INTRODUCTION

The night sky is one of the most beautiful sights in nature. Yet many people remain lost among the jostling crowd of stars, and are baffled by the progressively changing appearance of the sky from hour to hour and from season to season. The charts and descriptions in this book will guide you to the most splendid celestial sights, many of them within the range of simple optical equipment such as binoculars, and all accessible with an average-sized telescope of the type used by amateur astronomers.

It must be emphasized that you do not need a telescope to take up stargazing. Use the charts in this book to find your way among the stars first with your own eyes, and then with the aid of binoculars, which bring the stars more readily into view. Binoculars are a worthwhile investment, being relatively cheap, easy to carry and useful for many purposes other than stargazing.

Stars and planets

In the night sky, stars appear to the naked eye as spiky, twinkling lights. Those stars near the horizon seem to flash and change colour. The twinkling and flashing effects are due not to the stars themselves but to the Earth's atmosphere: turbulent air currents cause the stars' light to dance around. The steadiness of the atmosphere is referred to as the *seeing*. Steady air means good seeing. The spikiness of star images is due to optical effects in the observer's eye. In reality, stars are spheres of gas similar to our own Sun, emitting their own heat and light.

Stars come in various sizes, from giants to dwarfs, and in a range of colours according to their temperature. At first glance all stars appear white, but more careful inspection reveals that certain ones are somewhat orange, notably Betelgeuse, Antares, Aldebaran and Arcturus, while others such as Rigel, Spica and Vega have a bluish tinge. Binoculars bring out the colours more readily than the naked eye does. Section II of this book, starting on page 267, explains more fully the different types of star that exist.

By contrast, planets are cold bodies that shine by reflecting the Sun's light. They too are described in more detail in Section II, from page 304 onwards. The planets are constantly on the move as they orbit the Sun. Four of them can be easily seen with the naked eye: Venus, Mars, Jupiter and Saturn. Venus, the brightest of all, appears as a dazzling object in the evening or morning sky. Charts showing the positions of Mars, Jupiter and Saturn for a 5-year period can be found on the HarperCollins website:

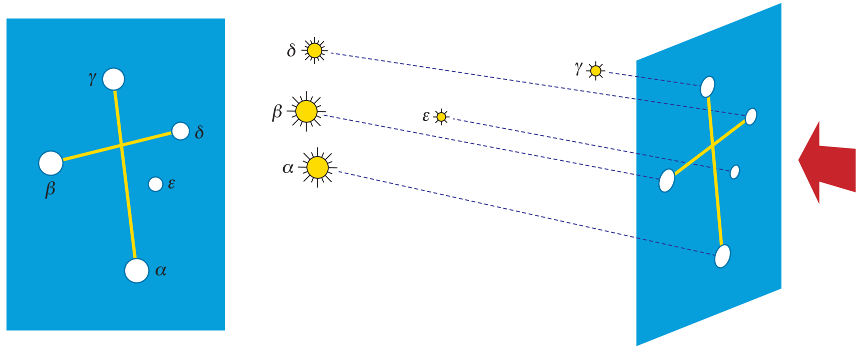
www.collins.co.uk/starsandplanets

About 2000 stars are visible to the naked eye on a clear, dark night, but you will not need to learn them all. Start by identifying the brightest stars and major constellations, and use these as signposts to the fainter, less prominent stars and constellations. Once you know the main features of the night sky, you will never again be lost among the stars.

Constellations

The sky is divided into 88 sections known as constellations which astronomers use as a convenient way of locating and naming celestial objects. Most of the stars in a constellation have no real connection with one another at all; they may lie at vastly differing distances from Earth, and form a pattern simply by chance. Incidentally, when astronomers talk of an object being 'in' a given constellation they mean that it lies in that particular area of sky.

Some constellations are easier to recognize than others, such as the magnificent Orion or the distinctive Cassiopeia and Crux. Others are faint and obscure, such as Lynx



Constellations: Stars in a constellation are usually unrelated to one another. Above, the stars of Crux, the Southern Cross, are shown as they appear from Earth, left, and in a 3D view as they actually lie in space, right. (Wil Tirion)

and Telescopium. Whether large or small, bright or faint, each constellation is given a separate chart and description in this book.

The main constellations were devised at the dawn of history by Middle Eastern peoples who fancied that they could see a likeness to certain fabled creatures and mythological heroes among the stars. Of particular importance were the 12 constellations of the zodiac, through which the Sun passes during its yearly path around the heavens. However, it should be realized that the astrological 'signs' of the zodiac are not the same as the modern astronomical constellations, even though they share the same names.

Our modern system of constellations derives from a catalogue of 48 compiled by the Greek astronomer Ptolemy in AD 150. This list was expanded by navigators and celestial mapmakers, notably the Dutchmen Pieter Dirkszoon Keyser (*c*. 1540–96) and Frederick de Houtman (1571–1627), the Pole Johannes Hevelius (see page 166) and the Frenchman Nicolas Louis de Lacaille (see page 216).

Keyser and de Houtman introduced 12 new constellations, and Lacaille 14, in parts of the southern sky not visible from Mediterranean regions; Hevelius and others invented constellations to fill in the gaps between the figures recognized by the Greeks. The whole process sounds rather arbitrary, and indeed it was. A number of the newly devised patterns fell into disuse, leaving a total of 88 constellations that were officially adopted by the International Astronomical Union (IAU), astronomy's governing body, in 1922 (see the table on pages 8–9).

