The Fundamentals of Stargazing

Science of Stargazing

01 - Layout of the Night Sky

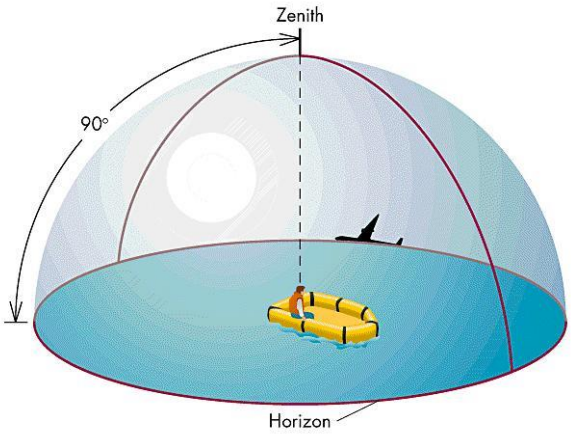
 www.CosmicPursuits.com

The Celestial Sphere

Look up on a clear night and you'll notice the sky looks like a vast hemispherical dome with stars fixed to its inner surface. If the Earth were transparent, you would see the stars on the other half of this starry dome, below your feet, and you'd get the impression you were standing at the center of a velvety-black sphere speckled with stars. Astronomers call this the *celestial sphere*.

While it appears that all stars are fixed to the celestial sphere, they are in fact at very different distances, but you cannot directly perceive this simply by looking into the sky. Ancient stargazers mused the stars may be tens or hundreds of miles away, and thought the stars were holes in the sky to let through the light of heaven. The stars are in fact tens of trillions of miles away, and are balls of burning gas sustaining themselves through gravitational forces and the energy from nuclear reactions in the cores.

But back to the layout of the sky. The line at which the earth's surface and the sky appear to meet is called the *horizon*. If you're surrounded by structures, trees, and hills, it may be hard to see the horizon. But if you're on a prairie or desert or the ocean, you should have little trouble seeing the sky down to the horizon.



The horizon, where the sky appears to meet the Earth

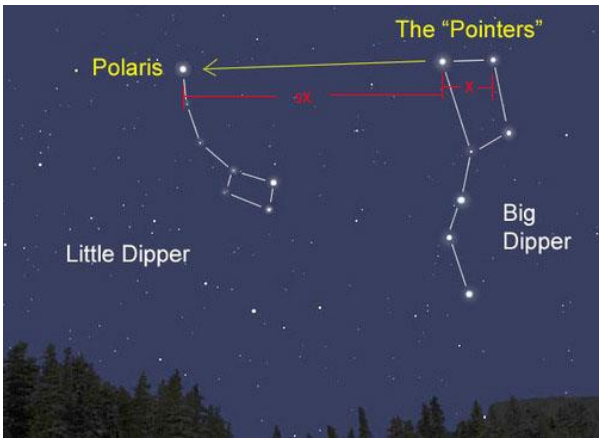
The imaginary point on the celestial sphere that is directly overhead, and therefore 90 degrees above the horizon, is called the *zenith*. The point that is 90 degrees below the horizon, which of course you cannot see, is called the *nadir*.

The imaginary points on the horizon which indicate the main directions, north, south, east, and west are known as *cardinal points*.

Let's have a look at the most important features and points on the celestial sphere. First, a look at the celestial poles and how to find north and south in the sky.

The North Celestial Pole

If you've see Orion in this month's sky tours, for example, you were facing south, more or less. To find north-- true north-- you need to find the North Star, also known as Polaris. To find Polaris, look first for the Big Dipper, which is a large dipper-shaped group of stars in the northeastern sky. Here's an image of what you're looking for...



The "Pointers" of the Big Dipper show the way to Polaris, as seen in the evening hours of February and March. The Big Dipper is on the other side of Polaris in the late summer and early autumn months

Look for the front stars of the bowl of the Dipper. They are called "The Pointers" because they point the way to the North Star. Follow the pointers, as in the diagram above, for a distance of about five times the distance between these two stars. You will arrive at a moderately bright star. This is Polaris, the North Star. When you are facing Polaris, you are facing north.

