

Using the SFA Star Charts and Understanding the Equatorial Coordinate System

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Last Updated: August 17, 2020

The SFA Star Charts are four separate charts. Chart 1 is for the north celestial region and chart 4 is for the south celestial region. These notes refer to the equatorial charts, which are charts 2 & 3 combined to form one long chart. The star charts are based on the Equatorial Coordinate System, which consists of *right ascension* (RA), *declination* (DEC) and *hour angle* (HA).

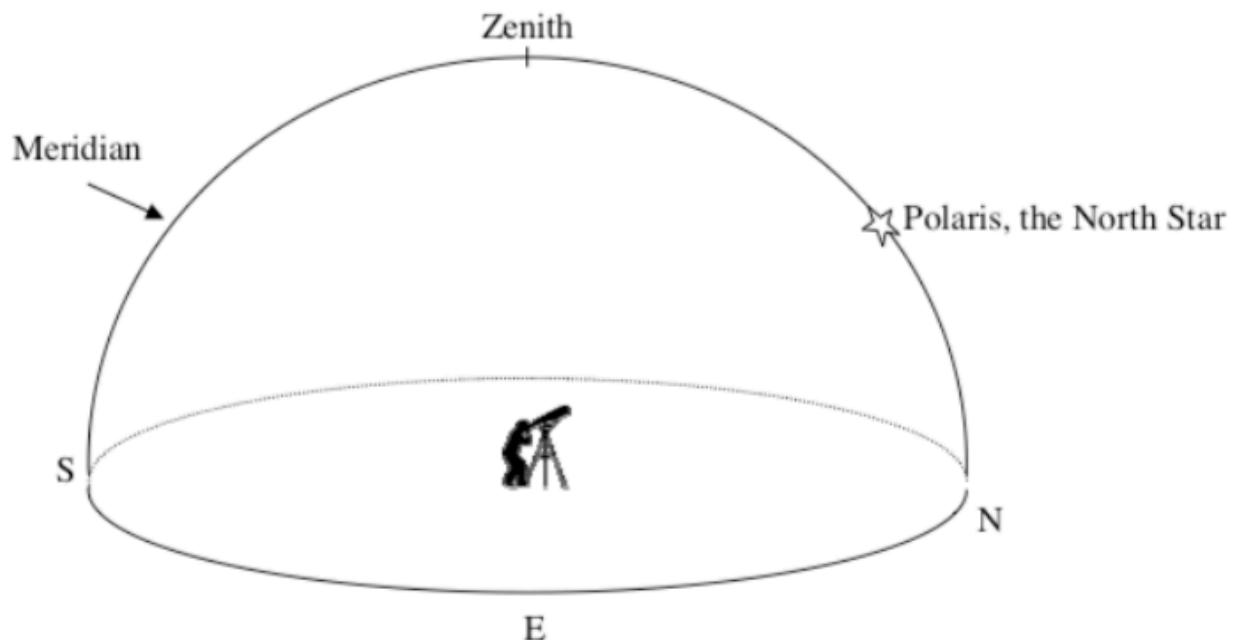
From the northern hemisphere, the equatorial charts can be used when facing south, east or west. At the bottom of the chart, you'll notice a series of twenty-four numbers followed by the letter "h", representing "hours". These hour marks are right ascension (RA), which is the equivalent of celestial longitude. The same point on the 360 degree celestial sphere passes overhead every 24 hours, making each hour of right ascension equal to 1/24th of a circle, or 15 degrees. Each degree of sky, therefore, moves past a stationary point in four minutes. Each hour of right ascension moves past a stationary point in one hour. Every tick mark between the hour marks on the equatorial charts is equal to 5 minutes. Right ascension is noted in (h) hours, (m) minutes, and (s) seconds. The bright star, Antares, in the constellation Scorpius, is located at RA 16h 29m 30s.

At the left and right edges of the chart, you will find numbers marked in degrees ($^{\circ}$) and being either positive (+) or negative(-). The bold, horizontal line across the center of the chart represents the *celestial equator* (0°). The celestial equator divides the sky into north (+) and south (-) in the same respect the equator divides the Earth into north and south. The numbers marked in degrees represent declination (DEC). Declination is the equivalent of celestial latitude where the plane of the celestial equator is 0° and the north celestial pole is $+90^{\circ}$ from the celestial equator and the south celestial pole is -90° from the celestial equator. Each tick mark of declination on the equatorial charts is equal to 1 degree. Each degree can be further subdivided into 60 equal arc-minutes, and each arc-minute may be divided into 60 arc-seconds. Declination is noted in ($^{\circ}$) degrees, (') arc-minutes, and (") arc-seconds. The bright star, Antares, in the constellation Scorpius is located at DEC $-26^{\circ} 25' 55''$.