As well as the officially recognized constellations, you can find other patterns among the stars called *asterisms*. An asterism can be composed of stars belonging to one or more constellations. Well-known examples are the Plough or Big Dipper (part of Ursa Major), the Square of Pegasus, the Sickle of Leo and the Teapot of Sagittarius.

Star names

The main stars in each constellation are labelled with a letter of the Greek alphabet, the brightest star usually (but not always!) being termed α (alpha). Notable exceptions in which the stars marked β (beta) are in fact the brightest include the constellations Orion and Gemini. The entire Greek alphabet is given in the table on page 10.

Particularly confusing are the southern constellations Vela and Puppis, which were once joined with Carina to make the extensive figure of Argo Navis, the ship of the

THE 88 CONSTELLATIONS

Name	Genitive	Abbrevn.	Area (square degs.)	Order of size	Origin*
Andromeda	Andromedae	And	722	19	1
Antlia	Antliae	Ant	239	62	6
Apus	Apodis	Aps	206	67	3
Aquarius	Aquarii	Aqr	980	10	1
Aquila	Aquilae	Aql	652	22	1
Ara	Arae	Ara	237	63	1
Aries	Arietis	Ari	441	39	1
Auriga	Aurigae	Aur	657	21	1
Boötes	Boötis	Boo	907	13	1
Caelum	Caeli	Cae	125	81	6
Camelopardalis	Camelopardalis	Cam	757	18	4
Cancer	Cancri	Cnc	506	31	1
Canes Venatici	Canum Venaticorum	CVn	465	38	5
Canis Major	Canis Majoris	CMa	380	43	1
Canis Minor	Canis Minoris	CMi	183	71	1
Capricornus	Capricorni	Cap	414	40	1
Carina	Carinae	Car	494	34	6
Cassiopeia	Cassiopeiae	Cas	598	25	1
Centaurus	Centauri	Cen	1060	9	1
Cepheus	Cephei	Cep	588	27	1
Cetus	Ceti	Cet	1231	4	1
Chamaeleon	Chamaeleontis	Cha	132	79	3
Circinus	Circini	Cir	93	85	6
Columba	Columbae	Col	270	54	4
Coma Berenices	Comae Berenices	Com	386	42	2
Corona Australis	Coronae Australis	CrA	128	80	1
Corona Borealis	Coronae Borealis	CrB	179	73	1
Corvus	Corvi	Crv	184	70	1
Crater	Crateris	Crt	282	53	1
Crux	Crucis	Cru	68	88	4
Cygnus	Cygni	Cyg	804	16	1
Delphinus	Delphini	Del	189	69	1
Dorado	Doradus	Dor	179	72	3
Draco	Draconis	Dra	1083	8	1
Equuleus	Equulei	Equ	72	87	1
Eridanus	Eridani	Eri	1138	6	1
Fornax	Fornacis	For	398	41	6
Gemini	Geminorum	Gem	514	30	1
Grus	Gruis	Gru	366	45	3
Hercules	Herculis	Her	1225	5	1
Horologium	Horologii	Hor	249	58	6
Hydra	Hydrae	Hya	1303	1	1
Hydrus	Hydri	Hyi	243	61	3
Indus	Indi	Ind	294	49	3
Lacerta	Lacertae	Lac	201	68	5
Leo	Leonis	Leo	947	12	1
Leo Minor	Leonis Minoris	LMi	232	64	5
Lepus	Leporis	Lep	290	51	1
Libra	Librae	Lib	538	29	1
Lupus	Lupi	Lup	334	46	1
Lynx	Lyncis	Lyn	545	28	5
Lyra	Lyrae	Lyr	286	52	1
Mensa	Mensae	Men	153	75	6
Microscopium	Microscopii	Mic	210	66	6
Monoceros	Monocerotis	Mon	482	35	4
Musca	Muscae	Mus	138	77	3
Norma	Normae	Nor	165	74	6
Octans	Octantis	Oct	291	50	6
Ophiuchus	Ophiuchi	Oph	948	11	1
Orion	Orionis	Ori	594	26	1
Pavo	Pavonis	Pav	378	44	3
Pegasus	Pegasi	Peg	1121	7	1
Perseus	Persei	Per	615	24	1
Phoenix	Phoenicis	Phe	469	37	3
Pictor	Pictoris	Pic	247	59	6
Pisces	Piscium	Psc	889	14	1
Piscis Austrinus	Piscis Austrini	PsA	245	60	1
Puppis	Puppis	Pup	673	20	6
Pyxis	Pyxidis	Pyx	221	65	6
Reticulum	Reticuli	Ret	114	82	6
Sagitta	Sagittae	Sge	80	86	1
Sagittarius	Sagittarii	Sgr	867	15	1
Scorpius	Scorpii	Sco	497	33	1
Sculptor	Sculptoris	Scl	475	36	6
Scutum	Scuti	Sct	109	84	5
Serpens	Serpentis	Ser	637	23	1
Sextans	Sextantis	Sex	314	47	5
Taurus	Tauri	Tau	797	17	1
Telescopium	Telescopii	Tel	252	57	6
Triangulum	Trianguli	Tri	132	78	1
Triangulum Australe	Trianguli Australis	TrA	110	83	3
Tucana	Tucanae	Tuc	295	48	3
Ursa Major	Ursae Majoris	UMa	1280	3	1
Ursa Minor	Ursae Minoris	UMi	256	56	1
Vela	Velorum	Vel	500	32	6
Virgo	Virginis	Vir	1294	2	1
Volans	Volantis	Vol	141	76	3
Vulpecula	Vulpeculae	Vul	268	55	5

