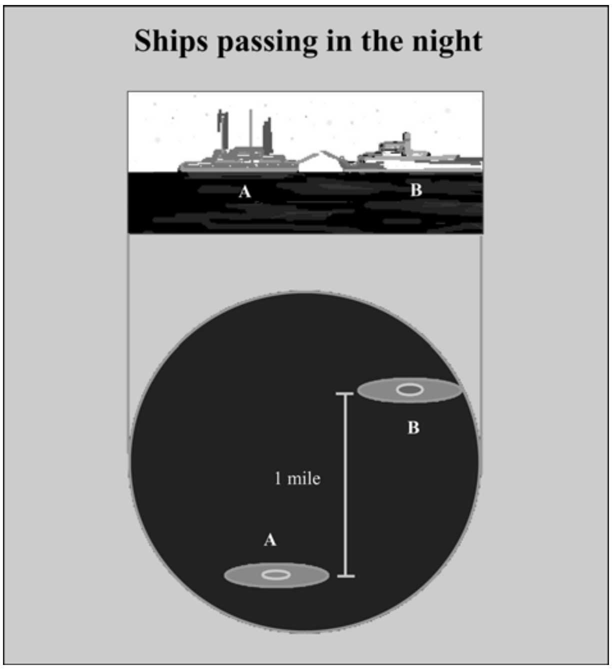
The slowly changing shape of the Big Dipper

Another member of the Ursa Major Moving Group can be seen with the naked eye. Look at Zeta (ζ) Ursae Majoris (Mizar), the second star from the tip of the Bear's tail. Do you see its 4th-magnitude companion immediately to the northeast? If so, you've seen the lightweight Rider (Alcor) of the ancient Arabian Horse (Mizar). You've also seen your first optical *double star* and perhaps your first physical *binary star* as well.

An optical *double star* is a pair of stars that, to the eye, appear very close together on the celestial sphere. Some double stars will look single to the unaided eye but appear as two close objects through binoculars. Although the two stars look like physical companions, they're actually many light years apart and just happen to appear in nearly the same line of sight; imagine two ships a mile apart passing one another on a distant horizon.

Now imagine that the closer the ships appear to get, the more difficult they become to see as two objects. But if you were to look at the ships with binoculars, they would once again be separated by a respectable distance. In time, they would once again blend. But if you looked at them through a telescope, they would split once again and so on. And so it is with the night sky and the chance alignment of stars. Some pairs of stars are easily seen with the unaided eye, others require either binoculars or a telescope to detect.

If two close stars are physically related, meaning that they lie at the same distance and orbit one another around a common center of gravity, then we call it a *binary star*



system. Since Alcor and Mizar are part of the Ursa Major Moving Group, they are, in fact, relatively close, being separated by only three light years. Although it's uncertain as to whether the two stars can be physically attracted at that distance, it is possible that they may be weakly associated, taking at least 750,000 years to orbit one another!

If you have a telescope, you'll see that Mizar splits again, having another faint, companion nearby. In fact, astronomers with powerful telescopes have found that each of these two components is again double! So Mizar is not a double star but a quartet of stars, a double-double. It becomes a *quintuple* star if you include Alcor.

So far, we've only encountered angular sky measures on the order of degrees. But they also divide into smaller units called arc minutes (′) and arc seconds (″): 1° is $\frac{1}{360}$ of a circle; 1 arc minute (1′) is $\frac{1}{60}$ of a degree, and 1 arc second (1″) is $\frac{1}{60}$ of an arc minute. Your pinky held at arm's length covers about 1° of sky; half a pinky, then is equal to 30 arc minutes (30′). The full Moon measures 30′ across, as does the Sun. The unaided eye can resolve objects that are separated by about 4′ and greater, while a pair of 10 × 50 binoculars can split double stars on the range of 34 arc seconds (34″) and greater, depending on your expertise or whether you use a tripod.

