CHAPTER TWO

Celestial Mechanics

The Constellations

Do you remember the first night that you stood for the very first time under a clear night sky and gazed with bewilderment at its beauty? And did you think something like this as you watched: "How many stars there are! How can anyone make any sense of this mass of stars?"

An attentive observer will soon notice that individual bright stars that are rather close together in the sky seem to form simple geometric shapes – squares, rhombuses, crosses, circles, arches. Giving a name to these shapes in the sky makes them more familiar to you and easier to locate again. That is probably how the first constellations originated and obtained their names. We probably will never know who the first person was to group stars into constellations, but it must have occurred a long time ago, most likely when human beings started walking erect, looked up at the sky, and were bewildered by its beauty.

By adding to the geometric shapes the dimmer stars the constellations changed from simple figures into images of gods, heroes, animals, and everyday objects. All peoples of this world have projected their beliefs onto the sky. Modern astronomers use the constellations from the ancient Greeks, which include not only objects and animals in the sky but also ancient mythological heroes. That is why various groups of constellations tell us stories about Greek myths and legends (Figure 2.2).

By the 1930s, there was sheer chaos in the sky. Apart from the classical constellations found on sky charts, there were also all of those that had been marked in the sky throughout the long history of astronomy. Especially in seventeenth and eighteenth centuries, astronomers almost competed with each other to see who could invent more new constellations from the leftover stars (Figure 2.5).

By sailing the South Seas astronomers came to learn about stars that were not visible from Europe or North Africa, and the need to introduce new constellations for the southern celestial hemisphere

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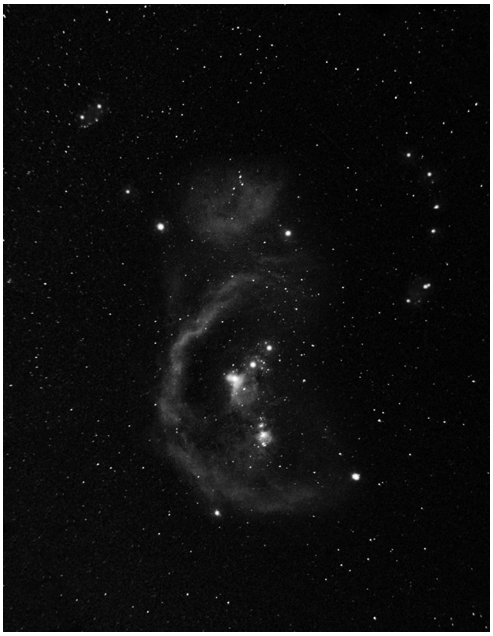


Figure 2.1 The winter Orion is one of the richest constellations in the sky. Among its numerous bright stars are the seventh and ninth brightest stars in the sky – silvery-white Rigel and the orange Betelgeuse. Apart from them there are also some hidden treasures in the constellation that are revealed by even a small pair of binoculars – numerous nebulae and clusters – among which the biggest attraction is surely the large and bright Orion Nebula

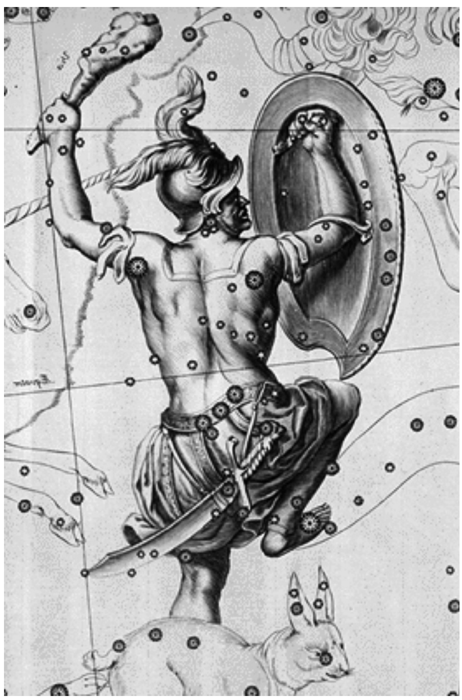


Figure 2.2 The star chart of Orion from the wonderful Hevelli's *Uranography* that was published in 1690

appeared. Native inhabitants already had numerous suggestions for these constellations, and some of these were taken into account, while others were not.

Most of the constellations included only the brightest stars; nobody knew to which constellations the fainter stars belonged. With the huge leaps in development of modern observational astronomy at

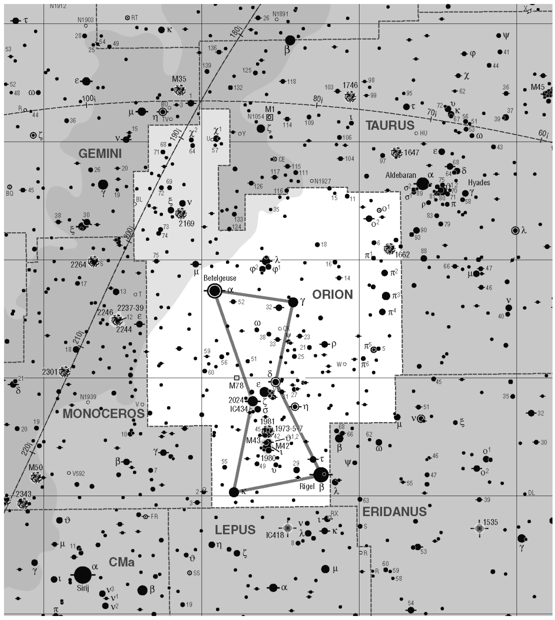


Figure 2.3 A modern star chart of Orion with the constellation borders

the beginning of the twentieth century, things began to change. In 1934, the International Astronomical Union divided the sky into 88 constellations with precisely defined borders. Today we know exactly which constellation even the faintest star belongs to. For today's astronomer, a constellation is a specific part of the sky and not merely a few bright stars that form its shape (Figure 2.3).

A constellation is thus a limited part of the sky, with stars and all nonstellar objects that usually have only one thing in common – they appear to be close together in our sky (and – as seen from Earth – seem to be roughly in the same direction). In reality some stars can be relatively close, while the others can be very far from each other and do not have any physical connection whatsoever. If we suddenly found ourselves on a different planet several hundreds light years away from the Sun, the night sky would look completely different to us.

Not all constellations are of the same size (Table 2.1), for in drawing the borders astronomers took into account historical facts. The largest constellation in the sky is Hydra, while the smallest is the famous Crux, which lies in the southern celestial hemisphere and was named in 1679.

Table 2.1 Alphabetic list of constellations

Latin name	Abbr.	Genitive	Meaning	Size [sq.°]	Page	Loc.
Andromeda	And	Andromedae	Andromeda	722	172	N
Antlia	Ant	Antliae	The Air Pump	239	182	S
Apus	Aps	Apodis	The Bird of Paradise	206	–	S
Aquarius	Aqr	Aquarii	The Water Carrier	980	183	S
Aquila	Aql	Aquilae	The Eagle	652	189	NS
Ara	Ara	Arae	The Altar	237	–	S
Aries	Ari	Arietis	The Ram	441	195	N
Auriga	Aur	Aurigae	The Charioteer	657	196	N
Boötes	Boo	Boötis	The Herdsman	906	202	N
Caelum	Cae	Caeli	The Chisel	125	206	S
Camelopardalis	Cam	Camelopardalis	The Giraffe	747	207	N
Cancer	Cnc	Cancri	The Crab	306	213	N
Canes Venatici	CVn	Canum Venaticorum	The Hunting Dogs	465	218	N
Canis Major	CMa	Canis Majoris	The Great Dog	380	228	S

Table 2.1 (continued)

Latin name	Abbr.	Genitive	Meaning	Size [sq.°]	Page	Loc.
Canis Minor	CMi	Canis Minoris	The Little Dog	183	233	N
Capricornus	Cap	Capricorni	The Sea Goat	414	234	S
Carina	Car	Carinae	The Keel	494	–	S
Cassiopeia	Cas	Cassiopeiae	Cassiopeia	598	236	N
Centaurus	Cen	Centauri	The Centaur	1060	243	S
Cepheus	Cep	Cephei	Cepheus	588	247	N
Cetus	Cet	Ceti	The Sea Monster	1231	252	NS
Chamaeleon	Cha	Chamaeleontis	The Chameleon	132	–	S
Circinus	Cir	Circini	The Compasses	93	–	S
Columba	Col	Columbae	The Dove	270	260	S
Coma Berenices	Com	Comae Berenices	Berenice's Hair	386	261	N
Corona Australis	CrA	Coronae Australis	The Southern Crown	128	268	S
Corona Borealis	CrB	Coronae Borealis	The Northern Crown	170	269	N
Corvus	Crv	Corvi	The Crow	184	271	S
Crater	Crt	Crateris	The Cup	282	271	S
Crux	Cru	Crucis	The Southern Cross	68	–	S
Cygnus	Cyg	Cygni	The Swan	804	272	N
Delphinus	Del	Delphini	The Dolphin	189	287	N
Dorado	Dor	Doradus	The Goldfish	179	–	S
Draco	Dra	Draconis	The Dragon	1083	288	N
Equuleus	Equ	Equulei	The Foal	72	287	N
Eridanus	Eri	Eridani	The River	1138	294	S
Fornax	For	Fornacis	The Furnace	398	296	S
Gemini	Gem	Geminorum	The Twins	514	297	N
Grus	Gru	Gruis	The Crane	366	395	S
Hercules	Her	Herculis	Hercules	1225	301	N
Horologium	Hor	Horologii	The Pendulum Clock	249	206	S
Hydra	Hya	Hydrae	The Water Snake	1303	307	NS
Hydrus	Hyi	Hydri	The Little Water Snake	243	–	S
Indus	Ind	Indi	The Indian	312	–	S
Lacerta	Lac	Lacertae	The Lizard	201	314	N
Leo	Leo	Leonis	The Lion	947	316	N
Leo Minor	LMi	Leonis Minoris	The Little Lion	232	325	N
Lepus	Lep	Leporis	The Hare	290	326	S
Libra	Lib	Librae	The Scales	538	330	S
Lupus	Lup	Lupi	The Wolf	334	332	S
Lynx	Lyn	Lyncis	The Lynx	545	334	N
Lyra	Lyr	Lyrae	The Lyre	286	335	N
Mensa	Men	Mensae	The Table Mountain	153	–	S
Microscopium	Mic	Microscopii	The Microscope	210	342	S
Monoceros	Mon	Monocerotis	The Unicorn	482	343	NS
Musca	Mus	Muscae	The Fly	138	–	S
Norma	Nor	Normae	The Set Square	165	332	S
Octans	Oct	Octantis	The Octant	291	–	S
Ophiuchus	Oph	Ophiuchi	The Serpent Holder	948	352	NS
Orion	Ori	Orionis	The Hunter	594	364	NS
Pavo	Pav	Pavonis	The Peacock	378	–	S
Pegasus	Peg	Pegasi	The Winged Horse	1121	376	N
Perseus	Per	Persei	The Victorious Hero	615	382	N
Phoenix	Phe	Phoenicis	The Phoenix	469	438	S
Pictor	Pic	Pictoris	The Painter's Easel	247	–	S
Pisces	Psc	Piscium	The Fishes	889	391	NS
Piscis Austrinus	PsA	Piscis Austrini	The Southern Fish	245	395	S
Puppis	Pup	Puppis	The Stern	673	397	S

Table 2.1 (continued)

Latin name	Abbr.	Genitive	Meaning	Size [sq.°]	Page	Loc.
Pyxis	Pyx	Pyxidis	The Compass	221	182	S
Reticulum	Ret	Reticuli	The Net	114	–	S
Sagitta	Sge	Sagittae	The Arrow	80	408	N
Sagittarius	Sgr	Sagittarii	The Archer	867	411	S
Scorpius	Sco	Scorpii	The Scorpion	497	428	S
Sculptor	Scl	Sculptoris	The Sculptor	475	438	S
Scutum	Sct	Scuti	The Shield	109	441	S
Serpens	Ser	Serpentis	The Serpent	636	444	NS
Serpens Caput	SCa	Serpentis Caput	The Serpent's Head	428	444	NS
Serpens Cauda	SCd	Serpentis Cauda	The Serpent's Tail	208	447	NS
Sextans	Sex	Sextantis	The Sextant	314	453	NS
Taurus	Tau	Tauri	The Bull	797	455	N
Telescopium	Tel	Telescopii	The Telescope	252	–	S
Triangulum	Tri	Trianguli	The Triangle	132	468	N
Triangulum Australe	TrA	Trianguli Australis	The Southern Triangle	110	–	S
Tucana	Tuc	Tucanae	The Toucan	295	–	S
Ursa Major	UMa	Ursae Majoris	The Great Bear	1280	473	N
Ursa Minor	UMi	Ursae Minoris	The Little Bear	256	482	N
Vela	Vel	Velorum	The Sails	500	485	S
Virgo	Vir	Virginis	The Virgin	1294	487	NS
Volans	Vol	Volantis	The Flying Fish	141	–	S
Vulpecula	Vul	Vulpeculae	The Fox	268	495	N

abbr. Genitive of the constellation's name is used with names of the stars, double stars and variable stars: Alpha Orionis, Delta Scuti . . . Many times it is abbreviated: instead of Alpha Orionis we write Alpha Ori, instead of Delta Scuti we write Delta Sct . . .
size Size of the constellation in square degrees.
page Page in this book, where the constellation starts.
location If the constellation lies in the north celestial hemisphere (above the celestial equator) it is labeled as N; if it lies on south celestial hemisphere, it is labeled as S. If the constellation lies along celestial equator, so that one part is on north celestial hemisphere and the other is on south celestial hemisphere, it is labeled as NS.

Maybe some of you might be wondering why we can use the constellations from the ancient Greeks, who lived roughly 2,500 years ago. Haven't things changed since then? Today we know that everything in the universe is moving. Our Solar System and all other stellar systems travel around the center of our Galaxy, and every star also travels in its own direction at its own specific speed. However, great distances divide us from the stars. It is true that a star may whizz across the universe with the fantastic speed of 50 km/s, but if we observe this star, for instance, from 100 light years away (approximately 1 million billions kilometers), we will be able to recognize its movement only with the most precise instruments. Centuries will pass before we will notice with our own eyes that a star has changed its position in the sky. And for this example we have chosen a rather fast star that is relatively close to us.