* **Origin:**

1. One of the original 48 Greek constellations listed by Ptolemy. The Greek figure of Argo Navis has since been divided into Carina, Puppis and Vela.
2. Considered by the Greeks as part of Leo; made separate by Caspar Vopel in 1536.
3. The 12 southern constellations of Pieter Dirkszoon Keyser and Frederick de Houtman, *c.* 1600.
4. Four constellations added by Petrus Plancius.
5. Seven constellations of Johannes Hevelius.
6. The 14 southern constellations of Nicolas Louis de Lacaille, who also divided the Greeks' Argo Navis into Carina, Puppis and Vela.

Argonauts. As a result of Argo's subsequent trisection, neither Vela nor Puppis possesses stars labelled α or β, and there are gaps in the sequence of Greek letters in Carina as well.

The system of labelling stars with Greek letters was introduced in the early 17th century by the German astronomer Johann Bayer on his star atlas called *Uranometria* (see page 246), so these designations are often known as Bayer letters. In heavily populated constellations, where Greek letters ran out, fainter stars were assigned Roman letters, both lower-case and capital, such as l Carinae, P Cygni and L Puppis.

An additional system of identifying stars is that of Flamsteed numbers, originating from their order in a star catalogue drawn up at Greenwich Observatory by the first Astronomer Royal of England, John Flamsteed (1646–1719). Examples are 61 Cygni and 70 Ophiuchi. For more information on Flamsteed numbers see page 178.

The genitive (possessive) case of the constellation's name is always used when referring to a star within it; hence Canis Major, for instance, becomes Canis Majoris, and the name α Canis Majoris means 'the star α in Canis Major'. All constellation names have standard three-letter abbreviations; for instance, the abbreviated form of Canis Major is CMa.

Before 1930, there were no officially recognized constellation boundaries; some constellations overlapped, and some stars were shared between constellations. In that year, the International Astronomical Union published definitive boundaries for all constellations. In the process, certain stars allocated by the Bayer and Flamsteed systems to one constellation found themselves transferred to a neighbour, leading to gaps in the sequence of letters and numbers.

Prominent stars also have proper names by which they are commonly known. For example, α Canis Majoris, the brightest star in the sky, is better known as Sirius. Stars' proper names originate from several sources. Some, such as Sirius, Castor and Arcturus, date back to ancient Greek times. Many others, such as Aldebaran, are of Arabic origin. Still others were added more recently by European astronomers who borrowed Arabic words in corrupted form; an example is Betelgeuse, which in its current form is meaningless in Arabic. The star names used in this book are those officially recognized by the International Astronomical Union.

THE GREEK ALPHABET

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

Star clusters, nebulae and galaxies have a different system of identification. The most prominent of them are given numbers prefixed by the letter M from a catalogue compiled in the late 18th century by the French astronomer Charles Messier (1730–1817). For example, M1 is the Crab Nebula and M31 the Andromeda Galaxy.

Messier's catalogue contained 103 objects. A few more were added later by other astronomers, bringing the total to 110. A far more comprehensive listing, containing many thousands of objects, is the *New General Catalogue* (NGC) compiled by J.L.E. Dreyer (1852–1926), with two supplements called the *Index Catalogues* (IC).

Messier numbers and NGC/IC numbers remain in use by astronomers, and both systems are used in this book. On the charts, such objects are labelled with their Messier number if they have one, or otherwise by their NGC number (without the 'NGC' prefix) or IC number (prefixed 'I').

Star brightness

Stars appear of different brightnesses in the sky, for two reasons. Firstly, they give out different amounts of light. But also, and just as importantly, they lie at vastly differing distances. Hence, a modest star that is quite close to us can appear brighter than a tremendously powerful star that is a long way away.

Astronomers call a star's brightness its *magnitude*. The magnitude scale was introduced by the Greek astronomer Hipparchus in 129 BC. Hipparchus divided the naked-eye stars into six classes of brightness, from 1st magnitude (the brightest stars) to 6th magnitude (the faintest visible to the naked eye). In his day there was no means of measuring star brightness precisely, so this rough classification sufficed. But with the coming of technology it became possible to measure a star's brightness to a fraction of a magnitude.

In 1856 the English astronomer Norman Pogson (1829–91) put the magnitude scale on a precise mathematical footing by defining a star of magnitude 1 as being exactly 100 times brighter than a star of magnitude 6. Since, on this scale, a difference of five magnitudes corresponds to a brightness difference of 100 times, a step of one magnitude is equal to a brightness difference of just over 2.5 times (the fifth root of 100).

MAGNITUDE DIFFERENCE CONVERTED TO BRIGHTNESS DIFFERENCE

Difference in magnitude	Difference in brightness
0.5	1.6
1.0	2.5
1.5	4.0
2.0	6.3
2.5	10
3.0	16
3.5	25
4.0	40
5.0	100
6.0	250
7.5	1000
10	10,000
12.5	100,000
15	1,000,000

Objects more than 250 times brighter than 6th magnitude are given negative (minus) magnitudes. For example, Sirius, the brightest star in the sky, is of magnitude −1.46. At the other end of the scale, stars fainter than magnitude 6 are given progressively larger positive magnitudes. The faintest objects detected by telescopes on Earth are around magnitude 27.

