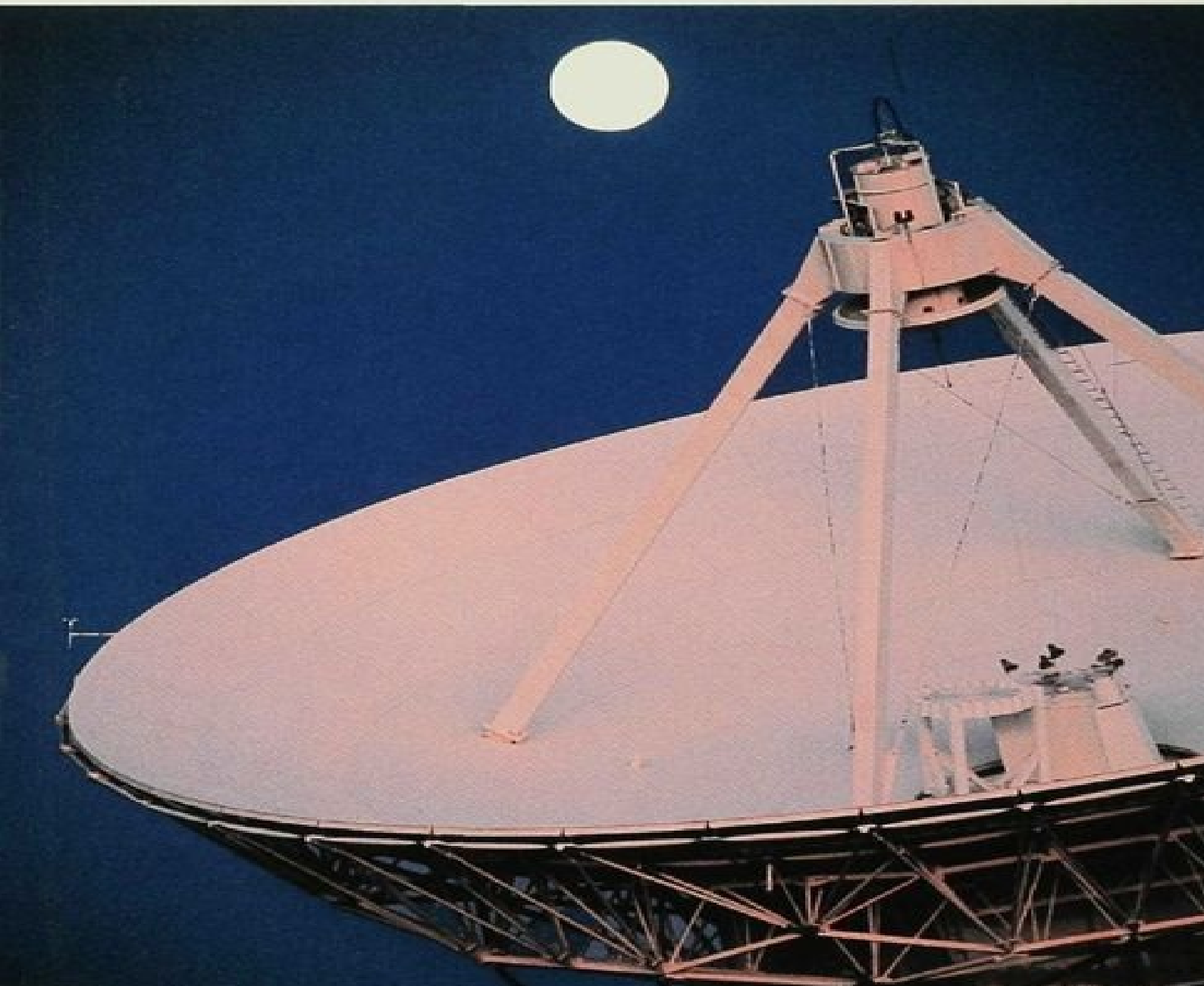


*Golden Field Guides* FROM ST. MARTIN'S PRESS

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# Night Sky

A guide to field identification





# NIGHT SKY

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## A FIELD GUIDE TO THE HEAVENS

a Golden Field Guide from St. Martin's Press

Original Title: SKYGUIDE



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## PREFACE

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The sky is a part of nature available to all people, yet how the sky appears is very localized and very personal: No one sees the sky in exactly the same way or the same time as you do. This guidebook provides an introduction to the natural sky for those with little knowledge of astronomy, so that they can begin to appreciate the beauty of the sky and of the laws of nature that determine the motions and appearances of celestial objects. It is hoped that readers will find this book useful even when they have graduated to more technical, more detailed works.