Polaris, by the way, is the brightest star in the asterism called the Little Dipper, which is smaller and fainter than the Big Dipper. If you are inclined, see if you can trace out the other stars of the Little Dipper.

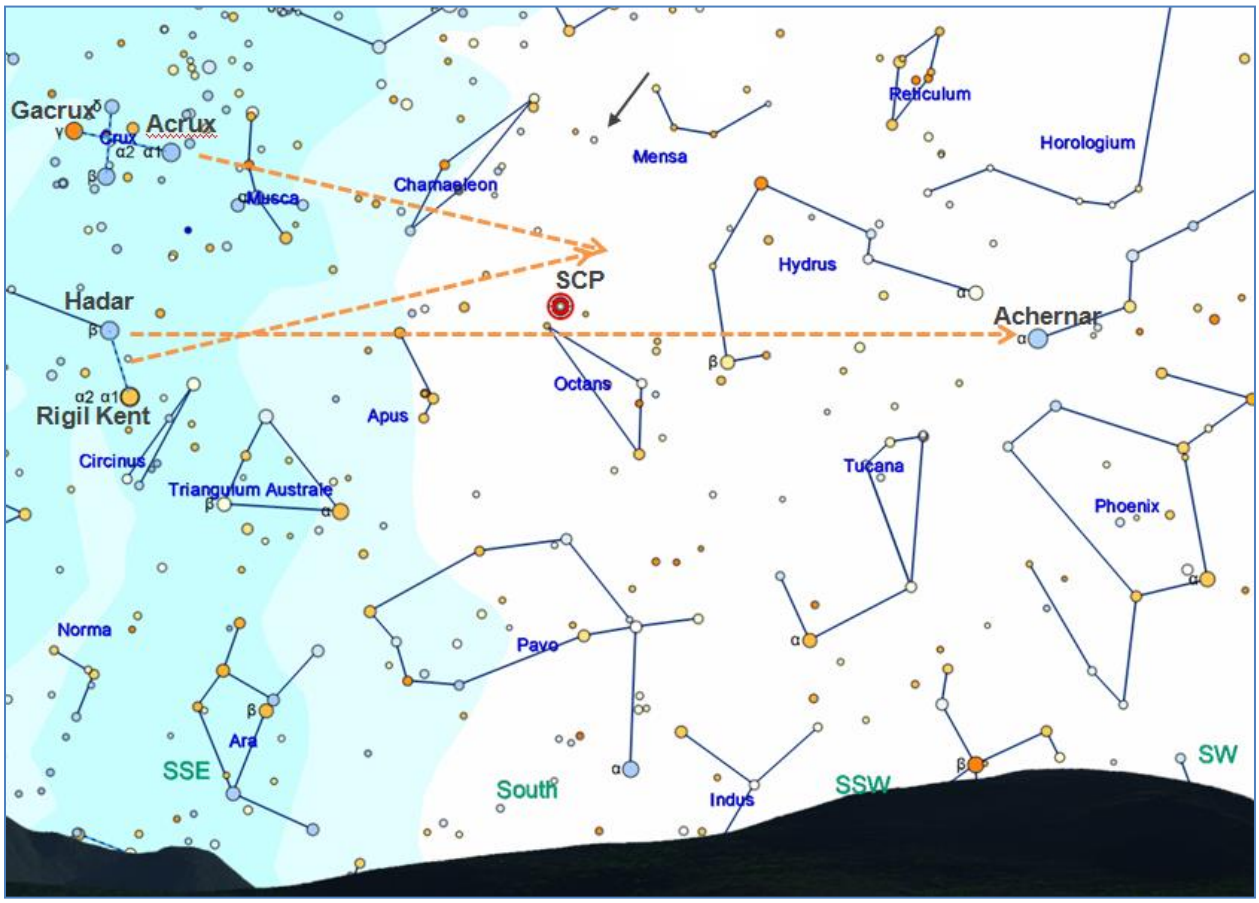
Polaris marks-- almost-- the position of the North Celestial Pole (NCP), a point on the celestial sphere that lies directly above the Earth's north pole. Which means if you were standing at the Earth's north pole, the North Celestial Pole is the imaginary point directly over your head. Polaris is not exactly at the NCP, though it is, by chance, very close... less than one degree. So from Earth's north pole, Polaris is nearly directly overhead.