Any object of magnitude 1.49 or brighter is said to be of first magnitude; objects from 1.50 to 2.49 are termed second magnitude;

THE TEN BRIGHTEST STARS AS SEEN FROM EARTH

Star name	Constellation	Apparent magnitude	Absolute magnitude	Distance (l.y.)
Sirius	Canis Major	−1.46	+1.43	8.60
Canopus	Carina	−0.74	−5.62	309
Rigil Kentaurus	Centaurus	−0.27	+4.12	4.32
Arcturus	Boötes	−0.05	−0.31	36.7
Vega	Lyra	+0.03	+0.60	25.0
Capella	Auriga	+0.08	−0.51	42.8
Rigel	Orion	+0.13	−6.98	863
Procyon	Canis Minor	+0.37	+2.64	11.5
Betelgeuse	Orion	+0.4 (variable)	−5.52	498
Achernar	Eridanus	+0.46	−2.69	139

and so on. The magnitude system may sound confusing at first, but it works well in practice and has the advantage that it can be extended indefinitely in both directions, to the very bright and the very faint.

When used without further qualification, the term 'magnitude' refers to how bright a star appears to us in the sky; strictly, this is the star's *apparent magnitude*. But because the distance of a star affects how bright it appears, the apparent magnitude bears little relation to its actual light output, or *absolute magnitude*.

A star's absolute magnitude is defined as the brightness it would appear to have if it were at a standard distance from us of 10 parsecs (32.6 light years). The origin of the parsec is explained on page 13. The table below shows the apparent and absolute magnitudes of the ten brightest stars visible in the night sky. Astronomers calculate the absolute magnitude from knowledge of the star's nature and its distance.

Absolute magnitude is a good way of comparing the intrinsic brightness of stars. For instance, our daytime star the Sun has an apparent magnitude of –26.7, but an absolute magnitude of 4.8 (when no sign is given the magnitude is understood to be positive). Deneb (α Cygni) has an apparent magnitude of 1.3, but an absolute magnitude of –6.9. From comparison of these absolute magnitudes we deduce that Deneb gives out about 50,000 times as much light as the Sun and hence is exceptionally luminous, even though there is nothing at first sight to mark it out as extraordinary.

A number of stars actually vary in their light output, for various reasons, and are a favourite subject for study by amateur astronomers. The nature of such so-called variable stars is discussed on pages 284–287.

Star distances

In the Universe, distances are so huge that astronomers have abandoned the puny kilometre (km) and have invented their own units. Most familiar of these is the *light year* (l.y.), the distance that a beam of light travels in one year. Light moves at the fastest known speed in the Universe, 299,792.5 km per second. A light year is equivalent to 9.46 million million km.

On average, stars are several light years apart. For instance, the closest star to the Sun, Proxima Centauri (actually a member of the α Centauri triple system), is 4.2 light years away. Sirius is 8.6 l.y. away and Deneb 1400 l.y. away.

The distance of the nearest stars can be found directly in the following way. A star's position is measured accurately when the Earth is on one side of the Sun, and then remeasured six months later when the Earth has moved around its orbit to the other side of the Sun. When viewed from two widely differing points in space in this way, a nearby star will appear to have shifted slightly in position with respect to more distant stars (see diagram on the facing page).

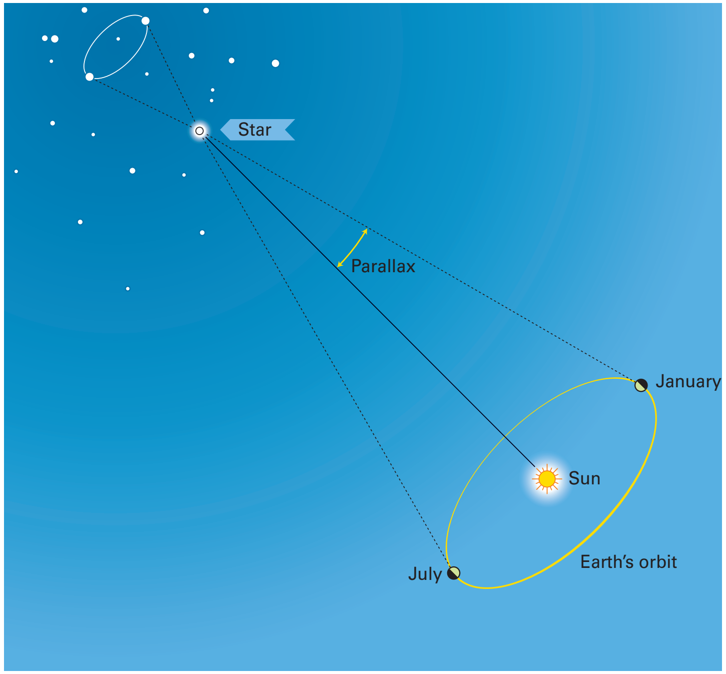
This effect is known as parallax, and applies to any object viewed from two vantage points against a fixed background, such as a tree against the horizon. A star's parallax shift is so small that under normal circumstances it is unnoticeable – in the case of Proxima Centauri, which has the greatest parallax shift of any star, the amount is about the same as the width of a small coin seen at a distance of 2 km. Once the star's parallax shift has been measured, a simple calculation reveals how far away it is.