Asterisms

The ancient astronomers often divided the constellations into smaller parts that were, in turn, given their own names. We call such a part of a constellation that has its own name but does not have the importance of a constellation an *asterism*. The best known asterisms that many wrongly consider to be constellations are the Big and Little Dipper. In reality, the Big Dipper is a part of the constellation Ursa Major, while the Little Dipper is part of the constellation Ursa Minor (Figure 2.4). Another well-known asterism is the Hunter's Belt, which is formed by three rather close and bright stars in the constellation of Orion.

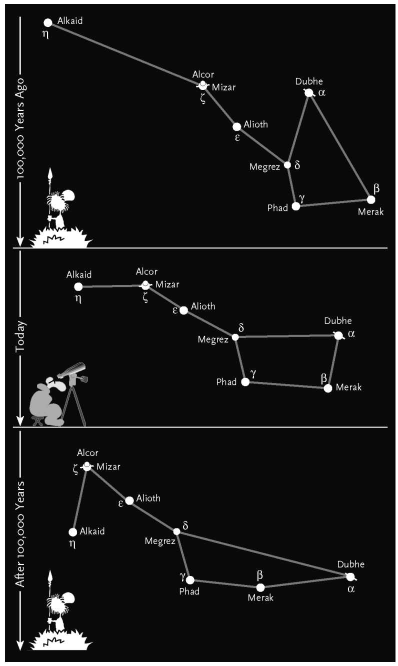


Figure 2.4 The shape of the Big Dipper 100,000 years ago, today, and in another 100,000 years. The appearance of constellations changes through time; however, millennia must pass for us to be able to notice these changes with the naked eye

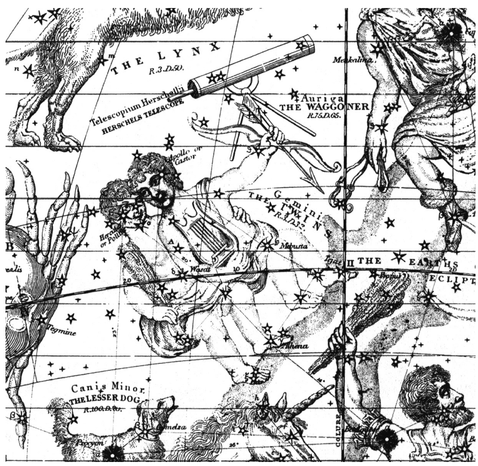


Figure 2.5 A part of a star chart from 1835 (author Elijah H. Burritt), in which we can see the classic constellations as well as Herchel's telescope. It was created from the dimmer stars between Gemini, Lynx, and Auriga by the Austrian astronomer Maximilian Hell at the end of the eighteenth century. Today the constellation no longer exists

The Celestial Sphere

When we look into a clear night sky it seems shaped like a ball, with Earth at its center. At any given moment in time we can see half of the sphere from our observing point. The second half lies below the horizon. The stars all appear equally distant from us and seem to be "pinned up" onto the inside of this celestial sphere. However, this sphere does not remain motionless. If we memorize the position of a certain bright star in relation to a nearby house or tree and then look at the same star from the same point an hour or two later, we will notice that it has moved to the west. The sky rotates from the east to the west (Figure 2.6). Of course, the rotation is not real; it just appears to be happening, for in reality Earth is rotating around its axis and we are rotating with it.

Figure 2.6 Here's how you can tell that the sky is really rotating. Place a photographic camera on a stable tripod and point it toward the sky. If you expose the image for a long period of time, say, for a couple of hours, arcs of the stars will be shown in the image, in this case the northern part of the sky. The star in the center is Polaris

Every sphere that rotates around its axis has two points that do not change their position. These are the poles, in our case represented by the north and south celestial poles. Because the rotation of the sky is a consequence of Earth rotating around its axis, the celestial poles are exactly above Earth's geographic poles – the north celestial pole is directly above Earth's North Pole and the south celestial pole directly above the Earth's South Pole.

In the same way as Earth the celestial sphere has its celestial equator, which lies directly above Earth's equator, or, to put it another way, exactly in the middle between the two poles. The celestial equator is a great circle that divides the celestial sphere into two equal hemispheres: the Northern and Southern Hemisphere.

Wherever we stand in Earth's Northern Hemisphere to observe the sky, the north celestial pole and celestial equator are always above the horizon, and the south celestial pole is always below the horizon. Wherever we stand in Earth's Southern Hemisphere to watch the sky, the north celestial pole is always below the horizon, and the south celestial pole and celestial equator are always above the horizon. If our observing point is exactly on the equator, the northern and southern celestial poles are on the (mathematical) horizon, and the celestial equator is in the zenith (Figure 2.7).

Celestial Coordinates

Soon after people started observing and describing stars in the celestial sphere, the need for a coordinate system arose. The system that was adopted made it simple to describe the position of the star (or any other celestial body) using only two coordinates. This was possible because in general stars do not change much in position relative to each other over time.

The celestial coordinate system is similar to the system we use for places on Earth. Geographic latitude is represented in the sky by declination, while geographic longitude is represented by right ascension. The choice of starting point for declination seemed to be obvious. It is measured in degrees from the celestial equator to the north (+) or south (–) celestial pole. The declination of the stars on the celestial equator is 0°, on the north celestial pole +90°, and on the south celestial pole –90°. For

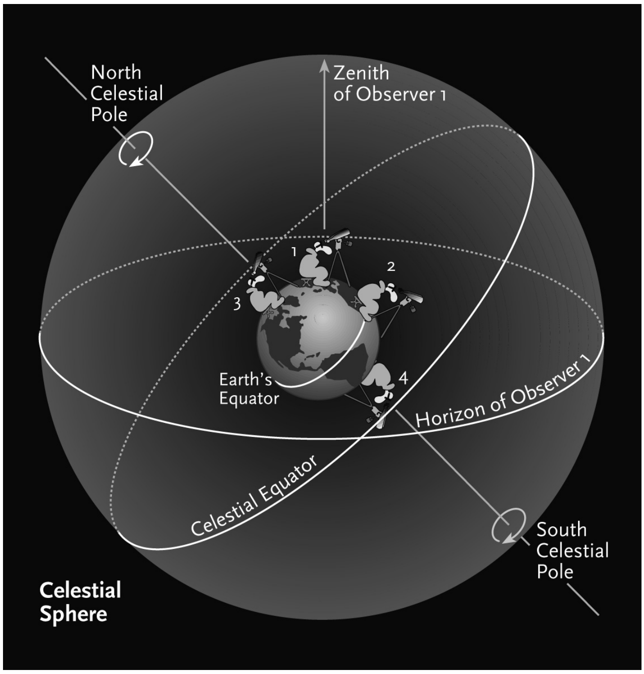


Figure 2.7 For all observers on Earth the sky appears to be a sphere with Earth (the observer) at the center. At any given moment of time we can see one half of the sphere (if there are no high hills there); the other half lies below the horizon. In the illustration we can see only the horizon for observer 1, that is, the observer watching from mid-northern geographic latitudes. With a bit of imagination we can guess how observers on other parts of Earth can see the sky. Observer 3 is sitting at the North Pole. In his zenith is the north celestial pole, and along his (mathematical) horizon runs the celestial equator. Observer 4 is sitting at the South Pole. In his zenith lies the south celestial pole, and along his (mathematical) horizon also runs the celestial equator. Observer 2 is sitting on the equator. In his zenith is the celestial equator, and on the horizon on opposite sides lie the north and south celestial poles

more precise measurements of declination the degree is divided into 60 arcmin (′), and an arc minute is divided into 60 arcsec (″) (Figure 2.8).

The selection of the coordinate starting point for the right ascension is – the same as on Earth – a matter of choice. In the same way as all geographic meridians are equal among themselves (they are all great circles on the sphere), so are the celestial meridians. Due to historic reasons we have agreed on Earth that we will start counting geographic longitude from the meridian that runs through the observatory in Greenwich, London. The coordinate starting point of the system on Earth is therefore at the point at which the Greenwich meridian crosses the equator. At that point the geographic latitude and longitude are both 0°. In the same way, astronomers needed to select a point on the celestial equator that would represent the starting point of the celestial coordinate system. They agreed that this would be the point where the ecliptic crosses the celestial equator and in which the Sun is at the spring equinox. This point is called the vernal point, or point γ (gamma), and it lies in the constellation of Pisces.[1]

Right ascension is measured in hours, from 0 h to 24 h. Its starting point is the vernal point, and it grows toward the east. The advantage of such a division (hours instead of degrees) lies in the fact that for every

[1] The ecliptic is the apparent annual path of the Sun across the celestial sphere. In one year the Sun crosses the ecliptic only once. The ecliptic is not parallel to the celestial equator but makes an angle of 23°26′. The intersections are two points. We have already mentioned the vernal point, and the second point is called the autumnal point, which is where the sun is in the autumn equinox.

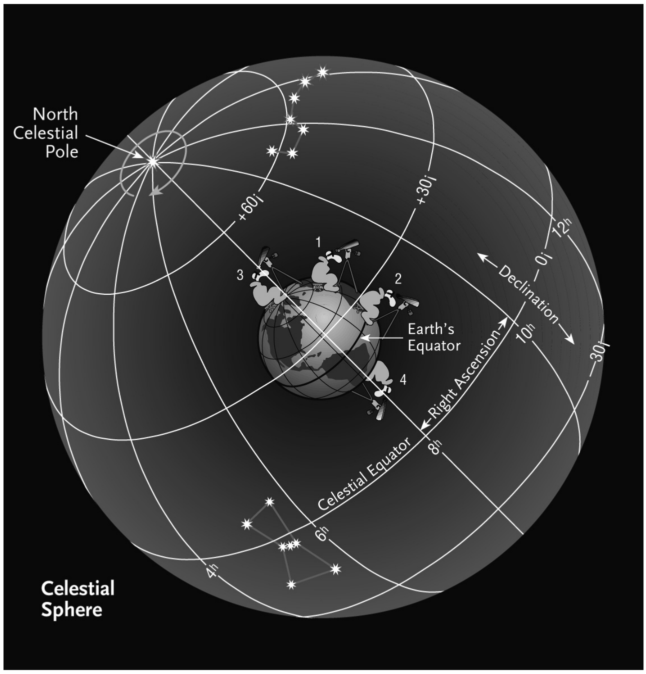


Figure 2.8 The sky coordinate system can best be understood if you visualize the coordinate system of latitudes and meridians on Earth and project it onto the sky. Once again four observers are shown on Earth. The first (1), who is observing the sky from mid-northern latitudes, can see the complicated net of the coordinate system in the sky, depending of the geographical direction of the sky he is looking toward (see Figures on pages 32 and 33). The remaining three have better luck. Their sky is extremely simple. Detailed drawings of what they see are shown on figure 2.10

hour the sky rotates for approximately one right ascension hour. That is why it is simple to ascertain from star charts when a certain constellation or star will be above the horizon. If, for instance, Orion is at its highest above the horizon and we are interested when (in how many hours) we will be able to see Cancer, we look at the central right ascension of the Orion (5.5 h) and the central right ascension of Cancer (8.5 h). From this we can immediately see that Cancer will be at its highest in approximately 3 h. Looked at it this way, the sky becomes a giant 24-h clock. But beware! On the equator the arc of 1 h measures 15°, and the closer we get to the poles, the coordinate system lines converge and the arcs, which represent 1 h, are shorter and shorter (see illustration above).

A right ascension hour is divided into 60 minutes (min) and a minute is divided into 60 seconds (s). The way you write minutes and seconds at the declination and right ascension is different, for they are different. If 1 h of right ascension on the celestial equator equals an arc of 15°, 1 min equals the arc of $15'$, and 1 s the arc of $15''$.

Because the celestial sphere rotates, the coordinate system rotates with it. The position of the celestial body on the celestial sphere can therefore always be given with two coordinates. To put it another way, if we know the two coordinates, we can always find the celestial body on the celestial sphere.

Rotating Sky

At the beginning, we mentioned that the night sky rotates. In fact, it only appears to be rotating, for in reality Earth is rotating around its axis. Because we know that Earth takes 24 h to make one complete rotation, we would expect that the same star that is rising on the horizon at this moment will appear on the horizon again in 24 h. However, observations show differently.

If we choose a bright star and note down the time this star sets behind the neighbor's roof (or some other clearly distinguishable and nonmoving object) we will discover that the next day (if viewed from the same point), the star will set behind the roof 4 min earlier. This phenomenon is even more

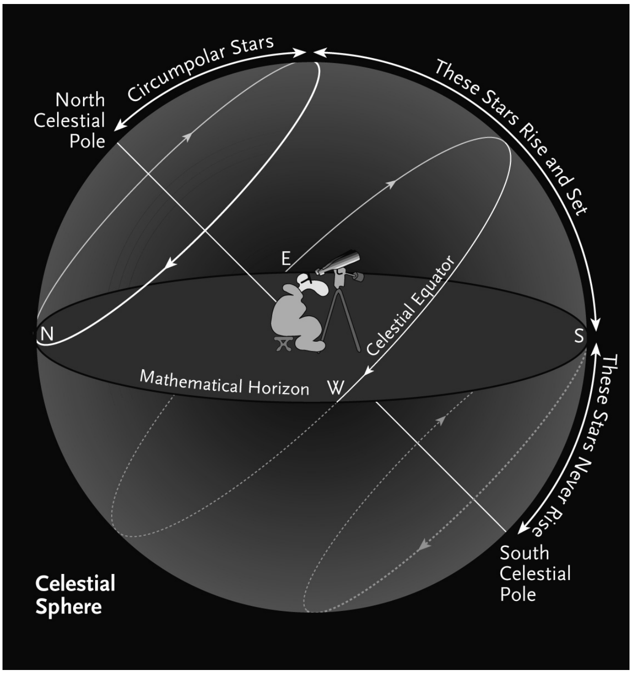


Figure 2.9 Which stars will be circumpolar, which will rise and set, and which will never appear above horizon depends on the geographic latitude of the observing point. If we move toward the equator, the north celestial pole moves toward the horizon, and the area of the sky around the pole, where the stars never rise and set, becomes smaller. If we move towards the north geographic pole, the north celestial pole moves toward the zenith, and the area of sky around the pole, where the stars never rise and set, increases. What the sky looks like at its extreme points (exactly on the pole and on the equator) is shown in the illustrations on the next page

noticeable if there is a longer period between the two observations. In other words, a star that is setting behind the neighbor's roof at the beginning of January at 10 p.m. will set behind the same roof at the beginning of February at 8 p.m. and at the beginning of March as early as 6 p.m. Over the year the constellations slowly drift toward the west, and on the east new ones appear. These changes in the sky are a consequence of Earth revolving around the Sun. That is why in the spring there are different constellations in the sky than in summer, autumn, or winter.