The South Celestial Pole

In the southern hemisphere, the Big and Little Dippers are not visible and the position of the north celestial pole is below the horizon. Finding the south celestial pole is a little trickier because there is no bright star marking its position, that is, there is no southern counterpart to

Polaris. The SCP lies in the small and faint constellation Octans, the Octant near a faint star called sigma Octanis that is barely visible to the unaided eye.

A good way to roughly estimate the location of the SCP uses the stars of the Southern Cross (also called "Crux") and two bright stars in the constellation Centaurus. These bright stars are easy to find, especially in the months of March through July well above the southern horizon in the southern hemisphere. The star map below shows you what to look for as you face south in the early evening hours during these months.



Using Crux and stars Rigil Kent and Hadar to estimate the position of the south celestial pole in the southern hemisphere

The Southern Cross is a small group of bright stars about the width of your three middle fingers held at arm's length. Below the Cross, look for two brighter stars that are separated by an apparent distance a little smaller than the length of the Southern Cross. The brighter yellow star is called Rigil Kent and the blue-white star is called Hadar. These are the brightest stars in Centaurus. They are sometimes called the "Southern Pointers". These stars are not visible from the mid-northern latitudes in the northern hemisphere.

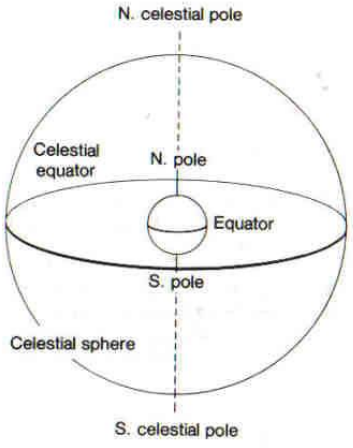
Extend an imaginary line through the long axis of the Southern Cross, from the star at the top (Gacrux) through the star at the bottom (Acrux). Now extend another line perpendicular to the midpoint between the Southern Pointers. The line from Crux intersects the line perpendicular to the pointers about 5 degrees northwest of the south celestial pole (SCP).

As a double check, draw an imaginary line from Hadar in Centaurus to the bright star Achernar which you will find above the southwestern horizon. The SCP lies just south of the halfway point between these two bright stars. Again, these are just approximate methods to estimate the location of the SCP and therefore to find which direction is south. They are not sufficiently accurate for aligning telescope mounts or for navigation.

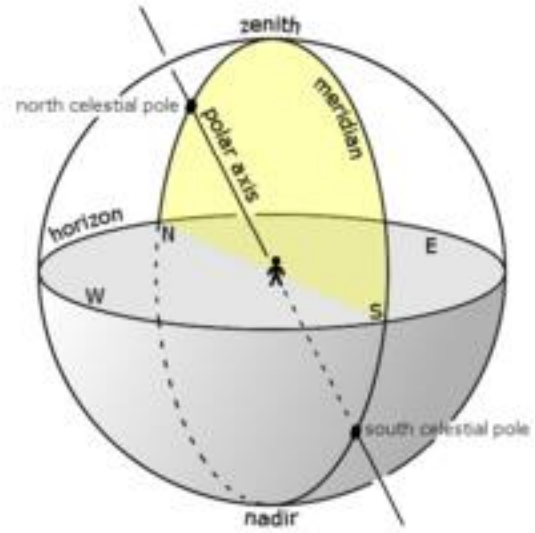
The Meridian and the Celestial Equator

Just as celestial poles lie on the celestial sphere above Earth's poles, there is a celestial counterpart to Earth' equator. Directly above the Earth's equator lies the *celestial equator*, which divides the northern half of the celestial sphere from the southern half.

As you can see from the image below, if you were standing at the north pole, the celestial equator would coincide with the horizon. And if you were standing on the Earth's equator, the celestial equator would stretch from the east to the west directly overhead. As seen from the equator, the north and south celestial poles would lie on the northern and southern horizon, respectively.



