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Excerpt
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# Introduction

## Familiarizing yourself with the night sky

Like our ancestors did thousands of years ago, it's quite natural for us today to view the night sky as an inverted bowl upon which the stars are attached and the Sun, Moon, and planets move. And it requires only a little imagination to further visualize that the inverted bowl of stars is actually the hemisphere of a globe – a celestial sphere – which we see from the inside out. Earth floats freely in space within this sphere, which lies at an immense but arbitrary distance. The sphere revolves slowly around our world, incrementally conveying the constellations from east to west until they return to their original positions a year later.

Of course, we recognize that the celestial sphere is an illusion: the Moon and Sun lie at very different distances, the stars are light-years away, and it is Earth's rotation and orbit that make the sky appear to move. But for purposes of tracking the motions and directions of celestial bodies, as well as learning the stars and constellations, a two-dimensional celestial sphere is an effective mental contrivance.

If we consider the sky as a sphere rotating about an axis, then it must possess directional bearings, a north and a south pole, and an equator. In the case of the celestial sphere, these are essentially projections into space of the Earth's cardinal directions, poles, and equator.

A compass can help you locate north, south, east, and west from your observing location, although it can be done just as well by noting where the Sun rises and sets (especially around the equinoxes). Although it is not important to be rigorously precise in noting the cardinal directions, it helps to know them in a general sense for skywatching purposes. When I describe a star or constellation rising in the 'northeast,' or lying 'due south,' and you know where these directions are, then you have won half the battle of getting yourself oriented.

Dividing the sphere, and hence the sky, into east and west halves is a circle called the celestial meridian. The meridian extends across the sky over your head and through the north and south points of your horizon. (There is also a circle crossing the horizon through the east and west points called the 'prime vertical,' but this doesn't come into play in this book as often as the meridian.) A celestial body is said to 'culminate' when it crosses the meridian. Hence, when I say that a certain star 'lies on the meridian (or culminates) tonight at 9 o'clock,' you know to look for it on a north-to-south line at the star's highest point in the sky.

Notice that I said 'the *star's* highest point.' All stars reach different altitudes above the horizon that are dependent on your latitude. In the Northern Hemisphere, stars toward the south never get very high in the sky, while those in the north arch overhead, or nearly so. Southern stars do, of course, rise higher the further south you go, but then stars in the northern sky begin to slip lower. Again, this adds to the illusion that the sky is one half of a sphere.

On the other hand, there is indeed a point in the sky that can be called 'highest,' with respect to you, the observer. It always lies directly over your head and is called the zenith. As such, the zenith is 90° (i.e., at a right angle), from all points on your horizon and also lies on the meridian.

The north celestial pole lies very near the end of the handle of the Little Dipper and is marked by the star Polaris (more popularly known as the North Star). In the Northern Hemisphere, its angular distance above your horizon is equivalent to your latitude. So, if you live at latitude 35° N, then Polaris lies 35° above your northern horizon. The closer you get to the North Pole, the higher the star appears in the sky, until at the North Pole, it stands at your zenith.

Conversely, the south celestial pole in the Southern Hemisphere is in the constellation Octans and marked by the faint star Sigma ($\sigma$). Its distance above any horizon is also latitude dependent. Since the entire celestial sphere pivots around these two points in the sky, they never rise or set. (For more on finding the celestial poles, see 'Finding true north, March 22 – 28,' and 'Finding true south, March 29 – April 4.')

By definition, the celestial equator is the great circle lying halfway between the north and south celestial poles. It is Earth's equator projected into space. Hence, if you were standing on the equator, the celestial equator would be the prime vertical circle running overhead through the east and west points on the horizon. In the Northern Hemisphere, the celestial equator lies south of your zenith at an angular distance equivalent to your latitude. Thus, if you live at latitude 30°, the celestial equator lies south of your zenith by that amount. (You can also say that at latitude 30° the celestial equator is inclined to the south horizon by 60°.)