An object close enough to us to show a parallax shift of 1″ (one second of arc) would, in the jargon of astronomers, be said to lie at a distance of one *parsec*, equivalent to 3.26 light years. In practice, no star is this close; the parallax of Proxima Centauri is 0″.77. Astronomers frequently use parsecs in preference to light years because of the ease of converting parallax into distance: a star's distance in parsecs is simply the inverse of its parallax in seconds of arc. For example, a star 2 parsecs away has a parallax of 0″.5, at 4 parsecs away its parallax is 0″.25, and so on.

The farther away a star is, the smaller its parallax. Beyond about 50 light years a star's parallax becomes too small to be measured accurately by telescopes on Earth. Before the launch of the European Space Agency's astrometry satellite Hipparcos in 1989, astronomers had been able to establish reliable parallaxes for fewer than 1000 stars from Earth; from space, Hipparcos increased the number of reliable parallaxes to over 100,000. A newer spacecraft, called Gaia,

THE TEN CLOSEST STARS TO THE SUN

Star name	Constellation	Apparent magnitude	Absolute magnitude	Distance (l.y.)
Proxima Centauri	Centaurus	11.13	15.57	4.23
α Centauri A	Centaurus	–0.01	4.38	4.32
α Centauri B	Centaurus	1.33	5.74	4.32
Barnard's Star	Ophiuchus	9.51	13.21	5.95
Wolf 359	Leo	13.51	16.61	7.80
Lalande 21185	Ursa Major	7.52	10.49	8.31
Sirius A	Canis Major	–1.46	1.43	8.60
Sirius B	Canis Major	8.44	11.33	8.60
UV Ceti A	Cetus	12.61	15.47	8.73
UV Ceti B	Cetus	13.06	15.93	8.73



Parallax: As the Earth moves around its orbit, so a nearby star appears to change in position against the celestial background. The shift in position is known as the star's parallax. The nearer the star is to us, the greater its parallax. Here, the amount of parallax is exaggerated for clarity. (Wil Tirion) launched in 2013, has extended the number to more than a billion.

Before the days of accurate parallaxes, astronomers had to use an indirect method of finding star distances. First they estimated the star's absolute magnitude by studying the spectrum of its light. They then compared this estimated absolute magnitude with the observed apparent magnitude to determine the star's distance. The distance obtained in this way was open to considerable error, and the values quoted in various books and catalogues often differed widely as a result.

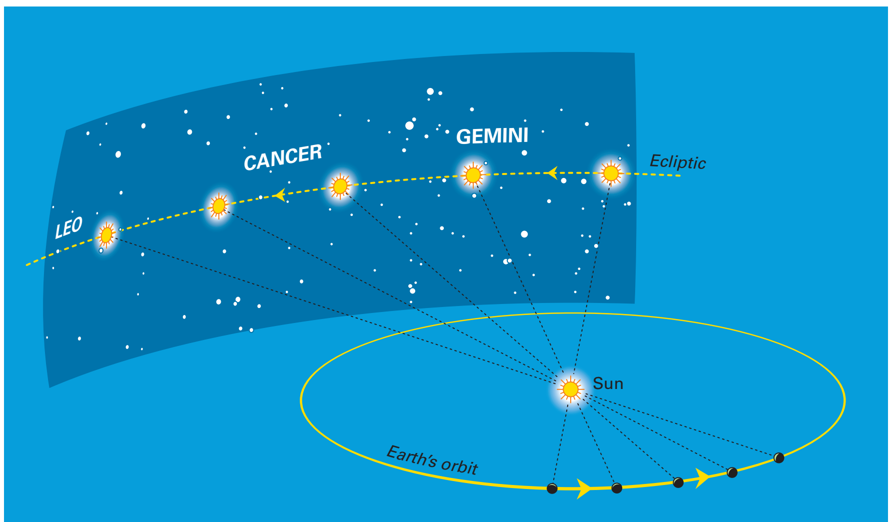
Distances of stars given in this book are taken from the revised edition of *The Hipparcos Catalogue* (2007). Most of these distances are accurate to better than 10 per cent, with the uncertainties tending to become greater for the more distant stars.