The celestial poles and equator lie above their terrestrial counterparts



The horizon, meridian, and cardinal points

But how about if you're standing at some intermediate latitude, between the north or south pole and the equator?

In that case, the celestial pole (NCP or SCP) would lie at some angle above the horizon. That angle is equal to your latitude. If you are at the equator, which is 0 degrees latitude, then the NCP and SCP would lie zero degrees above the horizon, that is, on the horizon. In Sydney, Australia, which has a latitude of 34 degrees south, the SCP will lie 34 degrees above the southern horizon. And in London, England, which has latitude 51 degrees north, the NCP (and Polaris) will lie 51 degrees above the northern horizon. This is how navigators have determined their latitude for thousands of years... by measuring the angle of the celestial pole above the horizon.

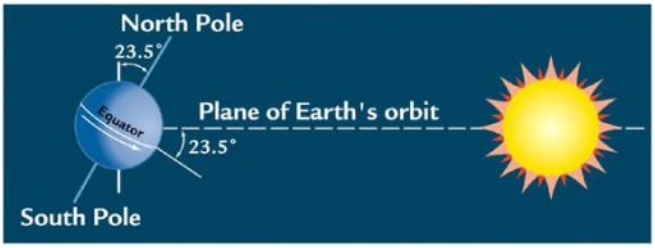
Once you can find north and south, it's time to trace another key feature of the celestial sphere. Guide your imagination to the imaginary great circle that runs from the northern (or southern) horizon, up through the north (or south) celestial pole, through the zenith, then down to the southern (or northern) horizon, around to the nadir, and back up again. This circle called the *meridian.*

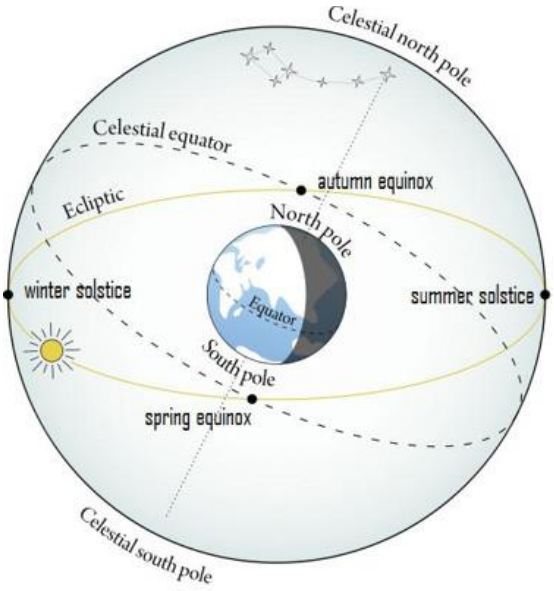
The meridian is important to stargazers for a number of reasons. For now, simply note that when a star is near the meridian, it's at its highest point in the sky during the night, and therefore it's at its optimum position for observation. When a star or planet appears to move east to west across the meridian during the evening, a movement caused by the Earth's rotation, the object is said to *culminate*.

The Ecliptic

Now to one last key circle on the sky: the *ecliptic*. The ecliptic is another great circle around the celestial sphere, just like the celestial equator. But the ecliptic is tilted with respect to the equator by 23.5 degrees (see below).

The ecliptic is the imaginary circle on the sky that marks the annual path of the Sun. It's tilted because the Earth itself is tilted relative to its orbit around the Sun by 23.5 degrees (see below).





The tilt of the Earth's axis, showing the plane of the ecliptic inclined to the celestial equator and the position of the equinoxes and solstices.

Because of this tilt, the Sun appears highest in the sky relative to the celestial equator when the Earth is at one position in its orbit. This happens on or about June 21, and we call this the *summer solstice* (in the northern hemisphere) and the *winter solstice* (in the southern hemisphere). When the Earth is at the opposite side of its orbit around the Sun in December the Sun is at its most southerly point in the sky relative to the celestial equator. This is the *winter*

solstice in the north and *summer solstice* in the south. Halfway between the two, on March 21 and September 21, the Sun is right on the celestial equator. These are *spring and autumnal equinoxes* when spring and autumn begin. The equinoxes and solstices are four points on the ecliptic.