The author wishes to thank many people who have played major and minor roles in bringing this book to the public. In particular, I am grateful to persons who have influenced my astronomical education at critical times: Arthur P. Smith of the Southern Cross Astronomical Society, Dan Snow of the Ralph Mueller Planetarium, Dr. Peter Pesch of Case Western Reserve University, and the late Dr. Sidney W. McCuskey, also of CWRU. Appreciation is due also to Barbara Williams, who initiated this project; to Jerome Wyckoff, who edited the text; and to Caroline Greenberg, who saw the book through to completion. The help, advice, and suggestions of my colleagues at the Hayden Planetarium in New York—particularly Allen Seltzer—have been most helpful. I am indebted to the facilities of the Perkin Memorial Library at the Hayden Planetarium. In a very special way, I must thank the artist for this book, Helmut Wimmer—co-worker, colleague, and friend.

The artist would like to thank, particularly, Barbara Williams for her confidence in his ability to visualize the book; also, Dr. Mark R. Chartrand for his assistance and guidance, and Ms. Sandra K. for her help in his research.

Mark R. Chartrand

Helmut K. Wimmer



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# INTRODUCTION

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Look up at the bright and unsullied hue of heaven and the stars which it holds within it, wandering all about, and the moon and the sun's light of dazzling brilliancy: if all these things were now for the first time, if, I say, they were now suddenly presented to mortals beyond all expectation, what could have been named that would be more marvelous than these things, or that nations beforehand would less venture to believe could be? Nothing, me thinks: so wonderous strange had been this sight. Yet how little, you know, wearied as all are to satiety with seeing, any one now cares to look up into heaven's glittering quarters!

This quotation could very well describe the present common disregard for the sky, yet it was written around 55 B.C. by the scholar Lucretius in his great work *De Rerum Natura*. Some things just don't change.

The sky is that part of the natural environment which we all share, no matter where we are on Earth—or even in space. Yet many people who can identify birds or rocks, trees or ferns, cannot point to any constellations by name, or find the planets in their wanderings among the stars. Few can tell where the Sun rises where it does or why the Moon has phases. This book is for them, and for all others who have ever wondered at the beauty of the night sky, watched the solemn progress of a lunar eclipse, or stood breathless for the timeless moments of the totality of a solar eclipse.

Lucretius refers to “the bright unsullied hue of heaven,” and here he had an advantage over us. Modern people live, for the most part, under canopies of polluted air and urban lighting; these cut us off from the crystal clarity of the night sky seen in areas far from cities. But there is still much to be seen, even from cities.

If you can, get to a park, beach, or other area as far as possible from cities. Campers in the Southwest probably enjoy the best skies, but merely getting 50 miles from a city can be a great help. But be warned: If you have learned your constellations in a city (which is possible, at least for the brighter ones), you may get lost in the skies of the country. There are so many more stars! They were there all the time, of course, but in the city they couldn't be seen.

Another important factor in viewing, especially with a telescope, is what astronomers call “seeing.” This refers to the steadiness of the images, rather than the transparency of the sky. If the stars are twinkling a lot, this is poor seeing, and a telescope will only exaggerate the poor images further. All objects in the sky appear to twinkle when near the horizon because their light is passing through more atmosphere before it reaches your eyes. With good seeing, objects high in the sky will seem steady. Ironically, some nights when there is just a bit of haze, and the transparency is not perfect, are the times of best seeing, at least in cities, because air turbulence is not distorting the image. Astronomers reduce this problem by placing their major instruments high atop mountains in carefully selected locations to get above as much of the atmosphere as possible.

Throughout this book references are made to “amateur” instruments. This is not meant to disparage but simply to refer to telescopes and other equipment that are within the range of the nonprofessional stargazer. It definitely does not imply inferior quality, for many small telescopes are of high quality.

Astronomy is one of those rare sciences in which the serious amateur can make important contributions. Here, “amateur” means only “not getting paid for it.” Yearly, amateur astronomers contribute over 100,000 observations of variable stars, discover new comets, watch grazing lunar

occultations, discover novae and supernovae, and count sunspots. All these add to the store of astronomical data from which professional astronomers draw to check their theories and calculations. In few fields can the amateur make such contributions.

You should try to make contact with a local amateur astronomical society. Many hold regular meetings with speakers, and occasionally have “star parties” at which many telescopes are set up to observe the sky. Here you will have an excellent opportunity to compare many instruments, observe many astronomical sights, and make friends.

Local science museums and even some public libraries often have telescopes available for public viewing on a regular basis, as well as introductory classes on astronomy. To learn your way around the night sky, there is no better place to start than your local planetarium, where the sky and the weather can be controlled. If you are traveling anywhere near one of the major observatories, you should try to plan to stop in on one of their public nights. A list of many of the major observatories and planetariums can be found [here](#).

A word of advice about buying telescopes: Decide first if your interest in the subject is serious and permanent, or if you just wish an occasional view of the sky. For a first instrument, binoculars are ideal. They are less expensive than a telescope of comparable size, easy to hold, have a wide field of view, and, if your interest wanes, can always be used for watching sports or birds! After you have had a little experience, ask local amateur astronomers for recommendations on what to buy, after reading [here](#). Some local amateur astronomical societies even offer used telescopes for sale.