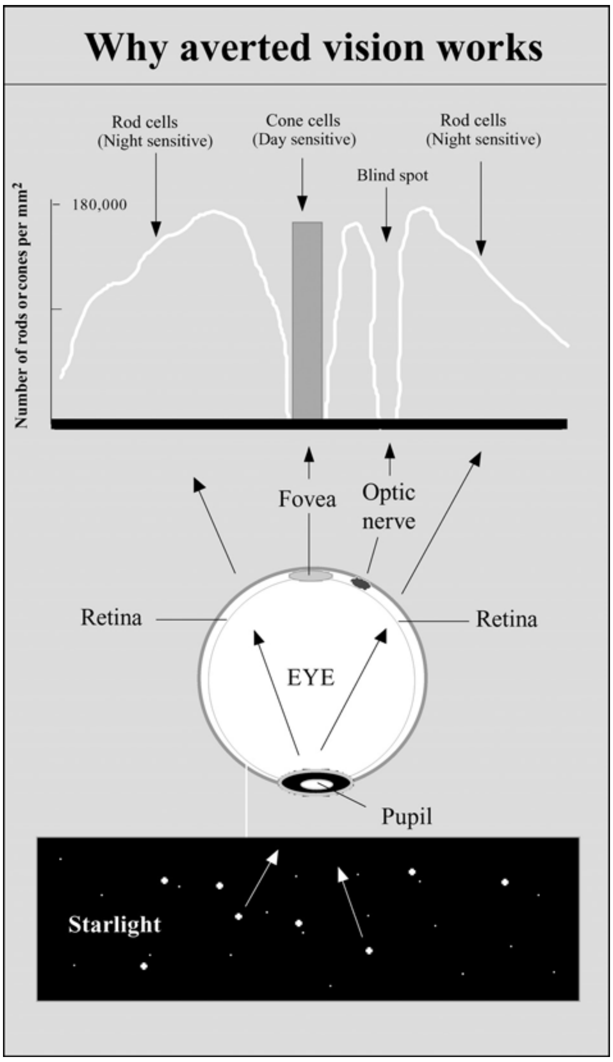
Look at Alcor and Mizar with your unaided eyes. These stars are separated by a respectable 14 arc minutes (14′), which is about half the apparent diameter of the Moon or Sun. Now use your binoculars to look for an 8th-magnitude star almost midway between them and a bit south. This is *Sidus Ludoviciana*. While surveying the heavens with a small telescope on December 2, 1722, J. G. Liebknecht, a German theologian and mathematician, chanced upon this star. After making some crude and inaccurate measurements of the star's position, he convinced himself that the object had moved. He then wrote and distributed a pamphlet announcing his discovery of a new planet, which he named after his sovereign, the Landgrave Ludwig of Hessen-Darmstadt. Liebknecht's contemporaries were not convinced, and they quickly proved that *Sidus Ludoviciana* is a fixed star. Furthermore, the noted German philosopher L. P. Thule distributed his own pamphlet criticizing Liebknecht's claim, adding that it was hardly necessary for Liebknecht to announce every telescopic star as new and to give it a special name.

Averted vision

If you cannot see *Sidus Ludoviciana* using direct vision, try looking out of the corner of your eye. The star should snap clearly into view. This observing technique, called averted, or peripheral, vision, is used by all visual astronomers. Averted vision places the object we want to study on the eye's night-sensitive (low-light) rod cells, which line the outer surface of the retina (the layer of cells at the back of the eye). When you use direct vision, the star's light falls on the retina's fovea (central portion), which is lined with day-sensitive (bright-light) cone cells, so it does not appear as prominent.

The more you practice using averted vision, the easier it becomes to see fainter and fainter objects. If you still can't see the star, don't worry. Try again on another night. Your eyes might be fatigued, or the sky conditions might not be optimal. Note, however, that sometimes when objects are bright enough, and close enough, *direct* vision will help you to resolve them best. Be sure to record the details of each observation in your observing log. Throughout the book, I will remind you when to use averted vision, especially if the object being discussed is faint.

Your retina may also have a specific spot that's highly sensitive to dim light. You can find that spot by trial and error. Once that visual "hot spot" is located, you will know how to position your head to best see dim objects. I find, for instance, that if I direct my gaze at the 4:00 position angle from the object, I have the best chance of seeing it clearly. Note, however, that the eye has a blind



spot at the position of the optic nerve; if starlight hits that spot, it will disappear. It takes practice to know just how far away from the object you have to look in the direction of your visual "hot spot" to get the maximum benefit. Observing, like any sport, requires practice if you want to be good at the game.