Since Earth and the other the planets lie near the same flat plane around the Sun, the ecliptic also marks the path of the planets around the sky as they revolve around the Sun. So every planet, the Sun, and even the Moon, are always found on or very close to the ecliptic during the year.

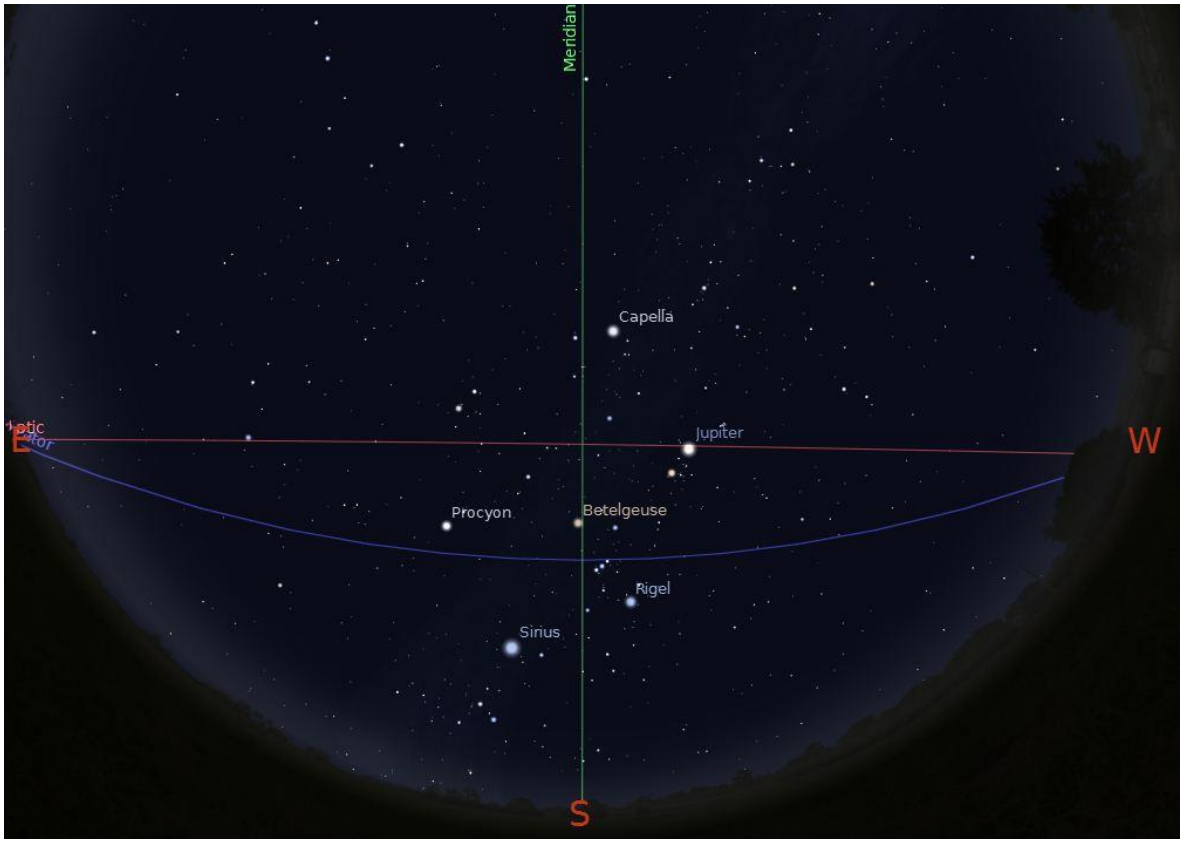
As it turns out, the great circle of the ecliptic passes through 12 of the 88 constellations. This group of constellations is called the *zodiac*. It includes Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Sagittarius, Capricornus, Aquarius, and Pisces. (The ecliptic actually passes through a 13th constellation, Ophiuchus, but it is not included in the zodiac because ancient astrologers regarded the number 13 as unlucky).