A second word of advice about buying telescopes: Avoid any telescopes sold in department stores or by opticians. The telescopes are almost invariably of poor quality and not worth the price, and the salespeople know little or nothing about them. There are only a few shops around the country specializing in amateur astronomy equipment, but these are easy to identify. By and large, the better amateur instruments are available from mail-order firms (see [here](#)).

When you first look through a telescope at, say, Mars or Saturn, or the Ring Nebula, don't expect to look like the photographs you see in many astronomy books. These photos were taken through the world's largest and best instruments. Your 6-inch reflector is not going to yield an image of comparable size and quality. Your telescope excels, however, in giving you a view that is particularly yours, is real, and is now. That intangible quality is something you can't get from staring at a picture.

Lastly, remember that astronomy is unique in that you can appreciate it on many levels, from just enjoying the sparkling beauty of the night sky, to keeping track of variable stars, to learning relativistic astrophysics. The depth to which you go is up to you. And although the same stars will appear in your skies in the same places year after year, all your life the planets will keep shifting in the heavens, comets will come and go, meteors will flash ephemerally across the sky, and new discoveries will be made, adding depth to your understanding of the old familiar sky.

Good observing!

# ASTRONOMICAL SYMBOLS AND ABBREVIATIONS

## SUN, MOON AND PLANETS

☉ The Sun	♀ Venus	♃ Jupiter	♆ Neptune
☾ The Moon	♁ Earth	♄ Saturn	♇ Pluto
☿ Mercury	♂ Mars	♅ Uranus	

## SIGNS OF THE ZODIAC

♈ Aries	♋ Cancer	♎ Libra	♏ Capricornus
♉ Taurus	♌ Leo	♏ Scorpius	♐ Aquarius
♊ Gemini	♍ Virgo	♏ Sagittarius	♑ Pisces

## TERMS INDICATING RELATIVE POSITION

♌ Conjunction	☐ Quadrature	♊ Ascending Node
♍ Opposition		♋ Descending Node

## ABBREVIATIONS

h, m, s—Hours, minutes, seconds of time	A.U. or a.u.—Astronomical units
° ' "—Degrees, minutes, seconds of arc	α or R.A.—Right ascension
	δ or Dec.—Declination
	lt-yr—Light-year

## THE GREEK ALPHABET

Α, α Alpha	Η, η Eta	Ν, ν Nu	Τ, τ Tau
Β, β Beta	Θ, θ Theta	Ξ, ξ Xi	Υ, υ Upsilon
Γ, γ Gamma	Ι, ι Iota	Ο, ο Omicron	Φ, φ Phi
Δ, δ Delta	Κ, κ Kappa	Π, π Pi	Χ, χ Chi
Ε, ε Epsilon	Λ, λ Lambda	Ρ, ρ Rho	Ψ, ψ Psi
Ζ, ζ Zeta	Μ, μ Mu	Σ, σ Sigma	Ω, ω Omega



# TERRESTRIAL COORDINATES

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How you see the sky depends upon where you are on Earth. Even the way the sky seems to move overhead depends upon your terrestrial location. To specify a location on Earth precisely, two coordinates are used—two because Earth's surface is two-dimensional.