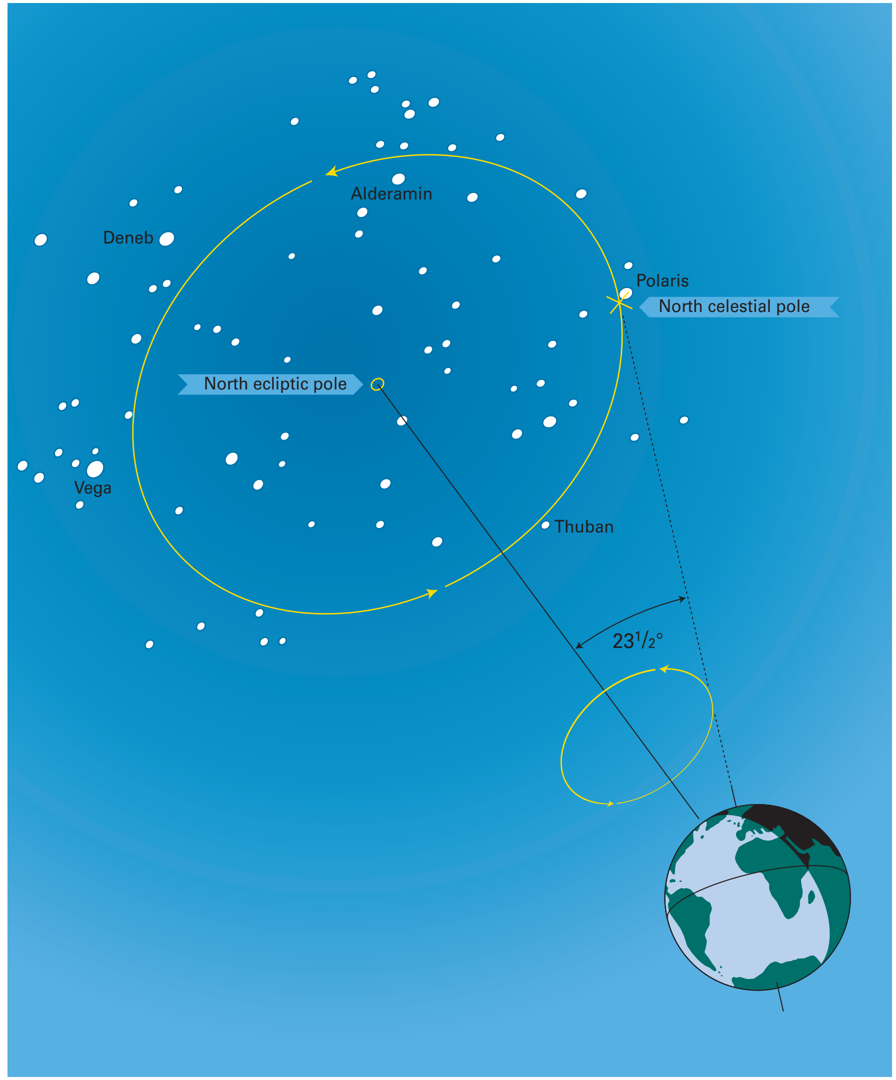
Star positions

To determine positions of objects in the sky, astronomers use a system of coordinates similar to latitude and longitude on Earth. The celestial equivalent of latitude is called *declination* and the equivalent of longitude is called *right ascension*. Declination is measured in degrees, minutes and seconds (abbreviated °, ′ and ″) of arc from 0° on the celestial equator to 90° at the celestial poles. The celestial poles lie exactly above the Earth's poles, while the celestial equator is the projection onto the sky of the Earth's equator.

Right ascension is measured in hours, minutes and seconds (abbreviated h, m and s), from 0h to 24h. The 0h line of right ascension, the celestial equivalent of the Greenwich meridian, is defined as the point where the Sun crosses the celestial equator on its way into the northern hemisphere each year. Technically, this point is known as the *vernal* (or spring) *equinox*.

Ecliptic: As the Earth moves along its orbit, the Sun is seen in different directions against the star background. The Sun's path against the stars is known as the ecliptic. The constellations that the Sun passes in front of during the year are known as the constellations of the zodiac. Below, the Sun's apparent motion through Gemini, Cancer and Leo is shown. (Wil Tirion)





Precession: The Earth is very slowly wobbling in space like a tilted spinning top, a movement known as precession. As a consequence, the celestial poles trace out a complete circle on the sky every 26,000 years. Only the path of the north celestial pole is shown here, but the effect applies to the south pole as well. (Wil Tirion)

The Sun's path around the sky each year is known as the *ecliptic*. This path is inclined at 23½° to the celestial equator, because that is the angle at which the Earth's axis is inclined to the vertical. The most northerly and southerly points that the Sun reaches in the sky each year are called the *solstices*, and they lie 23½° north and south of the celestial equator. If the Earth's axis were directly upright with respect to its orbit around the Sun, then the celestial equator and ecliptic would coincide. We would then have no seasons, for the Sun would always remain directly above the Earth's equator.

One additional effect that becomes important over long periods of time is that the Earth is slowly wobbling on its axis, like a spinning top. The axis remains inclined at an angle of 23½°, but the position in the sky to which the north and south poles of the Earth are pointing moves slowly. This wobbling of the Earth in space is termed *precession*.

As a result of precession, the Earth's north and south poles describe a large circle on the sky, taking 26,000 years to return to their starting places (see the diagram on page 15). Hence the positions of the celestial poles are always changing, albeit imperceptibly, as are the two points at which the Sun's path (the ecliptic) cuts the celestial equator.

As an example of the effects caused by precession, Polaris will not always be the Pole Star. Although Polaris currently lies less than 1° from the celestial pole, that is just a matter of chance. In 11,000 years' time the north celestial pole will lie near Vega in the constellation Lyra, having moved through Cepheus and Cygnus in the interim. Similarly, the vernal equinox, which lay in Aries between 1865 BC and 67 BC, now lies in Pisces and in AD 2597 will have reached Aquarius.

The effect of precession means that the coordinates of all celestial objects – the catalogued positions of stars, galaxies, and even constellation boundaries – are continually drifting. Astronomers draw up catalogues and star charts for a standard reference date, or *epoch*, commonly chosen to be the start or middle of a century. The epoch of the star positions in this book is the year 2000. For most general purposes, precession does not introduce a noticeable error until after about 50 years, so the charts in this book will be usable without amendment until halfway through the 21st century.