Stars, like any object in the night sky, can have multiple catalog identifiers and sometimes names. The *proper name* for a star is its *Bayer Designation*, which is a greek letter combined with the name of the constellation in which it resides. Generally, the brightest star in a constellation receives the first letter in the greek alphabet, alpha (α). The second brightest receives the second letter, beta (β), and so on. The *common name* for a star is what we call it in general conversation. For instance, α Lyra is the brightest star in the constellation Lyra and its common name is Vega. Vega also has more than 60 other catalog identifiers, such as HD 172767, SAO 67174 to name a couple.

The curved line moving horizontally across the equatorial charts is called the *ecliptic*. The ecliptic is the apparent path of the Sun through the sky over the course of one year. The dates along the ecliptic mark the dates the Sun is between the Earth and that point in the sky. For instance, locate November 20th along the ecliptic. On this date, the equatorial coordinates of the Sun are approximately RA 15h 38m DEC -20° 30'. The dates along the ecliptic are only used for locating the position of the Sun.

The dates along the top of the equatorial charts are used to find the stars that lie along the *meridian* for a given day at 8:00 P.M. local standard time. The *meridian* is an imaginary, stationary line that moves from the north celestial pole to the south celestial pole through the *zenith* (whatever is directly above you). It divides the sky into east and west. If you stand so that you're facing either due south or due north, you're facing the meridian.



The meridian is a helpful for locating constellations in the sky. For instance, locate today's date along the top of the chart. Note that you will have to approximate the location of the date if you cannot find the exact date printed. Generally, each tick mark between the date marks is one day. Once you've established the date, imagine a line drawn from the date to the right ascension mark at the bottom of the chart. The stars on the chart that fall on this line represent the stars that are in the middle of the sky (on the meridian) for that date at 8 P.M. local time. This is why the phrase "Local Meridian for 8 PM" is printed at the top of the chart.

The star charts are unaware of daylight savings time (DST). They assume that all "local time" is in reference to local standard time. If your location is observing daylight savings time when using the charts, you must locate the right ascension for 8 P.M. and subtract one hour.

Example: On August 21st, the stars that lie along the meridian at 8 P.M. are those at $RA=18h$ according to the chart. If daylight savings time is being observed, the stars that lie along the meridian are really those at $RA = 17h$ at 8 P.M. local time.

It's also good to know how much of the sky you should be able to see at any given time during the night and which constellations are visible. Consider that half of the Earth is in darkness and the other half is in sunlight. There are 24 hours of right ascension and half of 24 is 12. So, you can theoretically see about 12 hours of right ascension at any given time during the night. Since the meridian divides east and west, you can see 6 hours of right ascension to the left (east) of the meridian and 6 hours of right ascension to the right (west) of the meridian. Of course, this assumes that you do not have buildings, trees, mountains, etc. blocking your horizon.

Another point-of-reference previously mentioned is the zenith. The zenith is the point in the sky that is directly overhead. If you know what should be overhead before you go outside to stargaze, finding constellations will be much easier. You can locate the zenith on the star chart by intersecting the current right ascension at the meridian with a declination equivalent to your latitude on Earth.

Example: The City of College Station is at approximately $+30.5^\circ$ (north) latitude on the Earth. Let's assume that today's date is August 30th. During the month of August, College Station is under daylight savings time; so, we must remember to take that into account. First, locate the position of stars along the meridian for this date. I will estimate this to be around $RA\ 18h\ 30m$. Then, one hour of right ascension is subtracted due to daylight savings time, which means the stars at $RA\ 17h\ 30m$ are really those at the meridian for this date at 8 P.M.

Now, locate along the right (or left) edge of the star chart, $DEC\ +30.5^\circ$, since that is my latitude on Earth. Now, imagine where a line drawn vertically from the right ascension for this date would intersect a line drawn horizontally from the declination for this latitude. Your zenith for August 30th at 8 p.m. is the intersection of these lines. At 8 P.M. on August 30th, the constellation Hercules would be nearest the zenith.

Unfortunately, it is still daylight at 8 P.M. on August 30th in College Station. So, how would you know what would be at your meridian or zenith if it were 10 P.M.? Since east is to the left of the meridian on the equatorial charts and stars rise in the east, add one hour of right ascension for every hour after 8 P.M.. Therefore, at 10 P.M. on August 30th the right ascension at the meridian would be $19h\ 30m$. Now, count six hours of right ascension to the left and six hours to the right of the meridian. The constellations falling within this twelve hour span of right ascension will be visible in the sky at 10 P.M.

From our perspective in northern latitudes, some stars near the north celestial pole never fall below the horizon (set). These stars are known as *circumpolar* stars. Can you determine which stars are circumpolar without going outside?