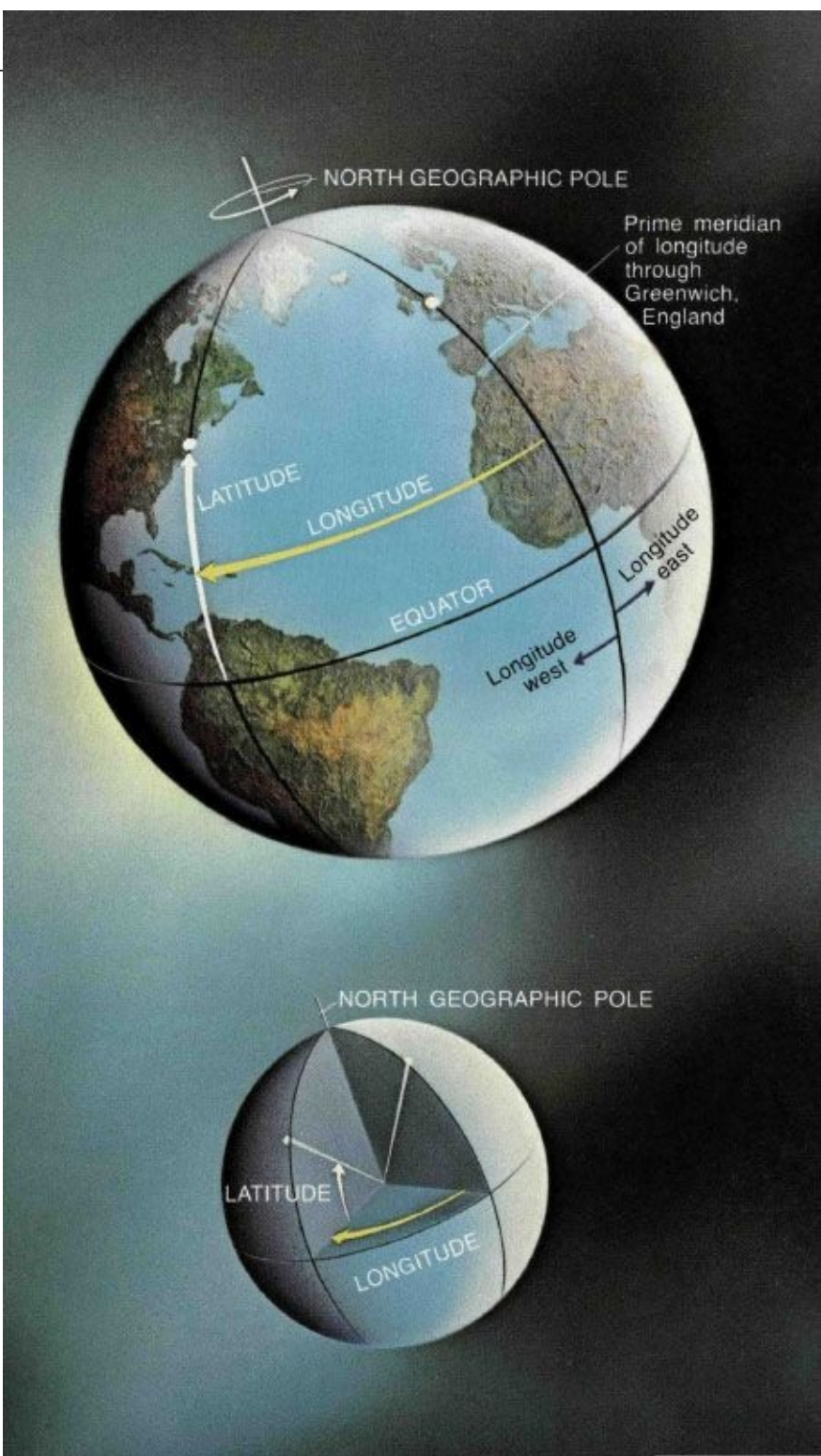
*Latitude* is the north-south coordinate, measured in degrees north and south of the equator, which is the imaginary line around our planet midway between the poles. The poles are the ends of the planet's axis of rotation, and for our purposes can be considered fixed. The equator is at latitude  $0^\circ$ . Northern latitudes are positive, southern ones negative. The north geographic pole is at latitude  $+90^\circ$ , the south geographic pole at  $-90^\circ$ . Locations having the same latitude are said to be on the same *parallel of latitude*.

*Longitude* is the east-west coordinate. A line from one pole to the other is called a *meridian of longitude*. (Such a line is an example of a *great circle*: a line on the surface of a sphere which is part of a circle whose center coincides with the center of the sphere.) A *prime meridian* is needed from which to start measurements eastward or westward. A century ago, different prime meridians were in use by different countries, each wanting the prime meridian to go through its capital. Since this situation was confusing to navigators and astronomers, all nations finally adopted the present prime meridian, which runs through Greenwich, England. Sometimes called the *Greenwich meridian*, it is marked at the Greenwich Observatory by a brass line in the pavement, so that you can stand with your feet in different hemispheres.

Longitude, like latitude, can be measured in degrees—from the prime meridian east and west up to  $180^\circ$ . At  $180^\circ$ , opposite the Greenwich meridian, is the *international date line*, which divides the Pacific Ocean. (For political and practical reasons, the line zigs and zags near the  $180^\circ$  meridian.) Along this line each new day begins and the previous day ends, so that, for example, when the time is 12:01 a.m. Wednesday just east of the line it is 12:01 a.m. Thursday just west of the line. Since the time of day when we see astronomical objects depends on Earth's rotation, longitude is often measured in hours, one hour equaling  $15^\circ$ . (See [here](#).)

Although Earth's surface is two-dimensional, the planet is three-dimensional. Latitude and longitude are not just lines on the surface, but refer to angles measured at Earth's center. Latitude is the angle between the equator and the location referred to, and longitude is the angle between the prime meridian and the meridian of the location referred to. Each degree of latitude or longitude can be divided into 60 minutes (abbreviated  $'$ ), and each minute into 60 seconds ( $''$ ). But navigators and astronomers commonly use degrees with decimal fractions, rather than minutes and seconds, because they make computations easier.





# HORIZON COORDINATES

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Looking up at the sky from a plain, we seem to be at the center of the universe, with a flat Earth stretching off to infinity in all directions. We are at the center of the *celestial sphere*, an imaginary globe of indefinitely large size, on the inner surface of which all heavenly bodies and their motions appear as if projected onto a screen. This concept allows us to ignore *distances* of celestial objects except when relevant, heeding only their *directions*.

Often an observer wants to specify the direction of a celestial object with respect to *his* location. One convenient way is by means of *horizon coordinates*, sometimes called *topocentric coordinates*.