Proper motions

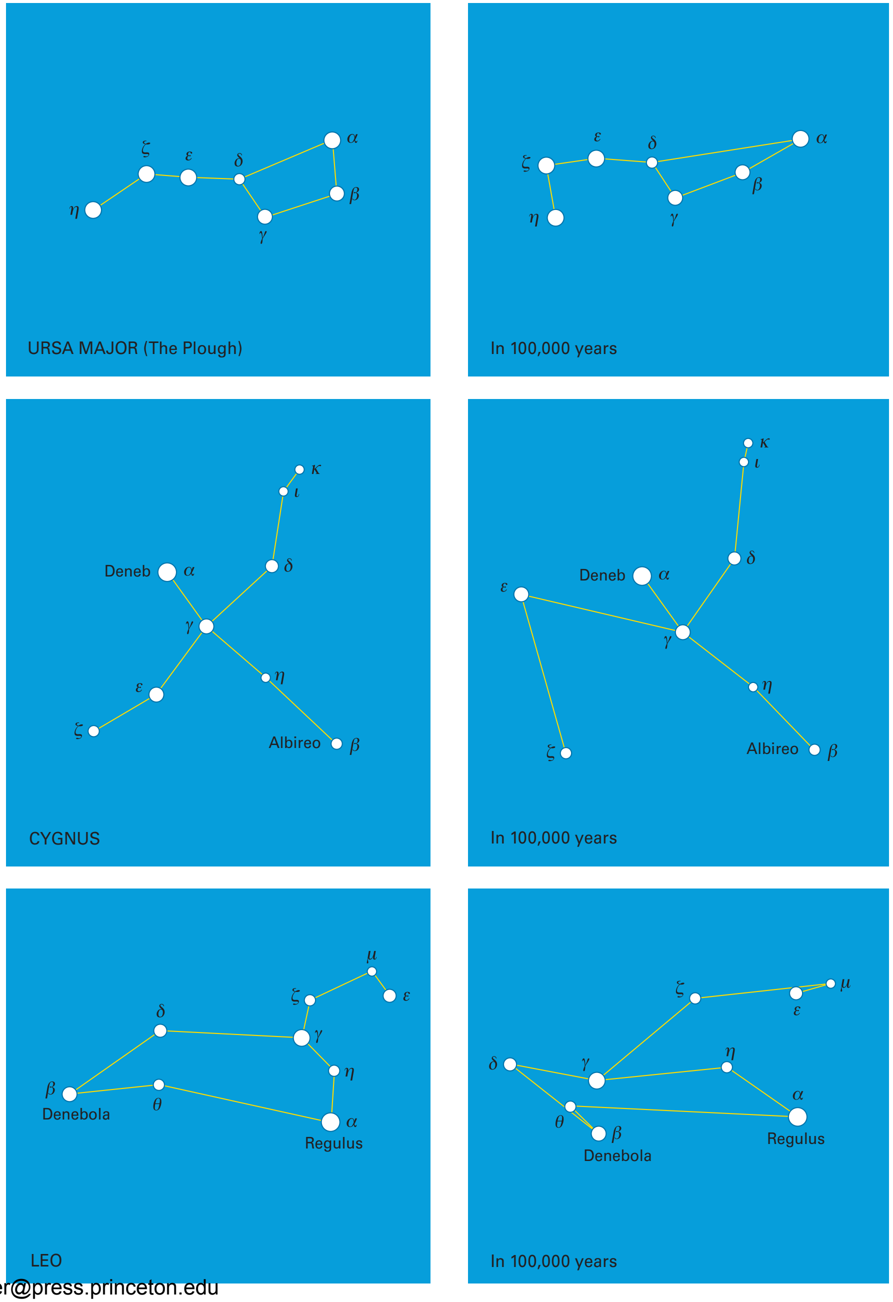
All the stars visible in the sky are members of a vast wheeling mass of stars called the Galaxy. Those stars visible to the naked eye are among the nearest to us in the Galaxy. More distant stars in the Galaxy crowd together in a hazy band called the Milky Way, which can be seen arching across the sky on dark nights.

The Sun and the other stars are all orbiting the centre of the Galaxy; the Sun takes about 250 million years to complete one orbit. Other stars move at different speeds, like cars in different lanes on a highway. As a result, stars are all very slowly changing their positions relative to one another.

Such stellar movement, termed *proper motion*, is so slight that it is undetectable to the naked eye even over a human lifetime, but it can be measured through telescopes. As with many other aspects of stellar positions, our knowledge of proper motions has been radically improved by the Hipparcos and Gaia satellites.

If ancient Greek astronomers could be transported forward to the present day, they would notice little difference in the sky, with the exception of Arcturus, a fast-moving bright star, which has drifted more than two Moon diameters from its position then. Over very long periods of time the proper motions of stars considerably distort the shapes of all constellations. The diagrams on the facing page show some examples of how proper motions will alter some familiar patterns.

An additional long-term effect of stellar motions is to change the apparent magnitudes of stars as they move towards us or away. For example, Sirius will brighten by 20 per cent over the next 60,000 years as its



Proper motions: Three familiar star patterns as they appear today, at left of diagram, and as they will appear in 100,000 years' time, right. The changes in appearance are due to the proper motions of the stars. (Wil Tirion)

distance shrinks by 0.8 light years. Then, as it moves away again, it will be superseded as the brightest star in the sky by Vega, which will peak at magnitude –0.8 nearly 300,000 years from now.

Appearance of the sky

Three factors affect the appearance of the sky: the time of night, the time of year and your latitude on Earth. Firstly, let's consider the effect of latitude.

At one of the Earth's poles, latitude 90°, an observer would see the celestial pole directly overhead (at the *zenith*), and as the Earth turned all stars would circle around the celestial pole without rising or setting (see the top diagram on the facing page).