Imagine a celestial sphere with Polaris on it (or the position of the north celestial pole). We know that the sky seems to rotate around Polaris. The stars that are close to the pole travel in smaller circles, and those that are further travel in larger circles. Because Polaris lies at 45° above the horizon (when viewed from mid-northern latitudes), the stars that are close to it are visible throughout the night and throughout the year, for they rotate around the pole and never fall below the horizon. We call these *circumpolar stars.* Stars that are far from the North Pole rise and set during their daily and annual movements across the sky.

Of course, there are also stars that are close to the south celestial pole (from mid-northern latitudes it is 45° below the horizon). These never come above our horizon during their daily and annual movements (and can thus never be seen from mid-northern latitudes). Whether a star is considered circumpolar or that it rises and sets or is never above the horizon depends on the geographical latitude of the observing point and the declination of the star. On the north geographical pole, where we have Polaris in the zenith and the celestial equator on the horizon, all stars above the celestial equator (with a positive declination) are circumpolar stars, while those below the horizon (with a negative declination) can never be seen. On the south geographic pole the situation is exactly the opposite.

If our observing point is on Earth's equator, we have the celestial equator in the zenith, while the poles lie on the opposing sides of the horizon. In this case none of the stars is circumpolar, and throughout the year we can see all stars (and constellations) that can be seen from Earth. (This is why large observatories are built as close as possible to the equator.) If our observing point is somewhere in between, certain stars always appear above the horizon, others rise and set, while some other can never be seen. Stars that rise and set at a certain geographical latitude φ have the declination δ within the following limits:

$$(90^\circ - |\varphi|) < \delta < (90^\circ - |\varphi|)$$

Constantly above (below) the horizon is the star on a positive (negative) geographical latitude φ, if its declination δ fulfils the condition:

constantly above on $\varphi > 0$
constantly below on $\varphi < 0$ $\delta > (90^\circ - |\varphi|)$

Constantly below (above) the horizon is the star on the positive (negative) geographical latitude φ, if its declination δ fulfils the condition:

constantly below on $\varphi > 0$
constantly above on $\varphi < 0$ $\delta < (|\varphi| - 90^\circ)$

For all of the above-stated conditions we have to take the absolute value for the negative (south) geographical latitude.

On mid-northern latitudes, the circumpolar stars (constantly above the horizon) are around the north celestial pole to the declination +45°. These stars can be seen on any clear night throughout the year. Constantly below the horizon (can never be seen) are stars with a declination below –45°. Stars with a declination of between +45° and –45° rise and set and can be seen only at certain periods of the year (Figure 2.10).

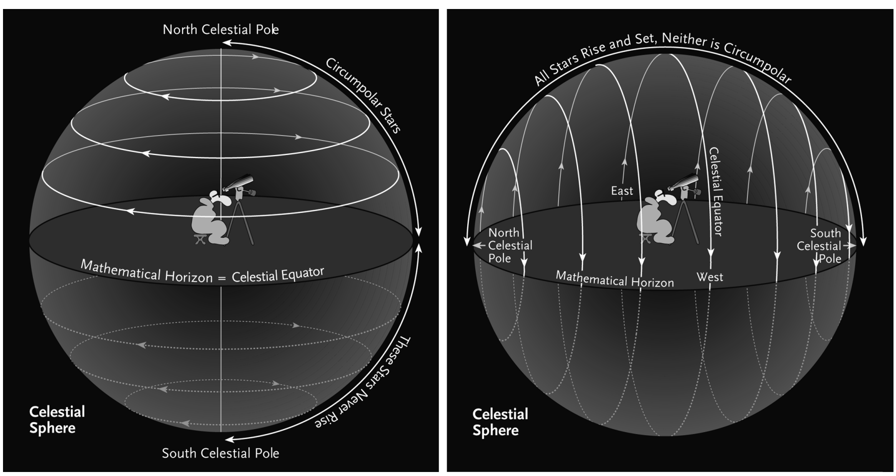


Figure 2.10 The appearance of the sky for the observer on the north geographic pole (illustration left) and on the equator. For an observer sitting on the north geographic pole, the stars rotate around the vertical axis and therefore never set during the night or during the year. However, this observer can see only stars in the northern celestial hemisphere (those with a positive declination), and he can never see those in the southern hemisphere. Sitting on Earth's South Pole, the observer can see the movement of stars just like the observer on the North Pole, except that he has the south celestial pole in his zenith and can see all the stars in the southern celestial hemisphere (with a negative declination). However, he can't see the ones in the northern celestial hemisphere. The observer on the equator is in the best position. During the night and throughout the year he can see all of the stars that can be seen from Earth

The Directions of the Sky and Using Star Charts

Where is north, south, east, and west in the spherical sky? It is defined by the celestial coordinate system. North is always in the direction of Polaris, regardless of which direction the binoculars are pointing and how they are turned. Let's look at the example.

All charts (in Part II of this book) are oriented so that north is up, east is on the left, south is down, and west is on the right. In our search, for example, of the globular cluster M 13 in Hercules we can use the chart on page 304, and if the constellation at the moment is above the eastern horizon, we have to know the orientation of the coordinate system in this part of the sky. If the sought-after cluster is on the chart above the Zeta, you will search for it in the sky in vain in that place. You have to turn the chart approximately 45° counterclockwise, as seen in the figure below. The cluster is thus left of Zeta. What about the other parts of the sky?

The coordinate sky net in various directions in places with median geographic latitude 45° has been shown on schematic figures. When we are turned toward the south (see Figure 2 on next page), you do not need to turn the charts at all. North truly is upward, south is downward, east is on the left, and west is on your right. For the other parts of the sky, the position of the coordinate system is more complex, as seen in Figures 1, 3, and 4.

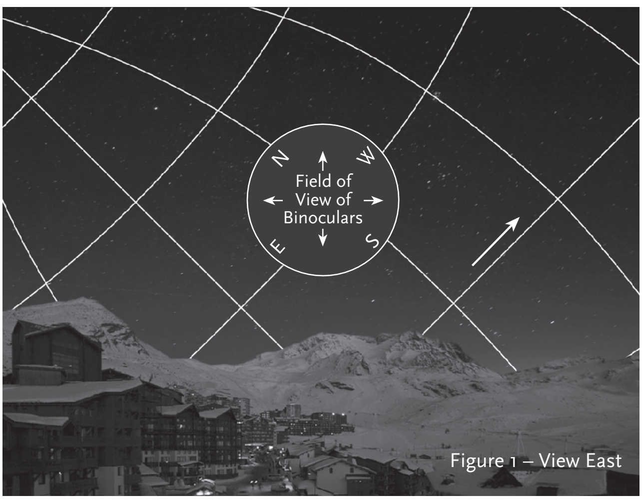


Figure 1 – View East

If we observe the stars above the eastern horizon, we have to rotate the chart for about 45° counterclockwise. If we are observing stars above the western horizon, we have to rotate the charts for about 45° clockwise. Only when the charts are turned in the right direction can we say that the sought-after object is, for instance, above the selected star or below it or left or right of it. This is why we try to avoid such descriptions, and instead describe the position of the celestial bodies as east of. . ., northwest of. . ., etc.

If we are observing the stars in a northerly direction, it depends on the position of the observed body in which direction and to how many degrees we have to rotate the chart so it will show what we can see in the sky. Experienced observers, who are well acquainted with the constellations, look at the position and orientation of a constellation in that part of the sky they are observing and then rotate the chart so that the orientation in the sky matches the chart. You do always need to know where the north celestial pole or Polaris is, for this tells us which way is north, and then the other

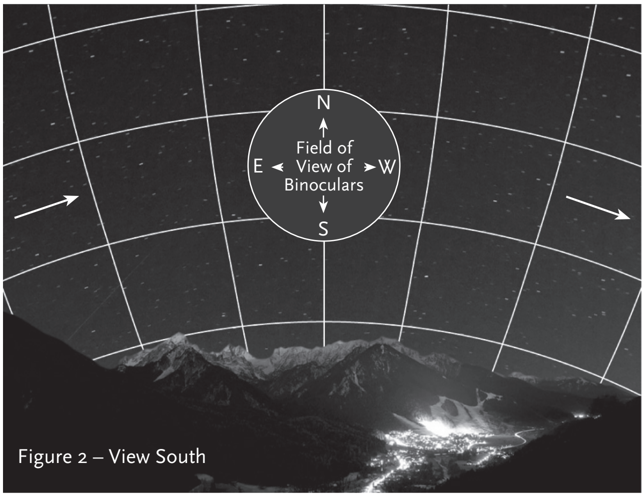


Figure 2 – View South

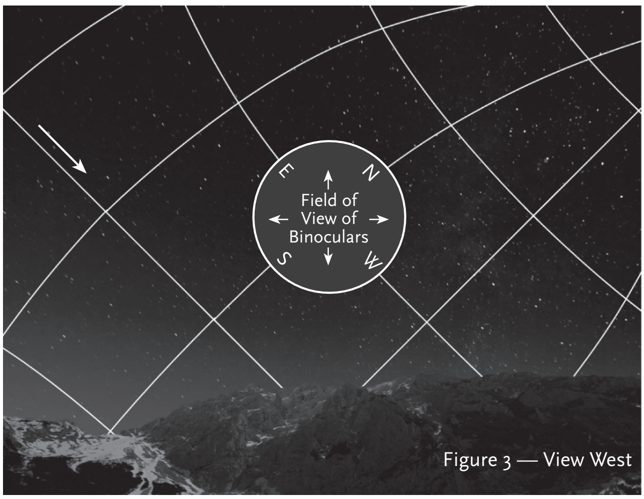


Figure 3 — View West

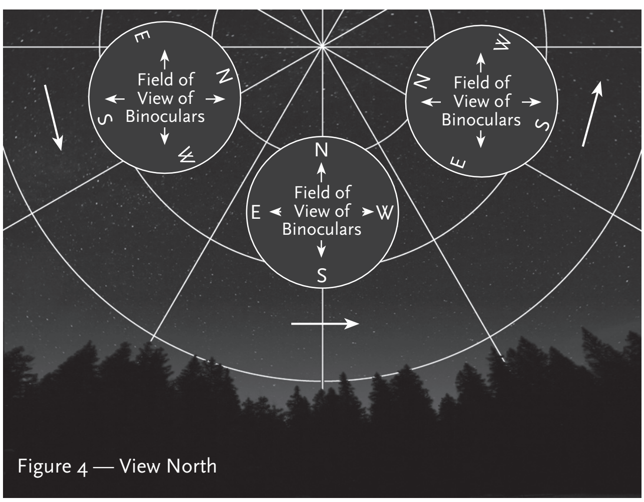


Figure 4 — View North

directions in the sky are easy to figure out. Let us here also point out that this seemingly complicated orientation of the field of view becomes easier the more experienced in observation you become. An experienced observer always knows how the field of view in the binoculars is oriented, without needing to think about it.

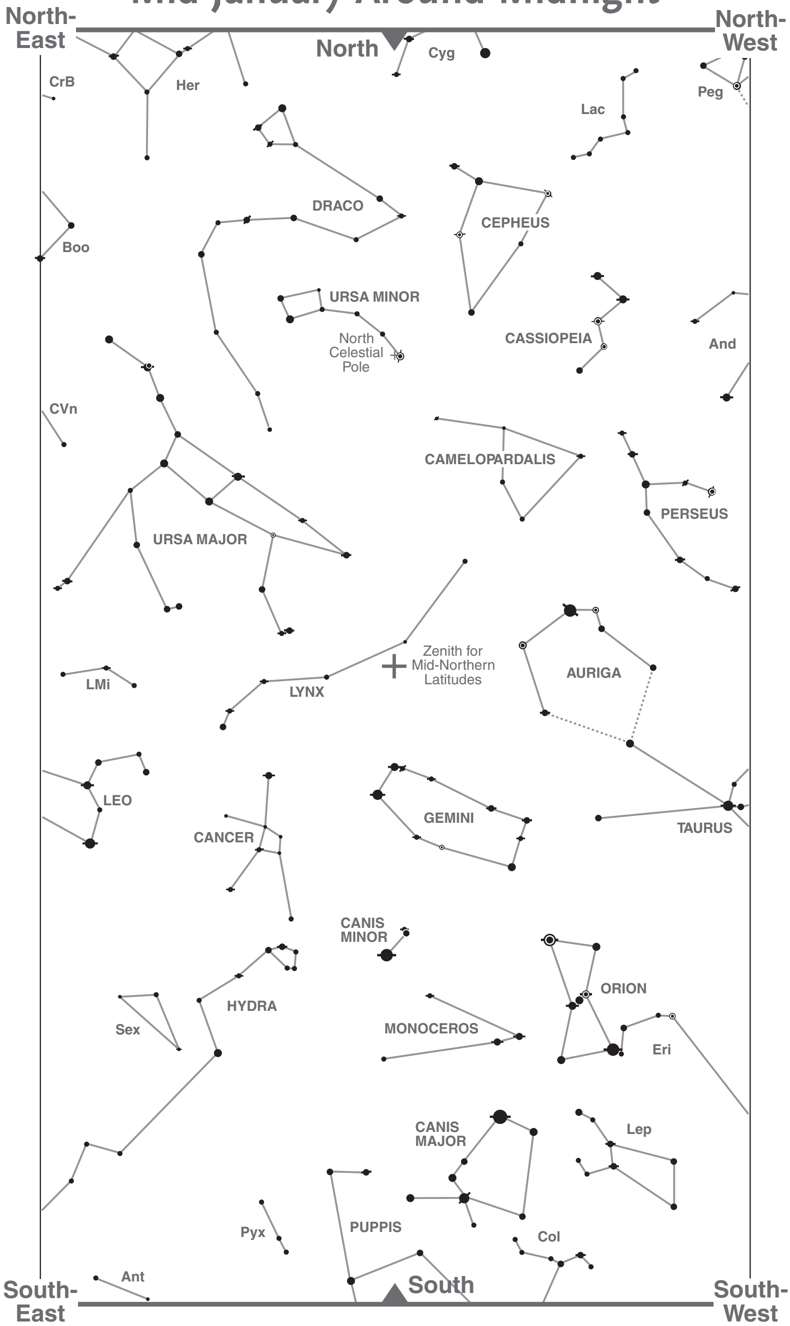
Seasonal Charts

In the seasonal charts that follow numbered 1 (January) to 12 (December), we can see how the constellations in the mid-northern latitudes change during the year. Every chart covers a piece of the sky along the meridian[2] from the southeast to the southwest (90°) and from the northern to the southern horizon. The charts depict the sky as it appears around midnight of the 15th of each month. The times that they can be seen hold true for the local time zone. Various conditions (daylight saving time, etc.) are not taken into account. This means that we have to add an hour to the times next to the dates in which daylight saving time applies. The circle with the stretched out hand next to each chart represents approximately 25° and is intended to be the rough estimation of the size of the individual constellation. The charts represent a good aid to the beginner in his or her first encounters with constellations. More on this in the First Steps section later.