Star color

One of the many enjoyable aspects of binocular observing is looking for color differences among the stars. For this you want to use direct vision, so that the star's light falls directly onto the eye's color-sensitive, cone cells. While most stars look white at a glance, a careful survey of the sky will show that some have a bluish tint (like glacial ice), others look more yellow (like our Sun); still others can appear orange or red. The color differences you see might be negligible or subtle at first, but they do become more apparent with experience. It's a skill (or perception) that grows with time.

Start by looking at Eta (η) Ursae Majoris (Alkaid), the star at the end of the Big Dipper's handle. Now move star by star along the Big Dipper until you reach Alpha (α) Ursae Majoris (Dubhe). Two things should be immediately apparent: All the stars in the Big Dipper have a whitish, or bluish-white hue, except for Dubhe, which has a distinct golden patina. Actually Dubhe is a double treat. Not only is the star colorful, but it has a striking (but physically unrelated), 7th-magnitude binocular companion about 5 arc minutes (5′) away, roughly in the direction of Beta (β) Ursae Majoris.

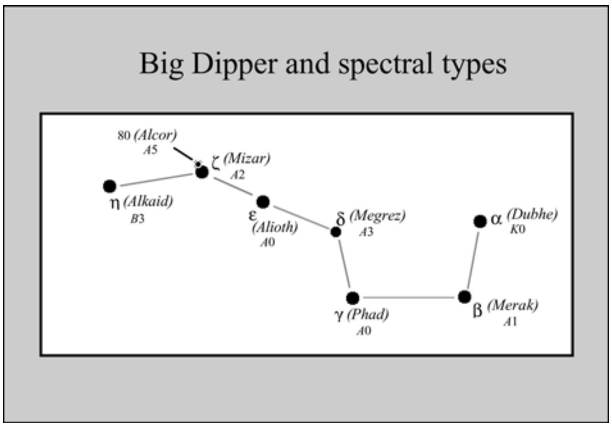
A star's color depends on the temperature of its surface gases. Think of molten metal when it cools: the color gradually shifts from blue-white, to yellow, to orange, to red, before it turns completely black. Each color in this *spectrum* (rainbow) corresponds to a specific *wavelength* of light, which emits a certain amount of heat energy. Like the hottest metals, the hottest stars shine with a bluish-white hue, while the coolest stars have a reddish tint. (Thus the saying "Red-giant stars aren't so hot.")

Ironically, in the visual arts, warmer colors have the coolest thermal properties, and vice versa, so don't be confused. The visual warmth of color refers to the appearance of an object as if its surface were being warmed by the rich golden shades of sunset, or by the orange glow of a distant fire; cool colors on the other hand refer to those that remind one of snow or ice. So, while Dubhe has a warmer visual hue than Alkaid, Dubhe's physical temperature is actually much lower, although still hot by Earth standards.

Using the color spectrum as a guide, astronomers have created a classification scheme for stars based largely on their surface temperatures. The scheme uses seven letters to represent the seven main spectral types. Ranging from hot to cold, they are O, B, A, F, G, K, M. (One favorite mnemonic for memorizing the spectral types of stars is Oh, Be A Fine Guy/Gal, Kiss Me.) For precision, astronomers have further subdivided the spectral types into 10 subclasses (which range from 0 to 9). If you know a star's spectral type, then you'll know its temperature range. A star's temperature is measured in *Kelvin* (K), which begins at absolute zero (−273 degrees Celsius, or −459 degrees Fahrenheit). The chart below shows the

The classification of stars by spectral type

Spectral type	Color range	Temperature (K)	Examples in Ursa Major (UMa)
O	Blue	31,500–50,000	
B	Blue-white	10,000–31,500	Eta (η) UMa
A	White	7,500–10,000	Beta (β), Gamma (γ), Delta (δ), Epsilon (ε), Zeta (ζ) UMa
F	Yellow-white	6,000–7,500	Theta (θ) UMa
G	Yellow	5,300–6,000	Xi (ξ) UMa
K	Orange	3,800–5,300	Alpha (α) UMa
M	Orange-red	2,100–3,800	Iota (ι) UMa



main spectral types, their color, temperature range, and some examples of stars in these classes in Ursa Major. Our Sun, for comparison is a type G2 star, and the North Star is type F7, so both shine with a distinct yellowish hue.