First, imagine a flat plane tangent to Earth's surface at your location. This is your *horizon plane*. The line along which it intersects the celestial sphere is your *horizon*. This divides the universe into the part you see above the horizon, and the invisible part below it. North is the point on the horizon in the direction of the geographic north pole; south is opposite. Facing south, east is on your left, west on your right.

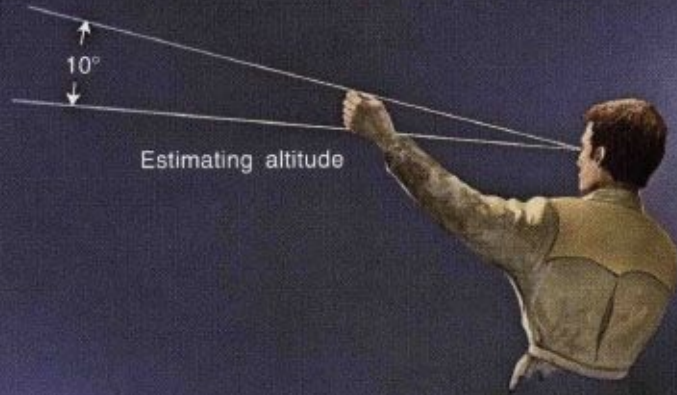
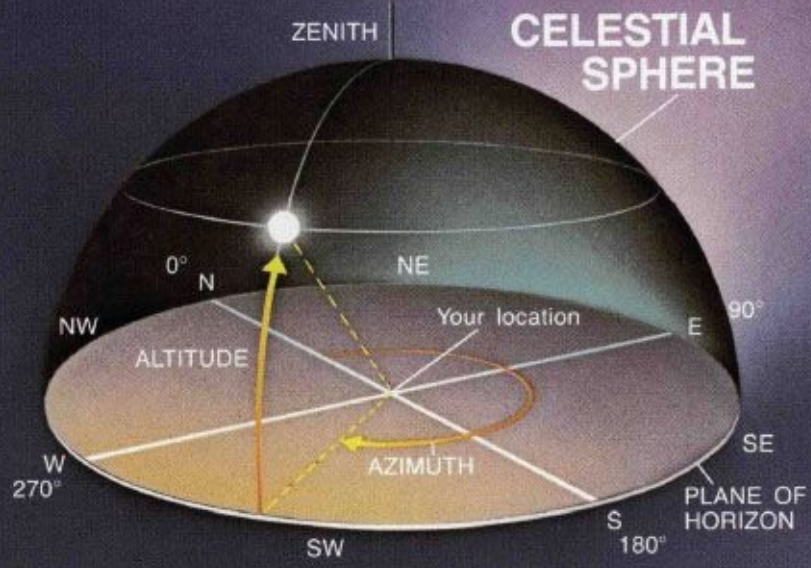
Your celestial sphere has a spot unique for you: the point directly overhead, the *zenith*. If you move, your zenith moves. No other location on Earth has the same zenith as yours. The point opposite the zenith on the celestial sphere is the *nadir*.

The location of a celestial object with respect to the observer's location is described by the two angles called altitude and azimuth.

*Altitude* is the angle between the horizon and the object. This angle is measured from the horizon and perpendicular to it. Altitude is not height above the ground, as of an aircraft. It is an angle centered on you; or, an arc along the celestial sphere. Altitude ranges from  $0^\circ$  at the horizon to  $+90^\circ$  at the zenith. Objects below the horizon have negative altitudes. Objects at the same altitude are said to be on a *parallel of altitude*. A line of constant altitude around the sky is called an *almucantar*.

*Azimuth* is the compass direction toward an object. More precisely, it is the angle measured around the horizon, beginning at north ( $0^\circ$ ) through east ( $90^\circ$ ) and so on until you reach a line drawn perpendicular from the object to the horizon. Thus east is azimuth  $90^\circ$ , south  $180^\circ$ , west  $270^\circ$ , and north  $360^\circ$ —the same as  $0^\circ$ .

You can estimate altitude or azimuth simply by extending your fist to arm's length. At this distance your fist will appear to be about  $10^\circ$  wide. If you align the bottom of your fist with the horizon, the top is at about  $10^\circ$  altitude. Stacking fist on fist, you can estimate wider angles. This method of approximately measuring distances across the sky is convenient when you are attempting to locate a star or other object that is a known number of degrees from an object you have already identified. A navigator uses a sextant to determine altitude and azimuth accurately.



# THE CELESTIAL SPHERE

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Imagine Earth as surrounded by a very large sphere on the surface of which all stars, planets, and other celestial objects are placed. This is similar to the observer's celestial sphere mentioned [here](#), but not exactly the same. Now we are imagining the astronomer's celestial sphere, with the center of Earth at the center of the sphere.

Next, imagine Earth's equator expanding outward until it intersects the sphere. The intersection will be a great circle on the sphere called the *celestial equator*. It is halfway between the *north celestial pole* (NCP) and the *south celestial pole* (SCP), which are the locations on the celestial sphere directly above the north and south geographic poles on Earth's surface.