[2] A meridian is an imaginary great circle on the celestial sphere. It passes through the northern point on the horizon, through the celestial pole, up to the zenith, through the southern point on the horizon, and through the nadir, and is perpendicular to the local horizon.

1

Mid January Around Midnight



25°

This constellations are seen on meridian also:

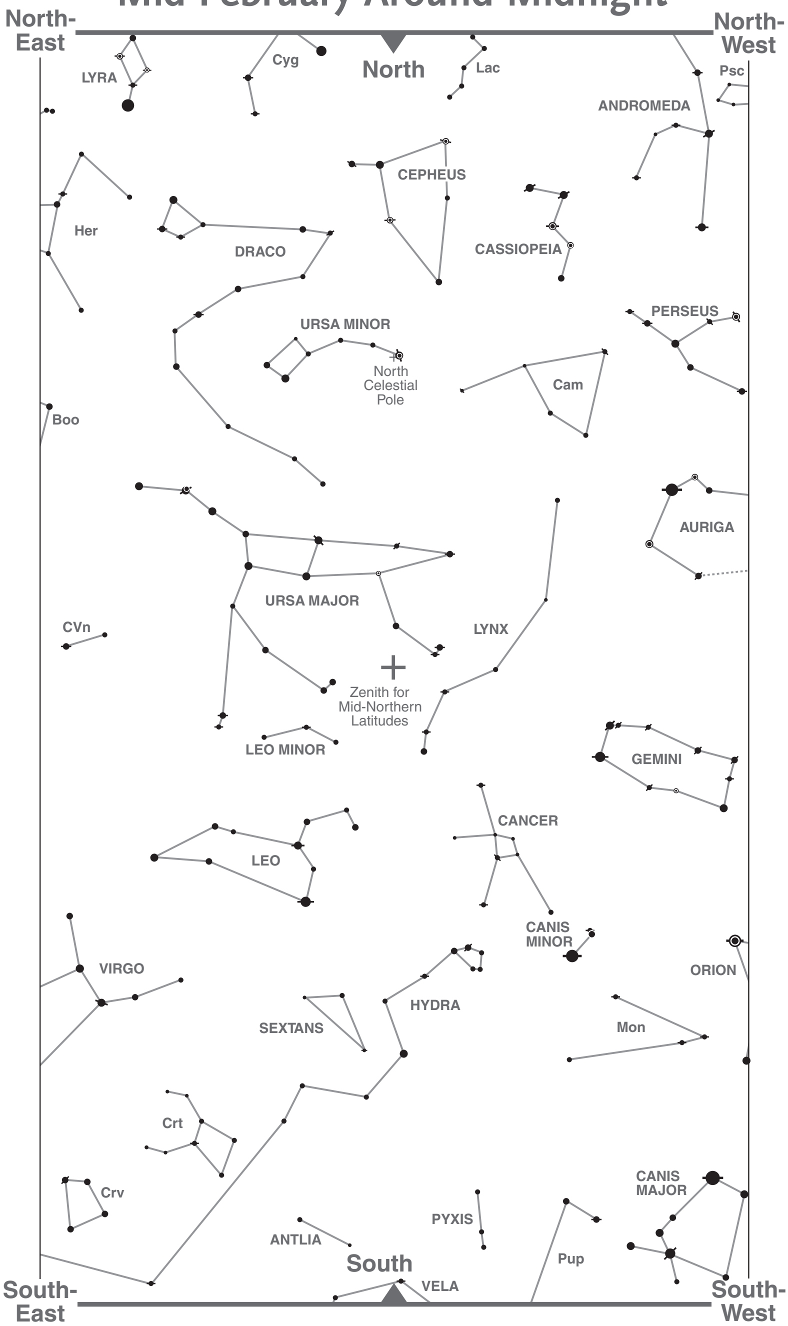
in mid February around 10 p.m.;

in mid March around 8 p.m.;

in mid December around 2 a.m.;

in mid November around 4 a.m.

Mid February Around Midnight



2

25°

This constellations are seen on meridian also:

in mid March around 10 p.m.;

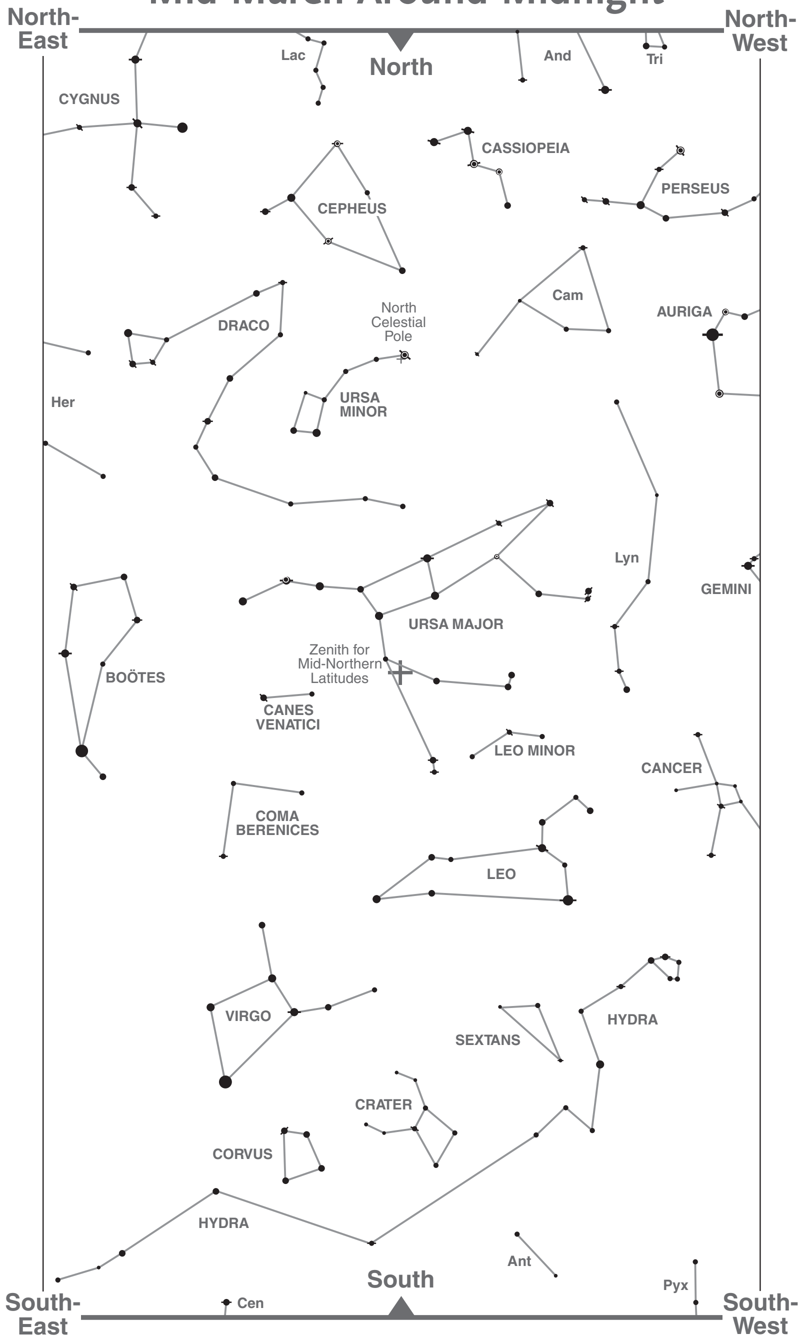
in mid January around 2 a.m.;

in mid December around 4 a.m.;

in mid November around 6 a.m.

3

Mid March Around Midnight



25°

This constellations are seen on meridian also:

in mid April around 10 p.m.;

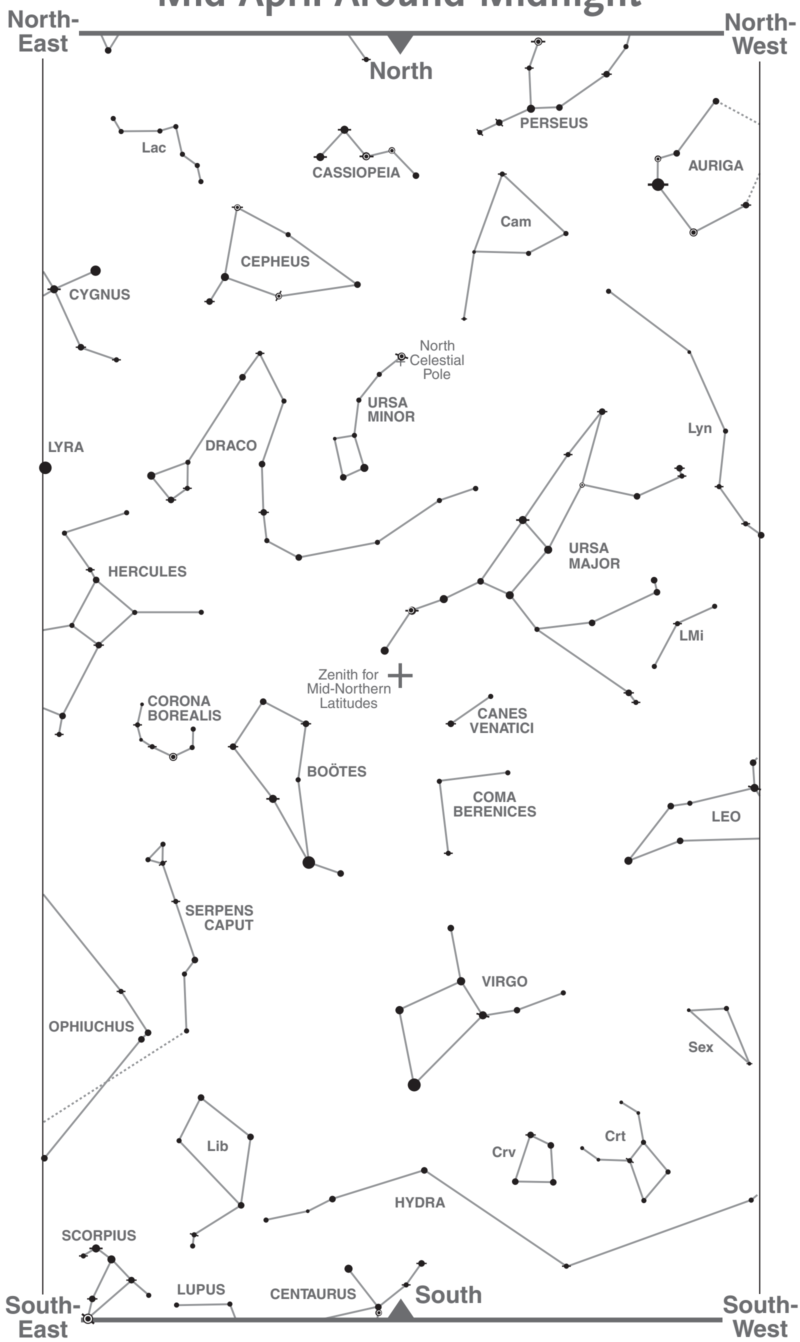
in mid February around 2 a.m.;

in mid January around 4 a.m.;

in mid December around 6 a.m.