The colors we see depend on the sensitivity of our eyes to certain wavelengths of light and atmospheric conditions, so any description is highly subjective. Some astronomers claim that the cells in our eyes cannot detect color in stars. True or not, do not let the science of color distract you from the pleasure of seeing – real or imaginary – color. One of the most popular pastimes in summer observing events, for instance, is to have different observers look at the colorful double star Albireo in Cygnus, the Swan, then share what colors they see. Few people ever agree, and the shades they describe can be illuminating and funny. In fact, you will notice throughout this book, that I am quite literally "colorful" in my descriptions of star color, saying a star is "sunflower yellow" or "hot-sauce orange." You won't necessarily see the colors I describe, but you should record whatever color *you* see. To record the colors of stars, I match what I see to the named colors on ColorPlace® paint swatches from Wal*Mart®.

Dubhe and the life of a star

More than a star's surface temperature, a star's color also tells us a little something about its size and age. All stars are born in vast clouds of dust and gas (a *nebula*[3]) under the agency of gravity. As matter condenses, it forms a body that fuses hydrogen atoms into helium at the core. When it does, a star is born, throwing off its signature heat and light. Of course, how brightly a star appears to us on Earth also depends on its distance. A flashlight beam looks brighter when it is closer, for instance. So why does Dubhe, which is 1.5 times farther away from the Ursa Major Moving Group, shine more brightly than the stars in the group?

In the early twentieth century, two astronomers (Ejnar Hertzsprung and Henry Norris Russell) created what's now known as the Hertzsprung–Russell (H–R) diagram – a clever way to make sense of our two-dimensional sky. They found that if you plot a star's temperature against its absolute magnitude (the apparent magnitude of a star if it were magically placed at a distance of 10 parsecs [32.6 light years]), 90 percent of all the visible stars line up in a curved diagonal line. They called this line the "main sequence," and it's a family portrait, of sorts.

Look at the main sequence on the H–R diagram on page 10. Notice how that for every increase in brightness, the star's size and temperature also rise. The lower-right end of the main sequence is dominated by cool, red-dwarf stars, which are only about 1/10th as big as the Sun; except for a few exceptions, these stars are too faint to be seen in simple binoculars. At the upper-left end of the main sequence, we find the contrary – hot, bright stars some 10 to 20 times larger than our Sun; most of the stars in the Big Dipper congregate here. The Sun, our closest star, lies in the middle of the main sequence.