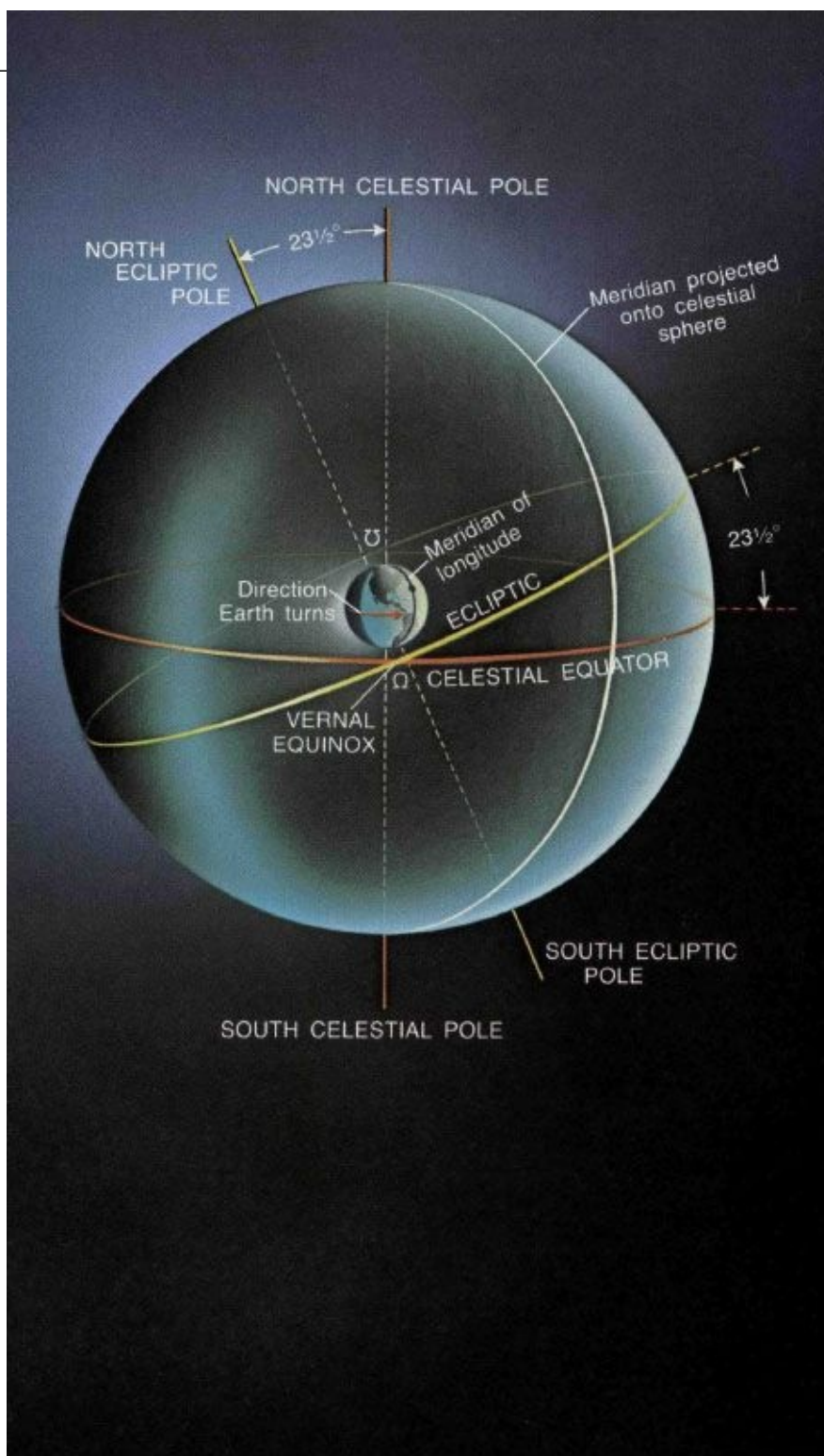
In the sky there are counterparts to meridians of longitude, but for reasons explained more fully [here](#), they are usually called *hour circles*. You should keep in mind that as Earth turns, the meridian of longitude under a given hour circle changes continuously.

Another fundamental plane in the sky is the plane of Earth's orbit, called the *ecliptic plane*, or *ecliptic*. As seen by us on Earth, the ecliptic is an imaginary line in the sky along which the Sun moves during a year's journey around the sky against the background of stars. As seen by an observer sitting "on the NCP," the Sun would move counterclockwise. Perpendicular to the plane of the ecliptic are the north and south *ecliptic poles*.

When Earth formed from a cloud of gas and dust about five thousand million years ago, its axis of rotation did not coincide with the axis of the ecliptic poles. The two axes, and hence the plane of the equator and the plane of the ecliptic, are inclined to one another at an angle of about  $23\frac{1}{2}^\circ$ . This angle is called the *obliquity of the ecliptic*. Thus the north ecliptic pole is at R.A. 18h, Dec.  $+66\frac{1}{2}^\circ$ , while the south ecliptic pole is located opposite at R.A. 6h, Dec.  $-66\frac{1}{2}^\circ$ .