Mid April Around Midnight

4



25°

This constellations are seen on meridian also:

in mid May around 10 p.m.;

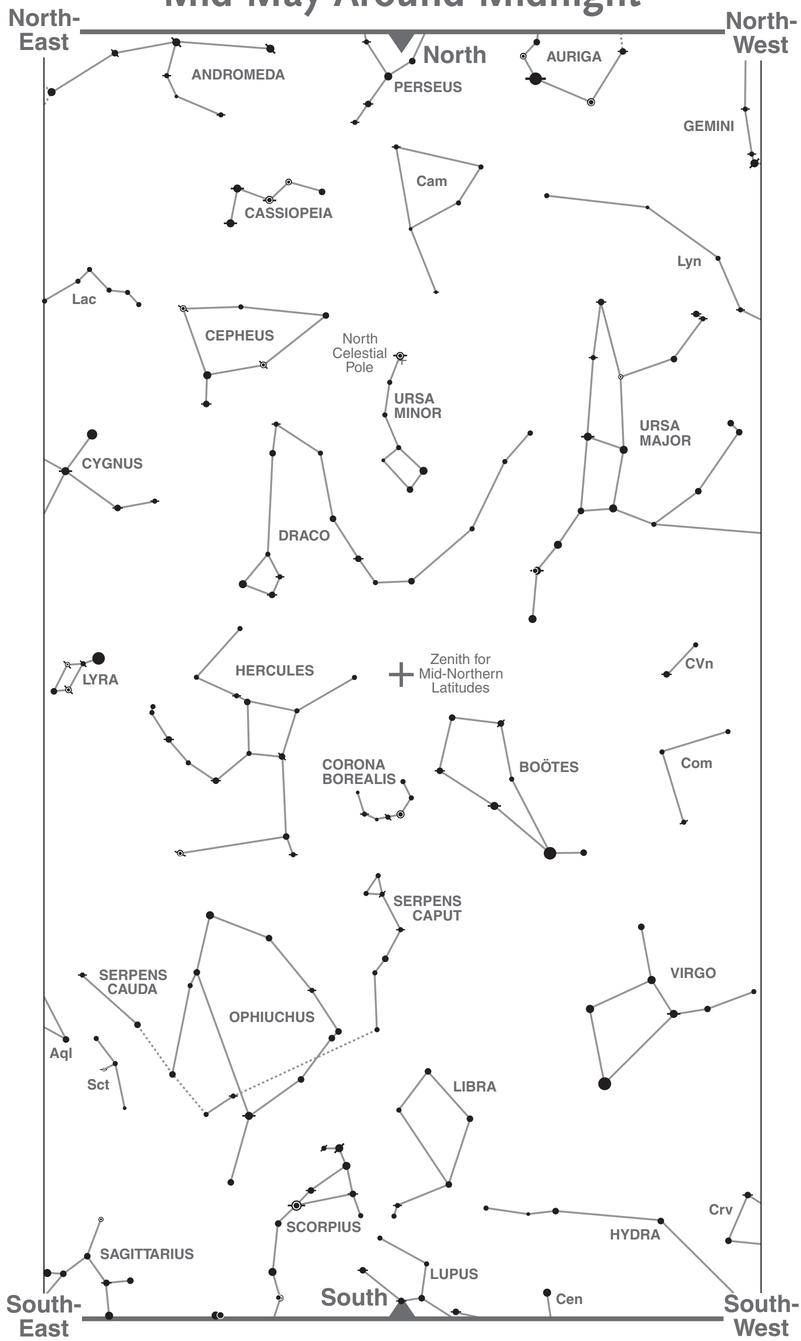
in mid March around 2 a.m.;

in mid February around 4 a.m.;

in mid January around 6 a.m.

5

Mid May Around Midnight



25°

This constellations are seen on meridian also:

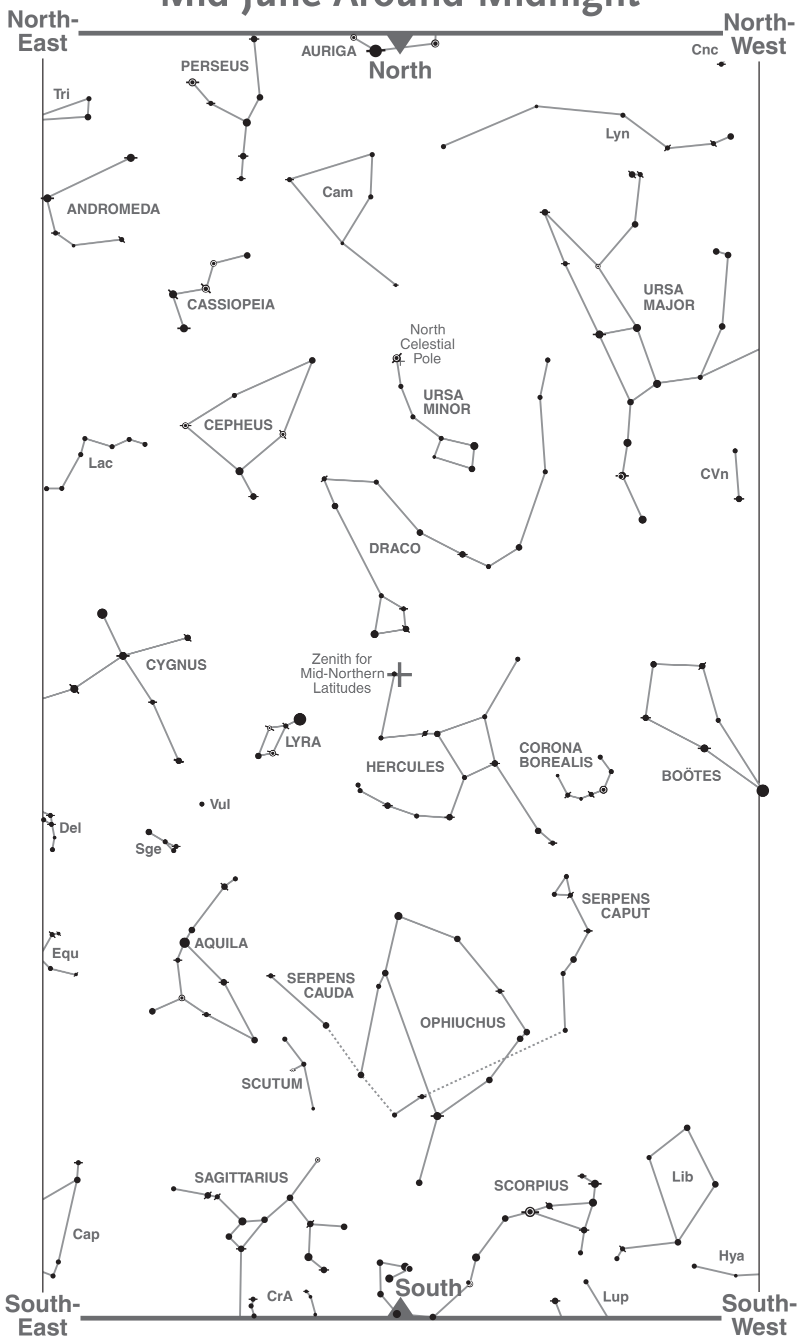
in mid June around 10 p.m.;

in mid April around 2 a.m.;

in mid March around 4 a.m.;

in mid February around 6 a.m.

Mid June Around Midnight



6

25°

This constellations are seen on meridian also:

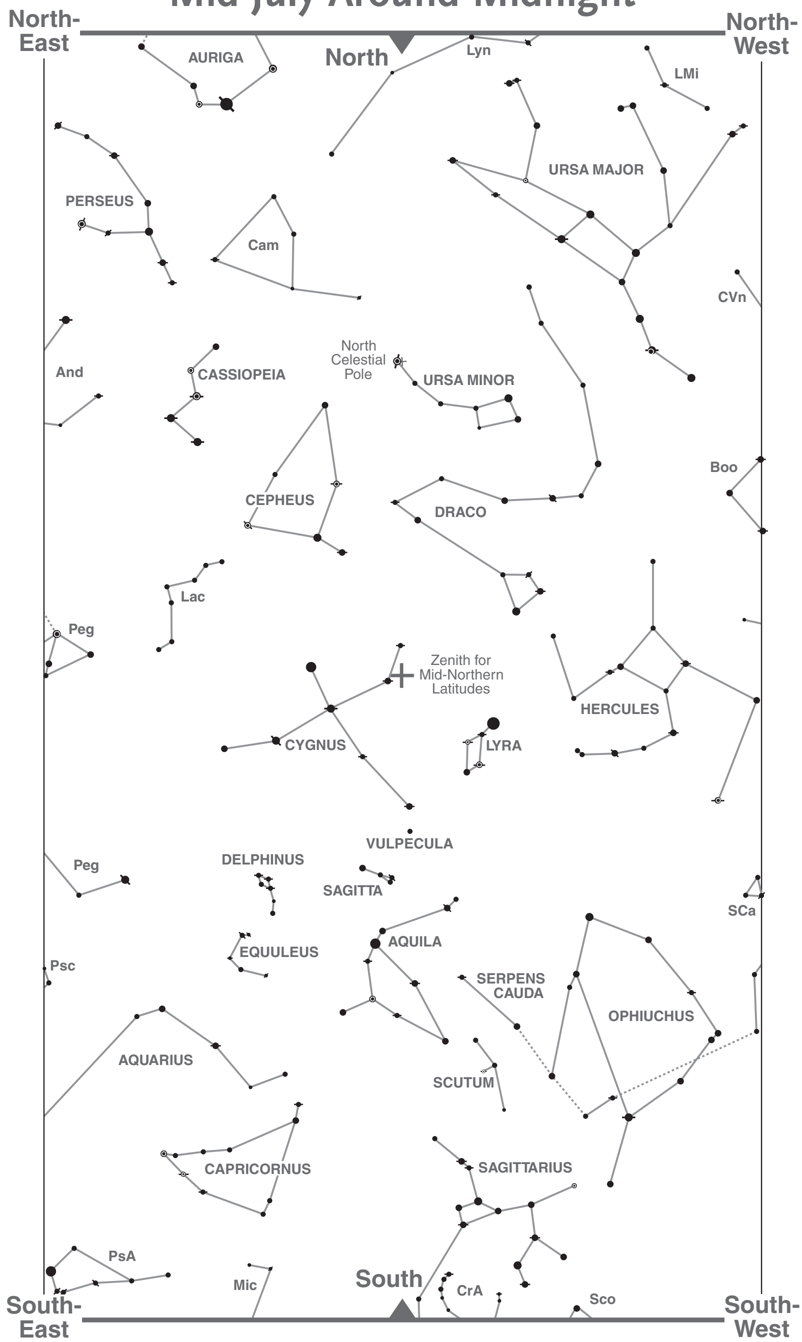
in mid July around 10 p.m.;

in mid May around 2 a.m.;

in mid April around 4 a.m.

7

Mid July Around Midnight



25°

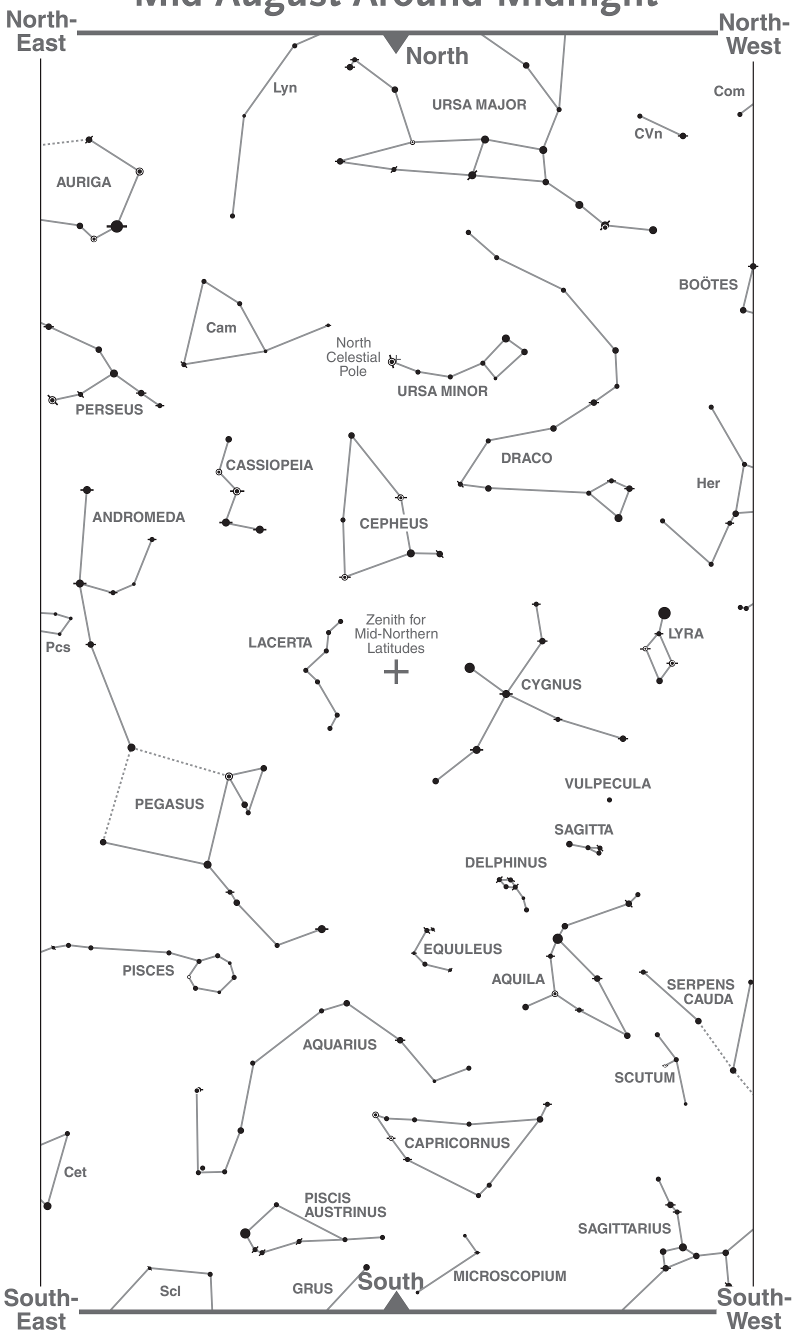
This constellations are seen on meridian also:

in mid August around 10 p.m.;

in mid June around 2 a.m.;

in mid May around 4 a.m.