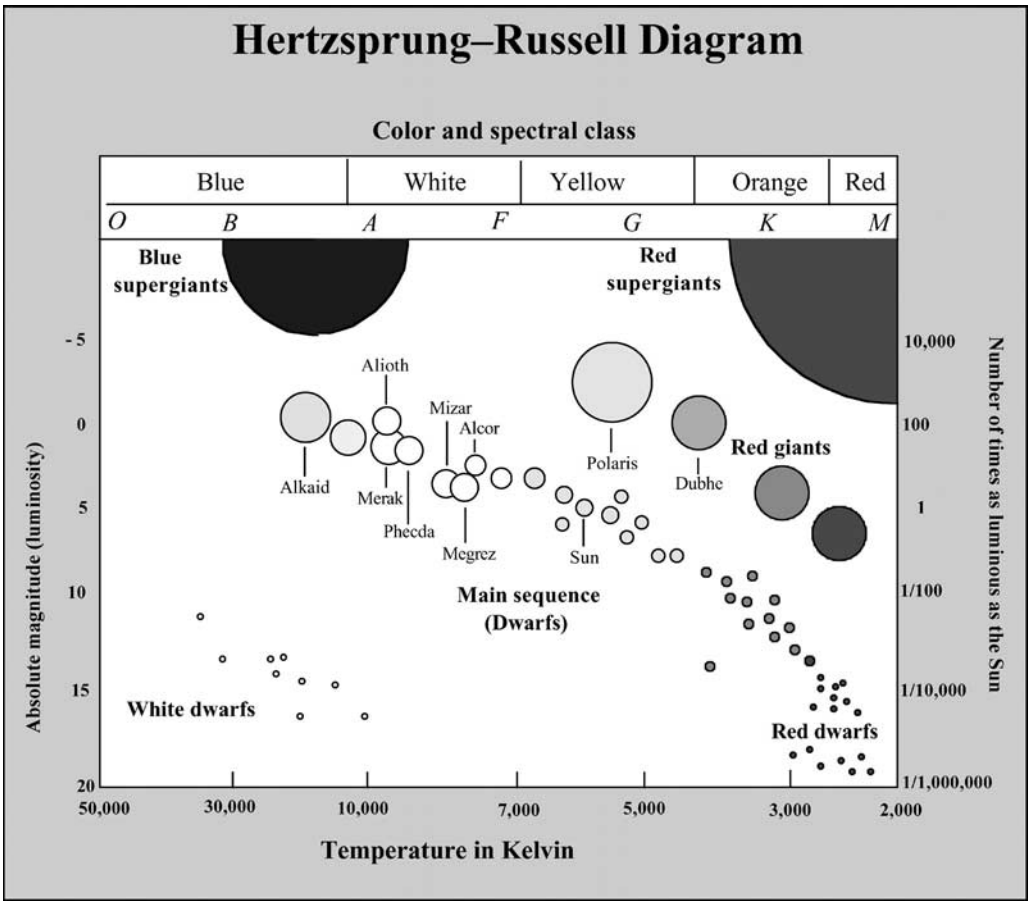
Despite the variety of star sizes on the main sequence, astronomers consider them all (including our Sun) to be dwarfs. The reason becomes clear if you look at the giant stars to the upper right of the main sequence in the H–R diagram. These stars, because of their cooler temperatures, are called red giants – even though some are yellow giants and some are orange giants. Red giants are typically about 25 times the size of the Sun and hundreds of times more luminous. With a surface temperature of 4,500 K, Dubhe is a type *K* (orange) giant 30 times larger than the Sun and 300 times more luminous. That's why, even though it's farther away than the Ursa Major Moving Group, Dubhe shines more brightly than any star in it.