The final great circle to note is the ecliptic, which passes through the twelve constellations of the zodiac, plus a thirteenth, Ophiuchus. It is, in essence, the projection of the mean plane of Earth's orbit into space. Since Earth's orbital plane is coincident with that of the solar system, the annual paths of the Sun, Moon, and planets lie very near the ecliptic circle. And because Earth's axis is tipped over nearly 23.3° with respect to this plane, the ecliptic, too, is inclined to the celestial equator by that amount.

Four equidistant points on the ecliptic represent solar milestones, when the Sun either crosses the celestial equator or is at its greatest distance from it. These points represent the four seasonal transitions. The spring and autumnal equinoxes occur where the ecliptic intersects the celestial equator. In spring, the Sun crosses the celestial equator moving northward; in autumn, it is heading south. The summer solstice is the point where the Sun reaches its northernmost extreme from the celestial equator; the winter solstice is the Sun's southernmost reach. Again, because the Earth's axis is tilted 23.3°, this is how much the Sun moves above and below the celestial equator.

## Directions in the sky

When finding your way around in the city, you know that to go 'north' or 'south' means to head toward the north or south cardinal point on the horizon. However, when a celestial object or event is said to be visible in the 'north,' you should look in the sky in a direction toward the north celestial pole. A star that is said to lie ten degrees 'south' of another star means that you look ten degrees from that star in a direction that leads toward the south celestial pole. 'Northeast' in the sky, then, would fall between cardinal east and the north celestial pole, and 'southwest' would be between cardinal west and the south celestial pole. If a celestial pole is not visible from a particular hemisphere (as the south celestial pole is not for those in the Northern Hemisphere, and vice versa), then its location must be inferred from the region of sky that lies directly opposite the visible celestial pole.

Sometimes, as when you are facing the southern sky in the Northern Hemisphere, the directions for east and west will seem reversed. After some practice, these directions will come more naturally.

## A matter of degrees

One of the best ways to find a faint star or a deep-sky object, such as a galaxy or star cluster, is to look for it in relation to a bright, well-known star. But when you look at the bright star, which is easy to see, how do you tell someone how far away the fainter object is from it? You could say that object X is five 'inches' north of star Y, but that assumes that everyone agrees on how big an inch appears on the sky. Such a method of judging apparent distance is not only awkward but inaccurate.

Astronomers measure apparent distances and separations on the sky using the angular scale: degrees, minutes of arc, and seconds of arc. In this book, we will be mostly concerned with degrees. In the above example, then, we might say that object X is '5°' north of star Y. Fine. But how much is a degree?

Everyone knows that a circle contains 360°, and a half circle 180°. A circle traced across the celestial dome (essentially half a sphere) from one point on the horizon to the point opposite would equal 180°. From the horizon to the zenith would be half that amount, or 90°. Half that distance again, midway up into the sky from the horizon, is 45°; half again is 22.5°, and so on.

This gives us an approximate scale that can be applied to quadrants of sky, but what about smaller areas in and around constellations? We need something familiar to help us gauge smaller chunks of sky. That 'something' is your fist. A fist at arm's length covers about 10° of sky; 12° if your hands are large. (For more on calibrating fist size, see 'Spring arrives,' March 15 – 21.) From horizon to zenith, you should be able to mentally stack nine fists. An even finer gauge is the Moon. The Moon's apparent diameter is about half a degree (as is the Sun's). So two full Moons side by side equal one degree.

We can go to a still smaller scale. Consider that a single degree consists of 60 minutes of arc, and each minute of arc consists of 60 seconds of arc. If the Moon's apparent diameter is half a degree, then it can also be described as being 30 minutes of arc, or 1,800 seconds of arc, in apparent diameter. (We say 'apparent' diameter as opposed to 'true' diameter to describe the size of these bodies as they appear on the celestial sphere. Obviously the actual sizes of the Moon, Sun, and planets are much greater than their angular sizes.)

The planets, too, exhibit tiny disks in the sky that are measured in seconds of arc. When nearest Earth, Mars has an apparent diameter of 25 seconds of arc; Jupiter, 50 seconds of arc; and Venus nearly a minute of arc.

## Star magnitudes

In addition to their myriad numbers, stars also come in a wide range of brightnesses. It is very often much easier to find a particular star or star group if you can determine beforehand how bright it is. To do so, we need some standard scale of brightnesses to use as a gauge.