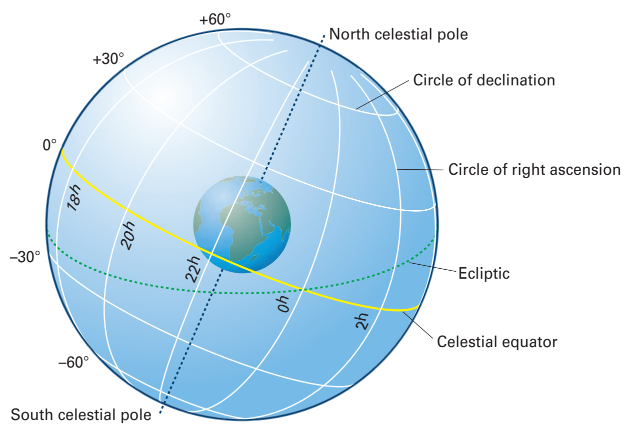
At the other extreme, an observer stationed exactly on the Earth's equator, latitude 0°, would see the celestial equator directly overhead, as shown in the middle diagram opposite. The north and south celestial poles would lie on the north and south horizons respectively, and every part of the sky would be visible at one time or another. All stars would rise in the east and set in the west as the Earth rotated.

For most observers, the real sky appears somewhere between these two extremes: the celestial pole is at some intermediate altitude between horizon and zenith, and the stars closest to it circle around without setting (they are said to be *circumpolar*) while the rest of the stars rise and set.

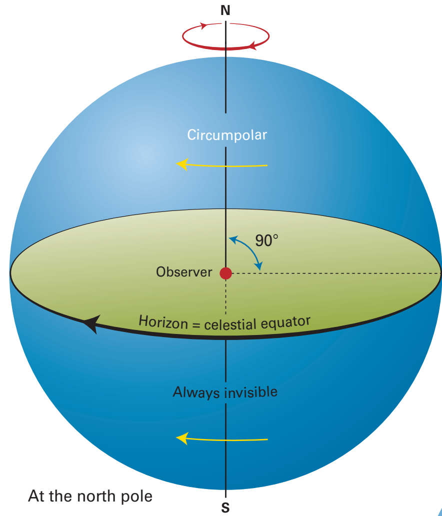
The exact angle of the celestial pole above the horizon depends on the observer's latitude. For someone at latitude 50° north, for instance, the north celestial pole is 50° above the northern horizon (bottom diagram opposite). As another example, if you were at latitude 30° south, the south celestial pole would be 30° above the southern horizon. In other words, the altitude of the celestial pole above the horizon is exactly equal to your latitude, a fact long recognized by navigators.

As the Earth turns, completing one 360° rotation every 24 hours, the stars march across the heavens at the rate of 15° per hour. Therefore the appearance of the sky changes with the time of night. An added complication is that the Earth is also orbiting the Sun each year, so the constellations on show change with the seasons.

For example, a constellation such as Orion, splendidly seen in December and January, will be in the daytime sky six months later and hence will then be invisible. The maps on pages 26–73 will help you find out which stars are on view each month of the year, wherever you are on Earth.

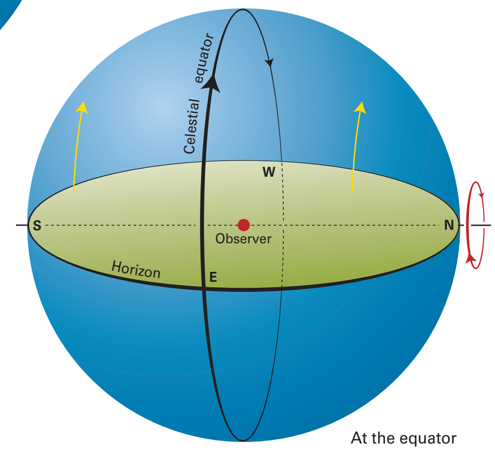


Celestial sphere: To understand celestial coordinates and motions, it helps to think of objects in the sky as lying on a transparent sphere surrounding the Earth, as shown in the diagram on the left. Right ascension and declination can be visualized as circles on this sphere, along with the celestial equator and the ecliptic. (Wil Tirion)

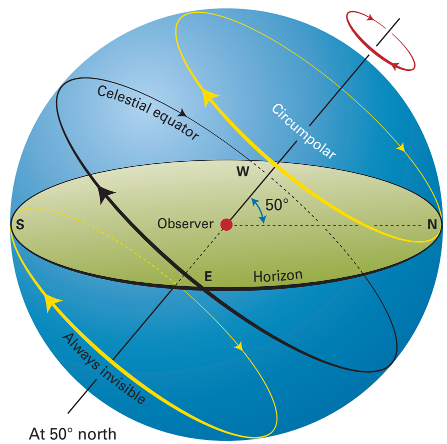


The changing appearance of the sky as seen from different latitudes on Earth.

Left: For an observer at the Earth's pole, only one half of the sky is ever visible, the other half being permanently below the horizon.



Right: At the equator, by contrast, all the sky is visible; as the Earth rotates, stars appear to rise in the east and set in the west.



Left: At intermediate latitudes, the situation is between the two extremes. Part of the sky is always above the horizon (the part marked 'Circumpolar'), but an equal part is always below the horizon and hence is invisible. Stars between these two regions rise and set during the night. (Wil Tirion)