Example:

The image below helps bring the above ideas together for you. It shows a wide-angle simulation of the night sky around the beginning of March at about 8 p.m. from a latitude of 45 degrees north. You see three of the four cardinal points around the horizon (north is not shown). You see the green line representing the meridian stretching from the south, overhead, and off through to the north; Polaris is the brighter star at the top of the image near the "M" in "Meridian", and nearly on the meridian. You see the ecliptic in red and the celestial equator in blue.

Notice how Orion's Belt nearly lies on the equator, and the planet Jupiter lies along the ecliptic. You also see the star Betelgeuse is culminating, that is, crossing the meridian at its highest point in the sky for the evening as it moves from east to west.

As a little project, next time you're outside at night, try to trace out the approximate positions of the north or south celestial pole (depending on your hemisphere), the celestial equator, and the meridian. Once you learn the zodiacal constellations, you can find the position of the ecliptic as well. A hint: the constellations Taurus and Gemini mark the northernmost extent of the ecliptic, while Sagittarius and Scorpius mark the southernmost part of the ecliptic, relative to the celestial equator.



A wide-angle view of the sky looking south in the evening in February/March showing the meridian (green), the celestial equator (blue), and the ecliptic (red)

You've covered a lot here. Who would have thought the sky has so many points and great circles? It may all seem a little confusing at first. But don't worry. You just need to review this material, think about it on your own, and trace out these points and circles in the heavens. In time, it will all become second nature as you work through *The Art of Stargazing*.

Measuring Angles in the Night Sky

As you learn to find your way around the night sky, it is immensely helpful to know how to estimate angles. For example, if you read the star cluster M41 is 4 degrees south-southeast of the star Sirius, you want to have some idea of what that means.

There are, as you may recall, 360 degrees in a circle. The north and south cardinal points on the horizon, for example, at 180 degrees apart, halfway around a circle. And the angular separation of any point on the horizon and the point directly overhead (the zenith) is 90 degrees. Halfway from the zenith to the horizon is 45 degrees. So far, so good.

Smaller angles are a little trickier. But your hands and fingers are remarkably accurate (and convenient) measuring tools. When you hold your hand at arm's length, you can estimate angles like this:

- Stretch your thumb and little finger as far from each other as you can. The span from tip to tip is about 25 degrees
- Do the same with your index finger and little finger. The span is 15 degrees.
- Clench your fist at arm's length, and hold it with the back of your hand facing you. The width is 10 degrees
- Hold your three middle fingers together; they span about 5 degrees
- The width of your little finger at arm's length is 1 about degree.

These measures work even for kids because while their arms are shorter, their hands are smaller.

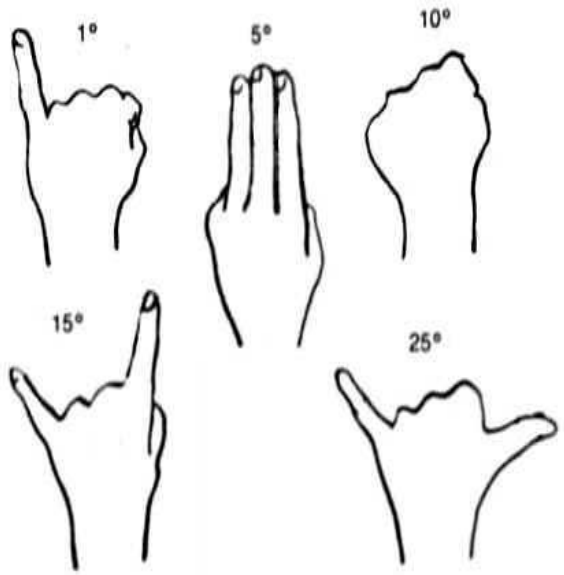


Fig E.
The Common Sky Measurements

Using your fingers to measure angles in the sky

As an exercise, wander out and have a look at Orion to practice estimating angular sizes in the sky. Using the above examples, estimate these angular distances: a) Betelgeuse to Rigel; b) Betelgeuse to Bellatrix (the star at the other shoulder of Orion); c) the width of Orion's Belt; d) the size of the "Sword", the three stars south of Orion's Belt.

Answers below:

a) 18 degrees
b) 7 degrees
c) 5 degrees
d) 1 degree