The two points on the celestial sphere where the equatorial and ecliptic planes meet are termed the *equinoxes*. The point at which the Sun crosses the celestial equator when going north in spring is called the *vernal equinox*. The point where the Sun crosses when going south in autumn is the *autumnal equinox*. (See [here](#) for the relationship of the equinoxes to the seasons.)

Keep in mind that the celestial sphere is indefinitely large. All that concerns us are the *directions* to celestial objects from us. For most purposes, it makes no difference whether the center of the celestial sphere is assumed to be at the center of Earth or at our location. Remember also that the illustration here and on other pages shows the celestial sphere as seen from the "outside," while we on Earth are looking out from inside. The celestial sphere is the "screen" on which the drama of the sky is played.



# CELESTIAL COORDINATES

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To specify an object's location on the celestial sphere, *equatorial coordinates* are used. These refer to the celestial equator.

The north-south coordinate (similar to latitude) is called *declination* (Dec, or  $\delta$ , the lower-case Greek letter "delta"), measured in degrees north ( + ) and south ( - ) of the celestial equator, which is at declination  $0^\circ$ . The celestial poles are at  $+90^\circ$  and  $-90^\circ$ .

The east-west coordinate is called *right ascension* (R.A., or  $\alpha$ , the lower-case Greek letter "alpha"). Its zero-point is the vernal equinox. Right ascension is expressed sometimes in degrees, but more commonly and usefully in hours, minutes, and seconds. Since Earth turns  $360^\circ$  in about 24 hours, one hour (1h) of right ascension (or time) is  $15^\circ$  of arc, one minute of time (1m) is 15 minutes of arc (written 15'), and one second of time (1s) is 15 seconds of arc (15").

A degree of declination always represents the same distance on the celestial sphere, but an hour of right ascension represents a shorter distance on the celestial sphere as we move farther away from the celestial equator. In other terms,  $1^\circ$  of arc in R.A. always equals 4m of time, but represents a shorter distance on the celestial sphere as declination increases. Thus an object at Dec.  $0^\circ$  (that is, on the celestial equator) seen in a fixed telescope with a field of  $1^\circ$  will cross the field in 4 minutes, but at Dec.  $45^\circ$  the object would be in the field about 6 minutes.

The vernal equinox is right ascension 0h, and the opposite point, the autumnal equinox, is 12h from which we go on to 24h, which is the same as 0h. Right ascension increases counterclockwise—that is, toward the east—around the north celestial pole. As observers we are inside the sphere; hence the sky pattern is reversed compared to the illustration, which shows the pattern from outside.

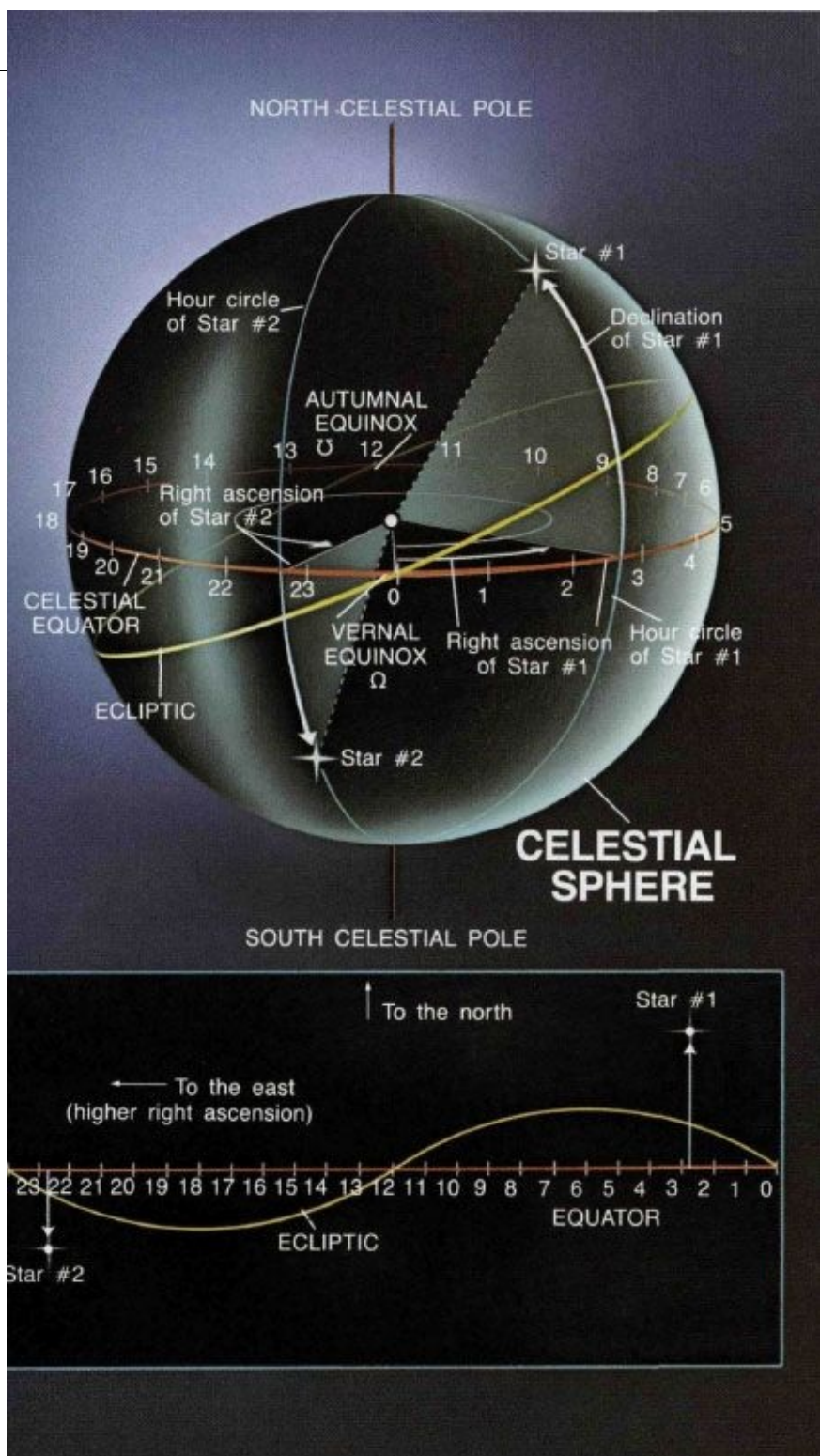
In the illustration are two stars: #1 and #2. Their positions can be specified thus:

Star #1:  $\alpha = 2\text{h}45\text{m}00\text{s}$ ,  $\delta = +62^\circ26'56''$ .

Star #2:  $\alpha = 22\text{h}40\text{m}55\text{s}$ ,  $\delta = -36^\circ44'05''$ .

*Celestial longitude* is similar to right ascension, except that it is measured along the ecliptic rather than along the celestial equator. *Celestial latitude* is the angular distance of an object from the ecliptic. These coordinates are useful for specifying the positions of planets, since planets are always close to the ecliptic.

Because it is curved, when the celestial sphere is represented on a flat page, distortions occur—areas get squeezed or stretched out of shape. The bottom illustration shows a flat map with the celestial equator and the ecliptic marked, along with one or two stars. Study carefully the two methods of showing the same thing. Both methods are useful in depicting the sky and will be used later in the book.



## TIME AND THE SKY

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Most timekeeping and calendrical schemes depend on celestial motions. A *day* is the time it takes for one complete rotation of Earth, a *month* for a complete cycle of Moon phases, a *year* for one circuit of Earth's orbit.

Unlike common clocks, the "face" of the celestial clock moves while the "hand" stands still. For observers in the northern hemisphere, the center of the clock face is the NCP (north celestial pole) marked approximately by the [star Polaris](#). Since the plane of an observer's horizon is tangent to Earth's surface at his location, the altitude of the NCP from his location is the same angle as his latitude. At latitude  $+40^\circ$ , the NCP is  $40^\circ$  above the north point on the horizon. All stars within that many degrees of the NCP will always be above the horizon. Similarly, all stars within that many degrees of the SCP will never rise. Since the celestial equator is perpendicular to the axis between the celestial poles, for any observer anywhere it will cross the sky and intersect the horizon at the due-east and due-west points, and its angle with the horizon will be  $90^\circ$  minus the observer's latitude.

For any observer, the "hand" on the clock is an imaginary line in the sky called the *celestial meridian*, or just *meridian*. It is the observer's meridian of longitude extended out to the celestial sphere. It runs from the due-north point, through his zenith, to the due-south point, and underneath Earth back to north. The meridian for one location is different from the meridian for any other location to the east or west. An observer due north or south of you shares the same meridian, but for that observer the NCP is at a different altitude.

An imaginary circle drawn on the celestial sphere through the celestial poles and a celestial object is the *hour circle* of that object. The angle, or arc, between the celestial meridian and the hour circle of the object is the *hour angle*. Since the sky moves westward, the hour angle increases westward, from 0h on the meridian through 24h. It decreases eastward. Thus an object in the eastern sky has a negative, or negative, hour angle. The hour angle is the measure of how long ago (or before) the object was (or will be) on the meridian.

In the illustration, the Sun's hour angle is about 2h, since it is about  $30^\circ$  west of the meridian. Our time of day is defined by the hour angle of the Sun, but since we want a new day to begin at midnight when the Sun is crossing the invisible lower meridian, we use this definition: Local Apparent Time = Hour Angle of the Sun + 12h. The time is *apparent* because it is according to where the Sun appears and local because it depends on the observer's location. A person east of you has a later local apparent time (a later time shown on a sundial), because the Sun crosses his meridian *before* it crosses yours. A person west of you has an earlier local apparent time because the Sun will cross his meridian *after* it crosses yours.



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