Mid August Around Midnight



8

25°

This constellations are seen on meridian also:

in mid September around 10 p.m.;

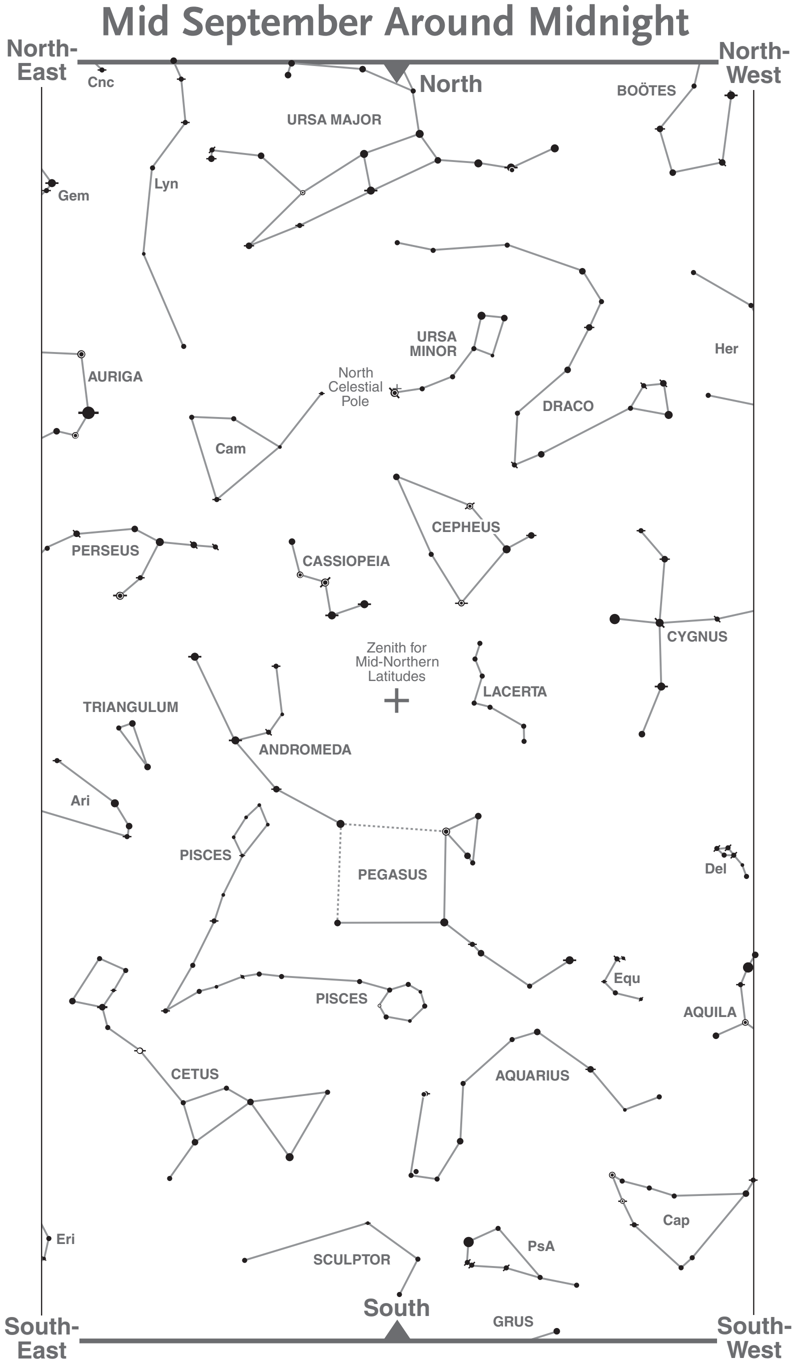
in mid October around 8 p.m.;

in mid November around 6 p.m.;

in mid July around 2 a.m.

9

Mid September Around Midnight



25°

This constellations are seen on meridian also:

in mid October around 10 p.m.;

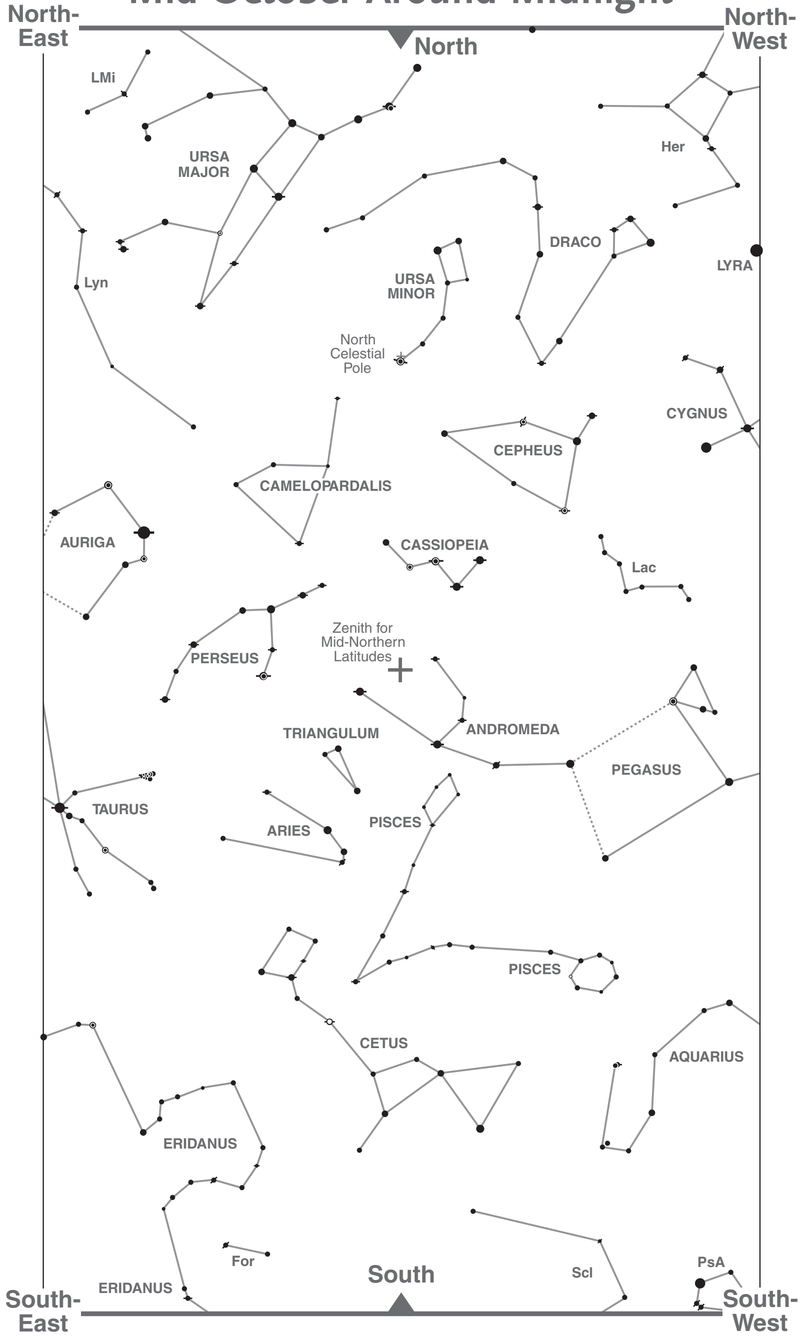
in mid November around 8 p.m.;

in mid December around 6 p.m.;

in mid August around 2 a.m.

Mid October Around Midnight

10



25°

This constellations are seen on meridian also:

in mid November around 10 p.m.;

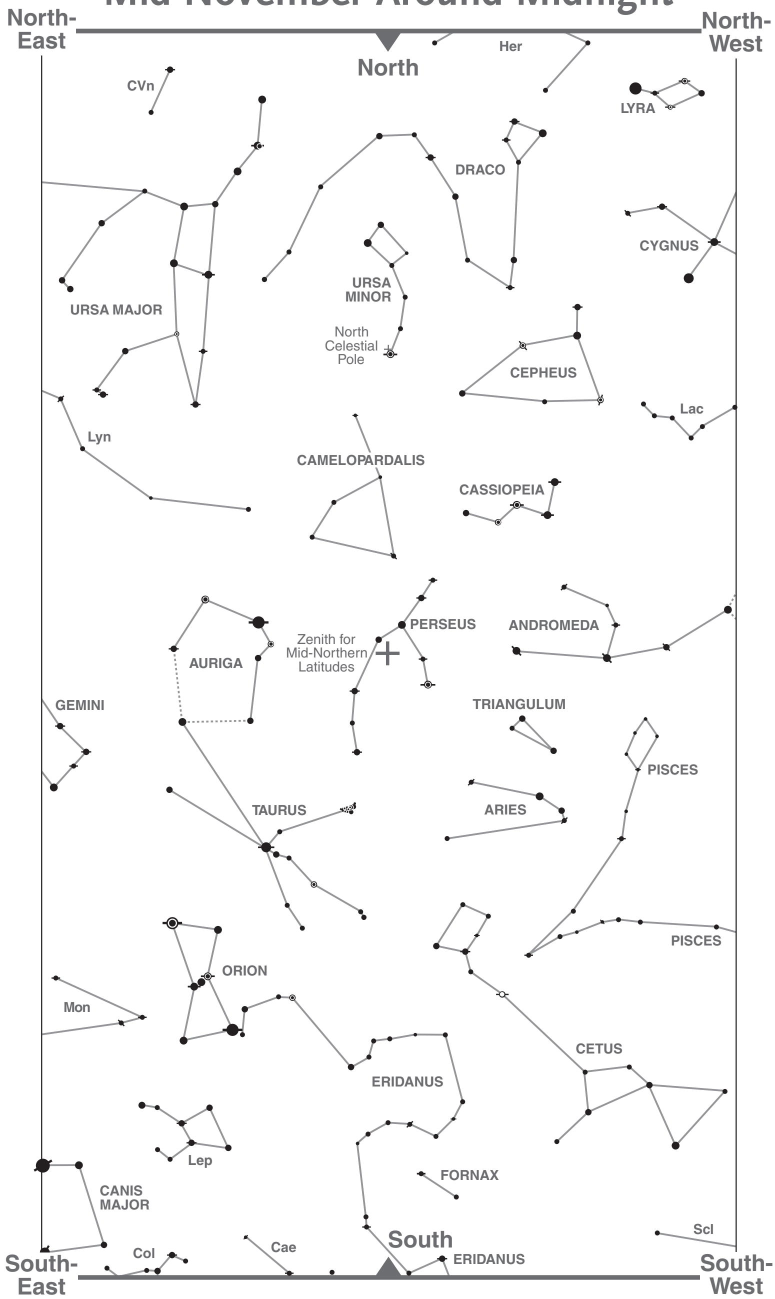
in mid December around 8 p.m.;

in mid January around 6 p.m.;

in mid September around 2 a.m.

11

Mid November Around Midnight



25°

This constellations are seen on meridian also:

in mid December around 10 p.m.;

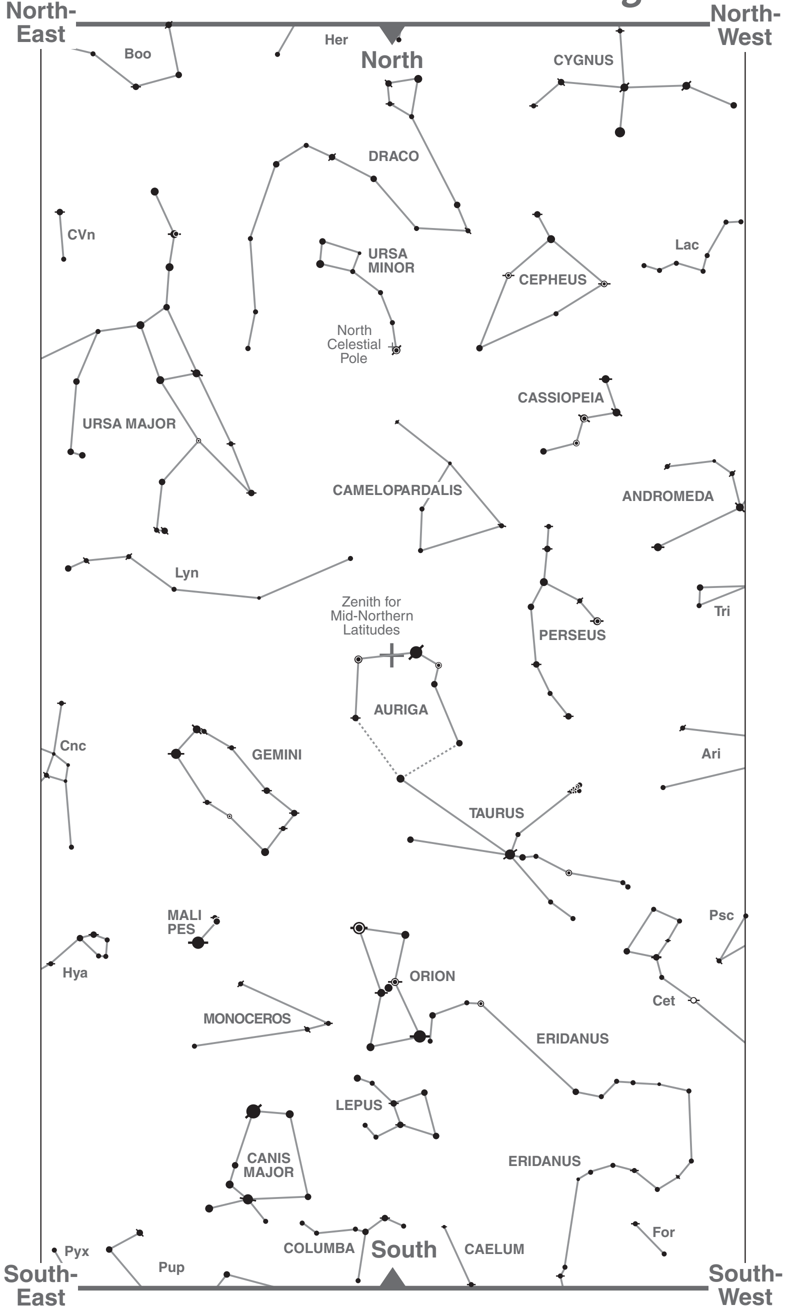
in mid January around 8 p.m.;

in mid October around 2 a.m.;

in mid September around 4 a.m.