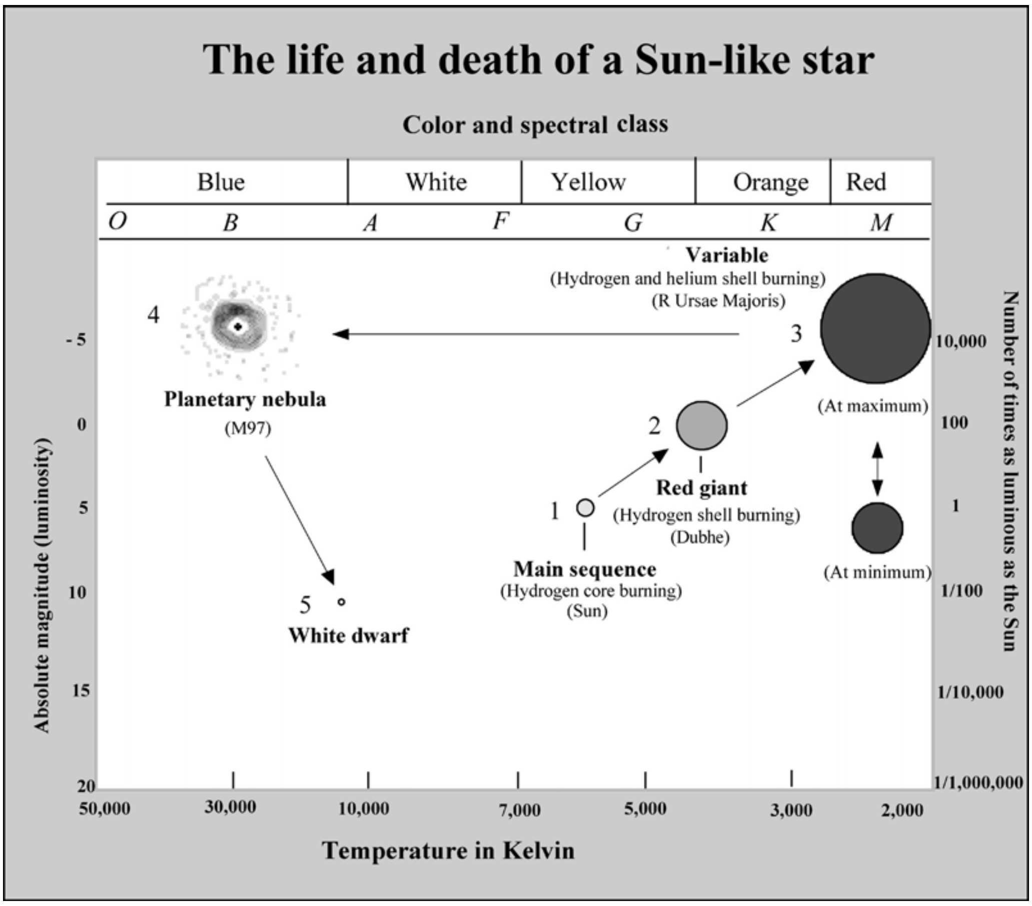
To see a red giant star is to see the ultimate fate of our Sun. After living its life on the main sequence for 10 billion years, a star like our Sun will evolve off the main sequence to become a red giant star. (Don't worry, our Sun is only about halfway through its life cycle, so it has a healthy 5 billion years left to burn.) When a star reaches the red-giant phase, it has exhausted, or nearly exhausted, its nuclear fuels and is fusing hydrogen into helium in a layer of gas outside the core. This new energy burn causes the star to swell by a factor of 10 or more; when the Sun reaches this stage, its outer atmosphere will envelop the Earth. Dubhe is now in this core, helium-burning stage, signaling to us that its death is near.

Eventually, a red giant's core becomes so hot that it fuses helium into carbon and oxygen, causing the star to swell even more. In many cases, strong stellar winds push the star's outer shells out beyond the star's gravitational hold. As more and more shells expand outward, the star appears to vary in brightness as viewed from Earth. Red-giant stars in this stage are called Mira stars,[4] or long-period-variables, with an amplitude range of 2.5 to 11 magnitudes over a period of 80 to 1,000 days.

3 Any bright nebulae in Ursa Major have all but faded from view, but we will encounter many fine examples in the rich summer Milky Way.

4 Mira stars are named for the prototype star in the constellation of Cetus known as Mira.


Hertzsprung–Russell Diagram
Color and spectral class
Blue
White
Yellow
Orange
Red
O
B
A
F
G
K
M
Blue supergiants
Red supergiants
Alioth
Mizar
Alcor
Alkaid
Merak
Phecda
Megrez
Polaris
Dubhe
Red giants
Sun
Main sequence (Dwarfs)
White dwarfs
Red dwarfs
Absolute magnitude (luminosity)
-5
0
5
10
15
20
Number of times as luminous as the Sun
10,000
100
1
1/100
1/10,000
1/1,000,000
50,000
30,000
10,000
7,000
5,000
3,000
2,000
Temperature in Kelvin


The life and death of a Sun-like star
Color and spectral class
Blue
White
Yellow
Orange
Red
O
B
A
F
G
K
M
Variable
(Hydrogen and helium shell burning)
(R Ursae Majoris)
4
3
Planetary nebula
(M97)
(At maximum)
2
Red giant
(Hydrogen shell burning)
(Dubhe)
1
Main sequence
(Hydrogen core burning)
(Sun)
(At minimum)
5
White dwarf
Absolute magnitude (luminosity)
-5
0
5
10
15
20
Number of times as luminous as the Sun
10,000
100
1
1/100
1/10,000
1/1,000,000
50,000
30,000
10,000
7,000
5,000
3,000
2,000
Temperature in Kelvin