In the second century B.C., the ancient Greek astronomer Hipparcos became the first to develop a qualitative scale for determining the brightness of a star. In the Hipparcos system, naked-eye stars were sorted into six different classes of brightnesses, or magnitudes. Twenty of the brightest stars were given first-magnitude status. The faintest stars that could be discerned were designated magnitude 6. Stars that fell between these two extremes were given intermediate magnitudes – 2, 3, 4, and 5.

With the advent of the telescope, however, countless stars fainter than magnitude 6 were observed and their brightnesses had to be measured more precisely. By the middle of the nineteenth century, astronomers agreed to refine the magnitude scheme in order to make it a quantitative rather than a qualitative scale. A difference of a single magnitude now corresponds to a brightness ratio of 2.5. Hence, a star of magnitude 1 is 2.5 times brighter than a star of magnitude 2, and 100 times brighter than a star of magnitude 6.

The original 20 first-magnitude stars ranged so widely in brightness that the very brightest, by virtue of the revised magnitude system, were assigned negative and zero values. In order of diminishing brightness, these are: Sirius, −1.46; Canopus, −0.72; Arcturus, −0.04; Rigel Kentaurus (Alpha Centauri), 0.00; Vega, 0.03; Capella, 0.08; Rigel, 0.12; Procyon, 0.38; Achernar, 0.46; Betelgeuse, 0.50; Hadar, 0.61; Altair, 0.77; Aldebaran, 0.85; and Antares, 0.96. The star Spica, at 0.98, is almost exactly a magnitude 1 star.

If it shines or reflects light in the sky, it has an apparent magnitude, not only the planets, the Moon, and the Sun, but meteors and artificial satellites as well. Venus, at its brightest, is magnitude −4.7; the Moon is magnitude −13; and the Sun is magnitude −26.5. On this scale, the Sun is about 9 billion times brighter in light output than Sirius, which is 25 magnitudes fainter. Sirius, on the other hand, is about a trillion times brighter than the faintest star (magnitude 28.5) visible with the Hubble Space Telescope.

Occasionally, I'll describe objects that can best be seen in binoculars or a small telescope. Whereas the naked eye can see only to magnitude 6 or so, a good pair of binoculars in dark skies can see stars as faint as magnitude 10; a 4-inch telescope, magnitude 12; an 8-inch, magnitude 14. Even if objects can be glimpsed with the naked eye, like the Andromeda Galaxy or the Orion Nebula, more features can be seen in those objects when you are able to gather more of their light. More light translates into more detail or, to invoke a technical term, greater 'resolution.' That's where even slight optical aid can help enhance the beauty of objects in the night sky.

## Stellar nomenclature

At least fifty of the brightest stars have names that are either of Greek or Latin origin (Sirius, Castor, Pollux), or Arabic (Altair, Fomalhaut). Many of the brighter naked-eye stars in the constellations, however, are designated not by name but by small letters of the Greek alphabet. In this system, introduced in 1603 by Johannes Bayer, the brightest star in a constellation generally is labeled Alpha or α, the second-brightest star is Beta or β, and so on down to Omega or ω. (There are important exceptions to this, however, as I will soon describe.)

The name of a star in the Bayer system is the Greek letter designation followed by the possessive of the constellation's Latin name. And, in fact, this is how astronomers still refer to these stars. For example, the brightest star in the constellation Canis Major, besides being called Sirius, is Alpha (α) Canis Majoris. (However, astronomers typically refer to the proper name of a star of that magnitude.) In the essays, I use both the Greek symbol as well as the name of the Greek letter to aid in helping you find the star on a star map.

As mentioned, the Bayer system, in a general sense, goes in order of descending brightness. But not always. For example, the seven brightest stars in Ursa Major, which comprise the Big Dipper, are lettered in order of their position from the cup, because they are not much different in brightness from one another. Thus, the brightest star in Ursa Major is fifth down, Epsilon (ε) Ursa Majoris, rather than Alpha. There are other exceptions as well. In Orion, Rigel is quantitatively the brightest star in that constellation, but Betelgeuse, the second-brightest, is designated Alpha, while Rigel is designated Beta. The same is true in Gemini, in which Pollux, the constellation's brightest star, is designated Beta, while Castor, the second-brightest star, is designated Alpha.