Mid December Around Midnight

12



25°

This constellations are seen on meridian also:

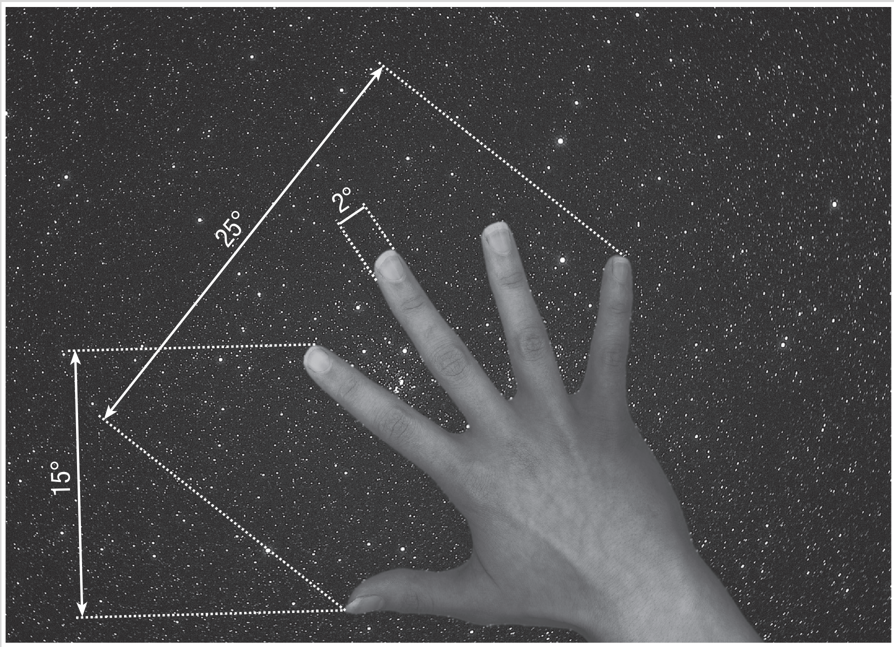
in mid January around 10 p.m.;

in mid February around 8 p.m.;

in mid November around 2 a.m.;

in mid October around 4 a.m.

Measuring Angles in the Sky
Astronomers measure the apparent distances between the stars in the sky with angles. (We say "apparent" because these are not the true distances between the stars.) Betelgeuse and Rigel in the constellation of Orion are 18.5° apart. From Betelgeuse to Gemini it is 33°. The apparent diameter of the Moon and Sun is approximately 0.5°. The comet tail is 90° long. The star is 15° above the horizon.



For a rough orientation – especially as we take our first steps across the sky – we can utilize something we always have on us, our hand. If we stretch it out and spread the fingers apart, we have a protractor; with this we can estimate the angle distances in the sky.

First Steps

If you have a friend or an acquaintance who is already familiar with the constellations, it is best if he or she helps you take your first steps across the sky and points out a few of the brightest stars and the constellations associated with them. Once you are familiar with a few constellations, you can use the seasonal charts (found in this book), a planisphere, a star atlas, or some other aids to find and recognize the remaining constellations.

A lot of people are familiar with the asterism called the Big Dipper. If you are among them, you can use the seasonal charts and first locate the neighboring constellations of the Great Bear and then their neighboring constellations and so on across the sky. But if you do not know a single star and a single constellation and want to learn how to recognize them by yourself using this book, then read the following paragraph very carefully.

In general, recognizing what is in the sky is pretty simple. What you need to know to begin is the rough direction of north–south from your observing point. You can define this direction with a

compass or by looking where the Sun is at midday – roughly south. At a certain date, say in mid-April at midnight, when you are standing under a clear night sky and turn toward the south, the spring constellations will cover the sky from the southern horizon across the zenith to the northern horizon. The sky is dominated by three bright stars (see chart P1 on page 51): Arcturus in Boötes, Spica in Virgo, and Regulus in Leo. It is enough to recognize one constellation, the one with the greatest number of bright stars. From this starting point you can then simply find the neighboring constellations, then their neighboring constellations, and so on across the celestial sphere. But beware! When you think you have found, for instance, Regulus and Leo, have a look at the chart that depicts stars up to magnitude 5 (we will speak about stellar brightness and its unit magnitude in the next chapter), which is found in the description of this constellation in the second part of this book (Figure 2.11A). In addition to the brightest stars that make up the shape of constellation Leo, you also should try to recognize all of the fainter stars. Only then can you be sure that you are truly looking at Leo. (It happens all too often that beginning amateur astronomers search for too small patterns of stars and are satisfied with the first grouping that is roughly similar to the one they are looking for.)

When you have established the location of Leo, you should look at seasonal chart 3 (a cutout from this chart can be found on Figure 2.11B), which includes the constellation Leo, and notice that the following constellations surround it: to the west is Cancer, north is Leo Minor, northeast is Coma Berenices, southeast is Virgo, south is the Sextans, and southwest is the head of the Hydra. Once you recognize these constellations, with the help of the descriptions that are included in the second part of this book, you will already know seven constellations. And then you can travel ahead across the celestial sphere.

Charts P1–P4 depict the spring, summer, autumn, and winter skies in the Northern Hemisphere, with only the brightest stars and thus only the most visible constellations or asterisms. Alongside the charts are the dates and hours of visibility. Novices in sky gazing should first – depending on the season and time – find one of these constellations. This should be the starting point. For easier

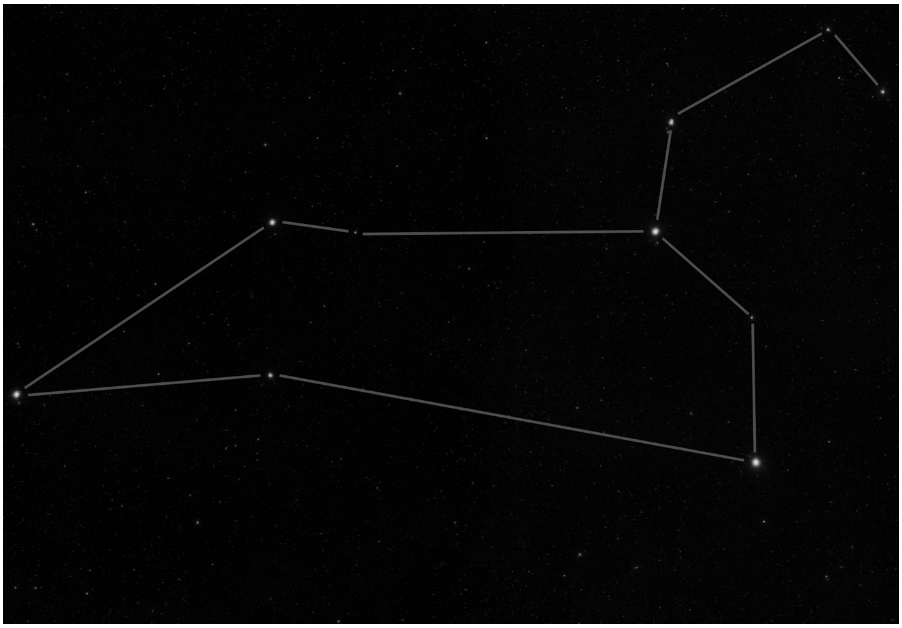


Figure 2.11 Photography of Leo with stars up to magnitude 8

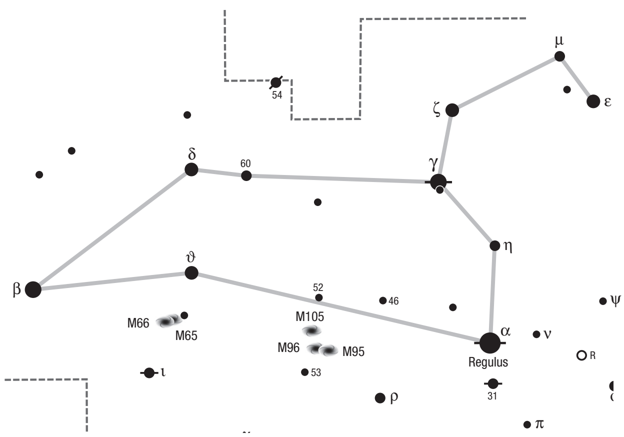


Figure 2.11A Map of Leo with stars up to magnitude 5

orientation we have also drawn in some of the more important angle distances and an open, stretched out hand, which represents approximately 25°. The zenith is also a useful point for orientation.

Places with no light pollution or smog are the most suitable for observing the night sky through binoculars. But on a clear, moonless night there are so many stars in the sky that sometimes even the more experienced observers can be mislead, let alone beginners. Thus, while you are still inside in a bright room, take a good look at the brightest stars and the angles between them on the chart. Only then should you step out under the night sky, turn toward the south, and for the first few minutes

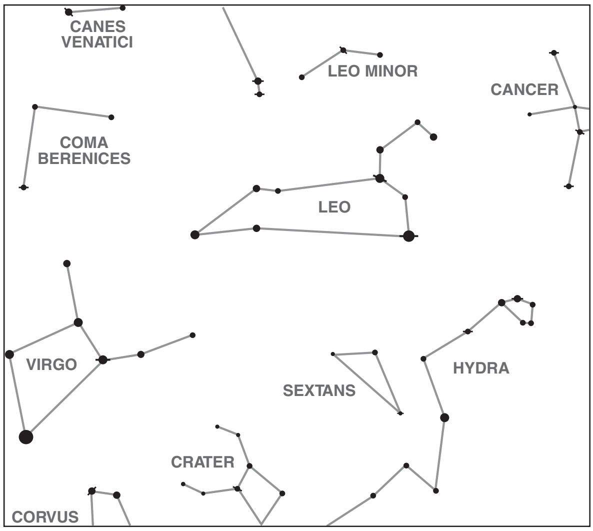


Figure 2.11B Leo and surrounding constellations

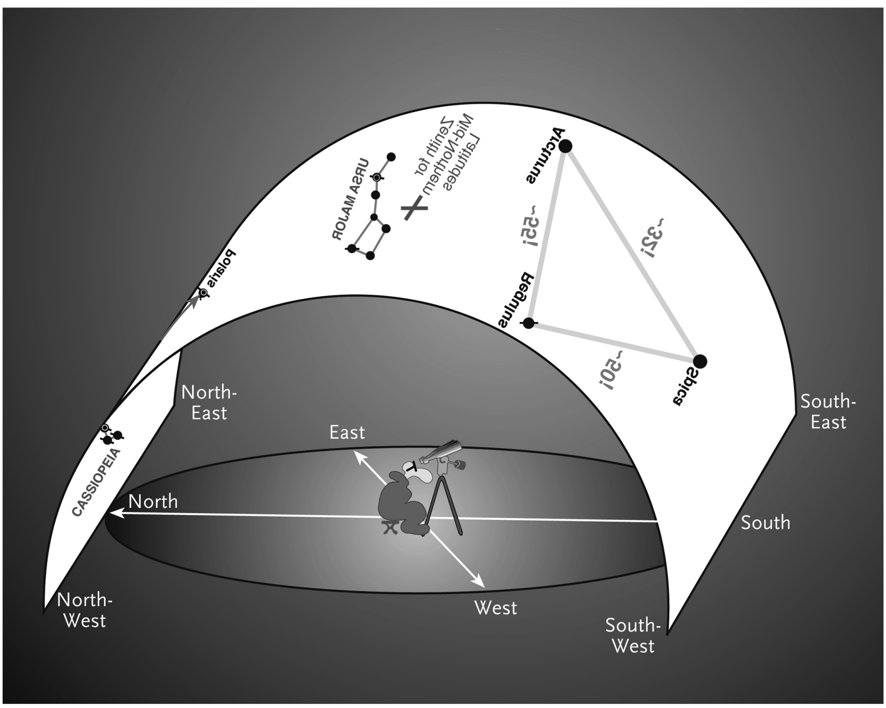
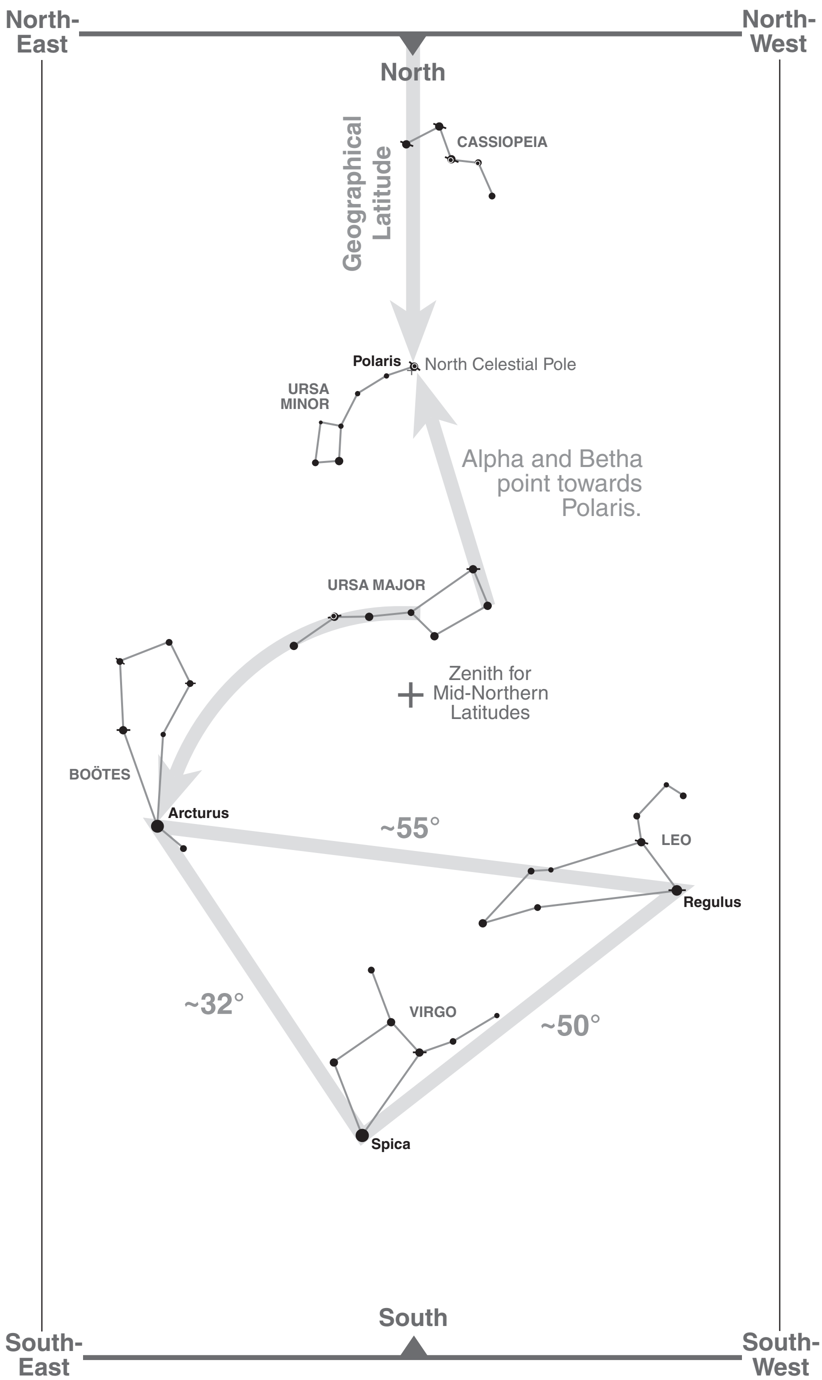


Figure 2.12 It helps to picture the charts for learning about constellations (P1 to P4, as well as the seasonal charts) folded over the meridian of the observing point from the south across the zenith to the north. If you have a problem with this, you should photocopy the chart from this book and then bend it while using it during observation

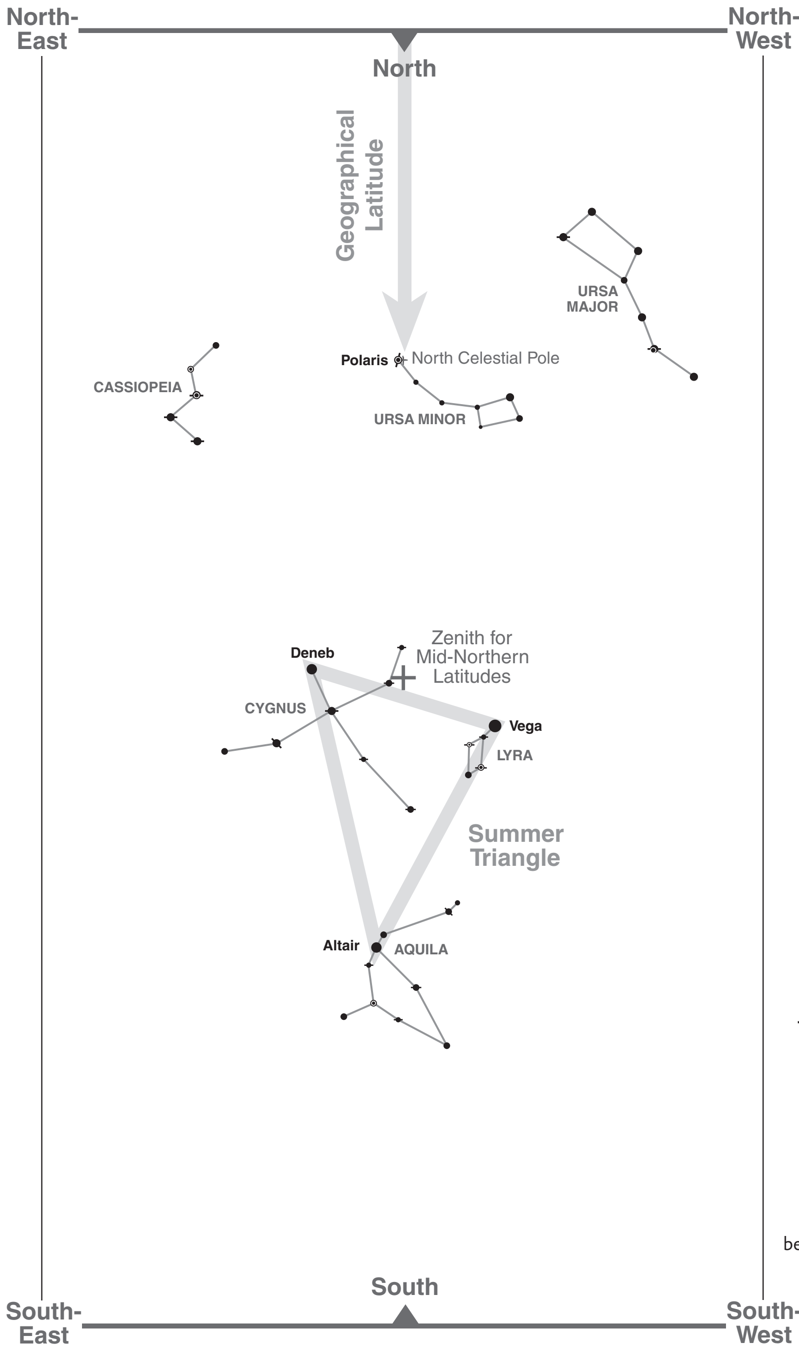
P1

25°



The appearance of the sky near meridian at:
mid January at 6 a.m.,
end January at 5 a.m.,
mid February at 4 a.m.,
end February at 3 a.m.,
mid March at 2 a.m.,
end March at 1 a.m.,
mid April at midnight,
end April at 11 p.m.,
mid May at 10 p.m.,
end May at 9 p.m.

P2

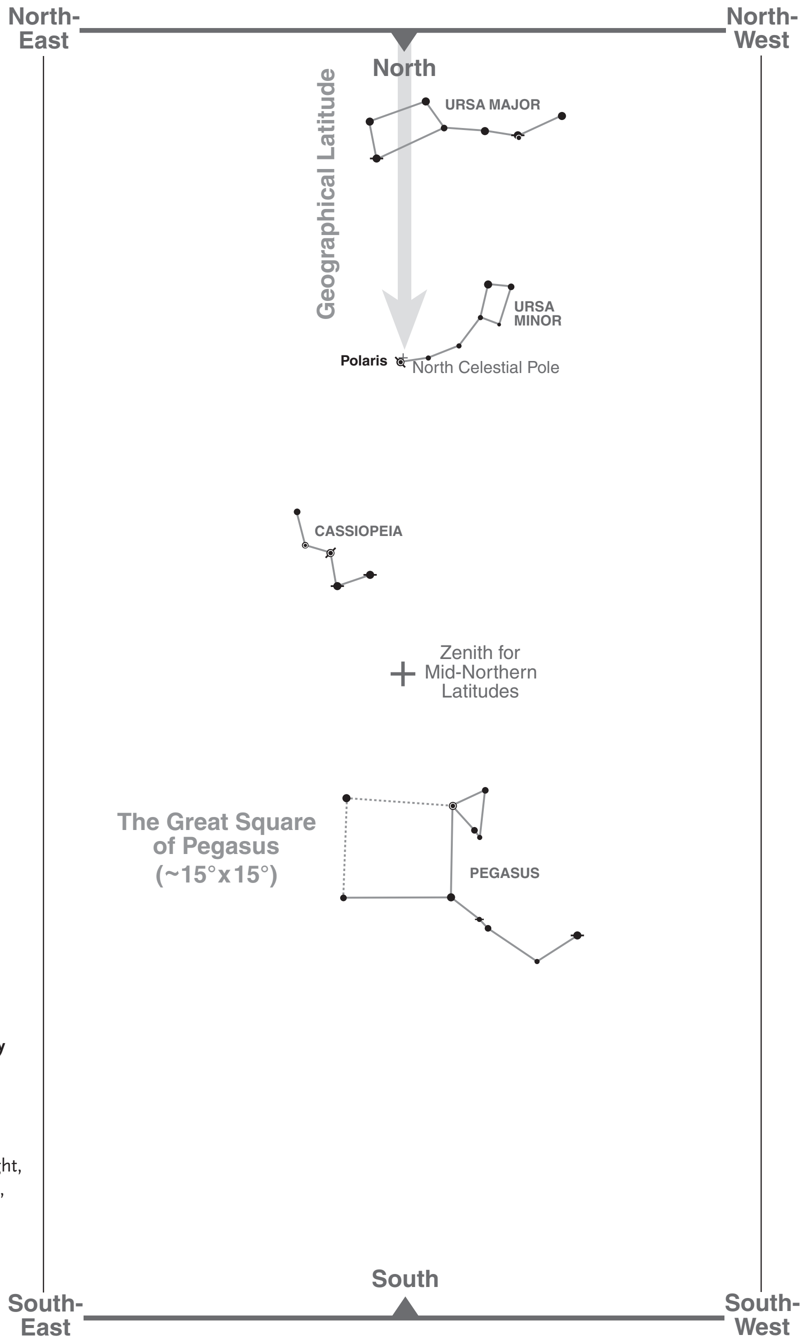


25°

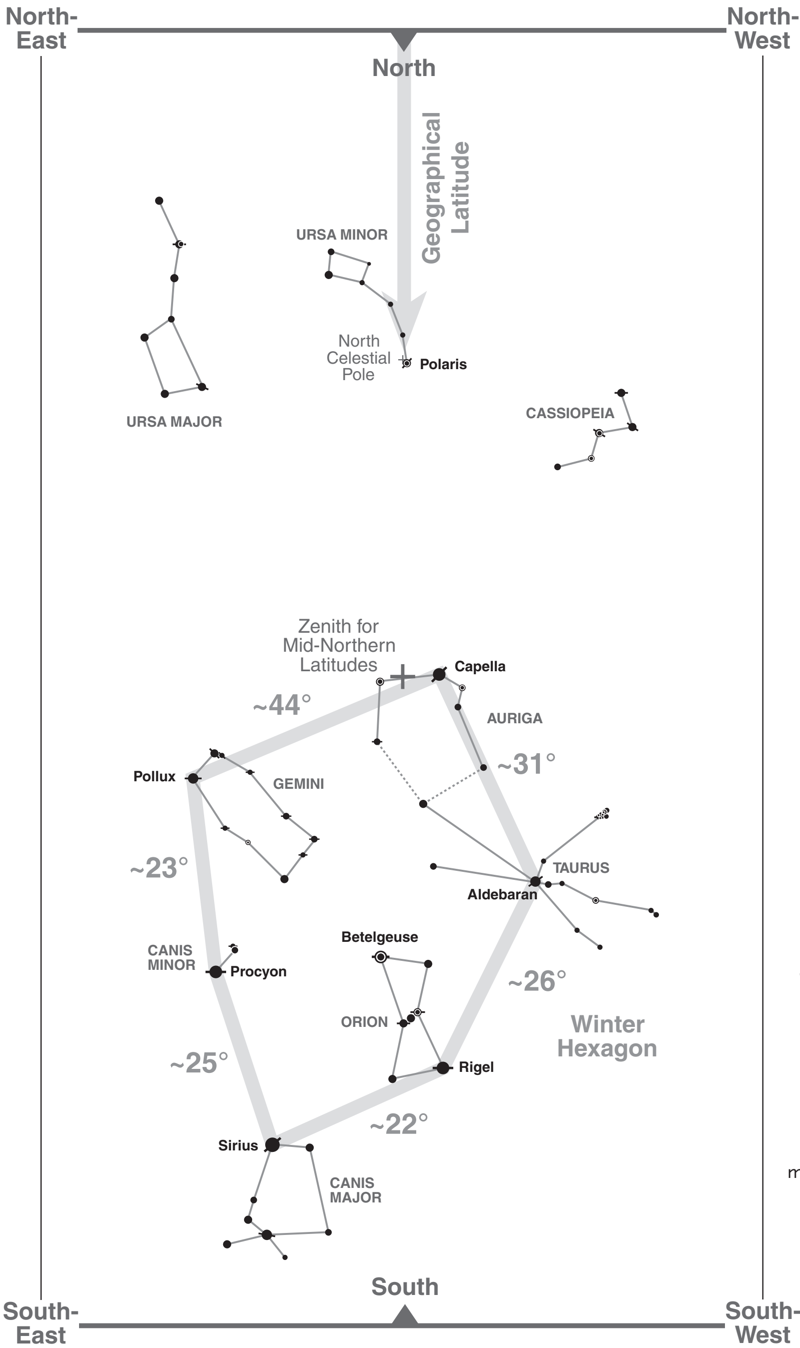
The appearance of the sky near meridian at:
end May at 4 a.m.,
begin June ob 3 a.m.,
end June at 2 a.m.,
begin July ob 1 v,
end July at midnight,
begin August ob 11 p.m.,
end August at 10 p.m.,
begin September ob 9 p.m.,
end September at 8 p.m.,
begin October ob 7 p.m.,
end October at 6 p.m.

P3

25°



The appearance of the sky near meridian at:
begin August at 3 a.m.,
mid August at 2 a.m.,
end August at 1 a.m.,
mid September at midnight,
end September at 11 p.m.,
mid October at 10 p.m.,
end October at 9 p.m.,
mid November at 8 p.m.,
end November at 7 p.m.,
mid December at 6 p.m.



P4

25°

The appearance of the sky near meridian at:
mid September at 6 a.m.,
end September at 5 a.m.,
mid October at 4 a.m.,
end October at 3 a.m.,
mid November at 2 a.m.,
end November at 1 a.m.,
mid December at midnight,
end December at 11 p.m.,
mid January at 10 p.m.,
end January at 9 p.m.,
mid February at 8 p.m.,
begin March at 7 p.m.,
mid March at 6 p.m.

while your eyes are still getting adjusted to the dark, you will see only the brightest stars and will certainly recognize them.

You can also bring a flashlight outside with you. When you turn it off, your eyes will not have had time to adjust to the dark, and you will only see the brightest stars in the sky. You can also try and learn about the constellations by observing them from light polluted places, where even under the best conditions you will only see stars up to magnitude 3, which, for the novice, is almost ideal. However, after you are able to recognize the brightest stars and want to learn about the entire constellation, you should find an observing point with dark, clear skies.

A final possibility is to start learning about the constellations at twilight, when the Sun has already set but it is not yet night, and only the brightest stars are visible in the sky. Such conditions exist every day for approximately half an hour.

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