For now, these things are all you need to know to get started observing the night sky. The few remaining terms relating to distances, types of stars, and other astronomical nomenclature will be defined in the text. You don't need to be versed in astronomical jargon to enjoy the night sky purely from an aesthetic point of view, but just as knowing where each of the cardinal directions lie from your home or how to read a road map can help you find your way from one place to another, these modest terms will help you move effortlessly from star to star until you know the heavens as well as your own neighborhood.

PART I

# The Sky by Seasons

You do not have to sit outside in the dark. If, however, you want to look at the stars, you will find that darkness is necessary. But the stars neither require nor demand it.

*Annie Dillard*

# Winter

## December 21–27
The seasonal lag

Winter, which usually arrives on or about December 22, never seems to be appropriately on time, no matter where you live. In the southern realms of the Northern Hemisphere, the first day of winter can be quite mild, even tropical, while in the north, cold air has been infiltrating since late September and several inches of snow may already be on the ground. Depending on where you live, you are either surprised that winter has snuck up on you or incensed that someone would make a big deal about the season's entrance long after its arrival.

Those of us living in the Northern Hemisphere may well take heart in the first day of winter, for it means that the Sun has reached its most southerly extreme – it's summertime in the Southern Hemisphere – and will soon be heading back toward the north, bringing with it more direct light and longer days. In fact, by late January, and definitely by mid-February, you can tell that it doesn't get dark quite as early as it did in mid-November and December.

Even as the Sun halts its southerly advance and begins its slow return to the north, the coldest days still lie ahead for those in the Northern Hemisphere. Granted, with daylight saving time not in effect during the autumn and winter months, the days seem that much more abbreviated, but still by December 22 the Sun sets around 5 o'clock and it is dark by 6 o'clock. (The Sun sets even earlier the further north you are.) Arctic air whisks in from the north whipping up little whirlwinds of leaves or snow, while over-running warm air from the south covers the sky with an unbroken blanket of slate-gray stratus clouds. For northerners, the winter solstice is not cause for celebrating the Sun's turnaround; it just means that the weather will be getting colder before it starts getting warmer again.

Why is this the case? With each passing day, the Sun's rays shine more directly on the ground. Shouldn't it, therefore, be coldest at the winter solstice and warmer thereafter?

It would, if Earth's surface temperature were solely dependent on the changing angle of the Sun. But it's not. Day-to-day weather is more dependent on the balance of incoming solar heat and outgoing radiation reflected from both the surface and the atmosphere. As long as more heat is being reflected than absorbed, the temperature falls. Hence, in the Northern Hemisphere around December 21 or 22, even though the Sun's elevation at noon is lowest and the daily duration of sunshine is at its minimum, the coldest days occur in January and February, as the Sun advances northward. Not until the rate of heating overtakes the rate of radiative cooling do the daily temperatures begin to rise, as they do in the spring.

Conversely, after the first day of summer, with the Sun slipping ever southward, temperatures reach their warmest weeks later, in July and early August. They don't begin to abate until the amount of heat the Earth returns to space exceeds the amount it receives, which occurs during the autumn months. This delay between the official onset of winter and summer and their associated temperatures is called the lag of the seasons.

For some latitudinal extremes in the Northern Hemisphere, the lag of the seasons can be ludicrous. Very often, cooler weather doesn't become noticeable in the extreme south until well into October, and even then, the few cool days are adjoined by a string of warm, humid ones. For example, in south Florida and Texas (latitude 26° N to 30° N or so), mild Christmases are not unusual, and you can often sit in your shirtsleeves sipping iced tea while basking in the warm sun in January. Conversely, I've seen nearly ten inches of heavy, wet snow dumped on Milwaukee (latitude 42° N) in April (almost a month after the spring equinox), and near-freezing temperatures in early June, (a couple of weeks before the summer solstice).

In such cases there doesn't seem to be so much of a seasonal lag as a seasonal identity complex, which, as I said earlier, often leads to surprise and malediction. The weather hasn't caught up with the month it's