Transit

An object is said to *transit* when it crosses the meridian plane from the observer's position. Transit also means reaching *upper culmination*. Transit can also be used in reference to other events. For instance, when the Great Red Spot on Jupiter crosses the middle of the planet from our perspective, it is said to "transit". Another example is an extra-solar transit. This is when a planet of another star crosses the disk of the star from our perspective. In this case, transit generally refers to the entire event much like when one of Jupiter's moons crosses the planet's disk from our perspective.

Local Sidereal Time

Sidereal time is based on the "fixed" positions of the stars relative to Earth's rotation. As the Earth rotates, the stars appear to move across the sky much like the hour hand on a clock rotates to keep pace with the mean solar day. Right ascension is expressed in hours, minutes and seconds and is both position and time. The *local sidereal time* (LST) is the right ascension that lies along the meridian from the observer's geographic longitude at that instant. The dates along the top of the star charts reference local sidereal time.

Hour Angle

The *hour angle* (HA) is measured westward from the meridian and is a component of the equatorial coordinate system. It is a means of measuring the time that has elapsed since an object last transited when observed from Greenwich, England. The *local hour angle* (LHA) is the measurement from the observer's geographic position, which is what we are interested in knowing. LHA can be expressed mathematically as *LST minus the right ascension of the object*.

The LHA can be expressed in either degrees or time depending on need. Recall that each hour of RA is equal to 15 degrees. Therefore, if you want to express LHA in degrees, you must ensure that both LST and RA are converted appropriately. When measured in degrees, LHA yields the position of the object on the celestial sphere measured westward from the meridian.

1. $LHA = LST - RA$
2. IF $(LHA < 0)$ { $LHA = LHA + 24$ }
- 3a. Next Transit = $24 - LHA$
- OR -
- 3b. IF $(LHA > 12)$ { $LHA = LHA - 24$ }

Step #1: This is the initial calculation for the local hour angle.

Step #2: This is the corrective step to unambiguously determine how much time has elapsed since the object's last transit.

Step #3a (optional): This step will yield how much time must elapse before the object will transit again.

It should be noted that according to many references, a (-) negative value resulting from Step #1 represents the time until the next transit. However, this is somewhat ambiguous. For instance, if $LST = 0h$, all values for LHA will be negative regardless of where they are on the celestial sphere. If $LST = 23h$, almost all eastward (object is rising) values will be (+) positive and represent the time since the last transit. Step #2 corrects this to the time since the last transit and Step #3a inverts it to the time until the next transit.

Step #3b (optional): In order to keep with tradition and display a value as (-) negative for rising objects and (+) positive for setting objects, use this equation instead of Step #3a. An object with a $LHA = -6$ is on the eastern horizon; $LHA = 0$ is on the meridian; and $LHA = +6$ is setting on the western horizon.

Example: *Determining the local hour angle can give us an idea of when an object will rise above the horizon. M42 (Great Nebula in Orion) is located at RA 05h 35m 17s. As a matter of convenience for this example, round that up to RA = 6h. What time will M42 rise above the horizon on August 21st if you are observing from College Station, TX?*

1. Using your star charts, determine the LST at 8:00 P.M. on August 21st correcting for Daylight Savings Time (DST).

LST on August 21st @ 8 P.M. = $18h - 1h = 17h$

2. Determine the LHA.

LHA = $17h - 6h = 11h$ (This is how much time has elapsed since M42's last transit.)

3. Determine how much time will elapse before the next transit.

NextTransit = $24h - 11h = 13h$

4. The next transit will occur at 8 P.M. + 13h = 9:00 A.M. the next morning.

5. Subtract 6h from the previous step to determine when M42 will be on the eastern horizon. 9:00 A.M. - 6h = 3:00 A.M. Therefore, M42 will begin rising above the horizon at approximately 3:00 A.M. the morning of August 22nd.

Stellar Magnitudes

On both charts 1 & 4, in the lower right-hand corner, are a series of black dots representing stars with numbers next to them. This is the magnitude scale for all of the charts. The larger the dot, the brighter the star is in the sky. The brighter the star, the lower the number such that a 1st magnitude star is brighter than a 5th magnitude star. A 1st magnitude star is 2.512 times brighter than a 2nd magnitude star. A 1st magnitude star is 100 times brighter than a 6th magnitude star. An experienced observer, under good seeing conditions, can detect stars as faint as 6th magnitude. There are three primary types of magnitude: *apparent*, *visual*, *absolute*. Apparent magnitude (m) is a measure of brightness as observed from Earth. It can be a physical measurement or a subjective measurement. Visual magnitude is measured in the visible part of the spectrum (the part of the spectrum we can see with our eyes) usually centered around 550 nanometers (5500 angstrom). Typically, star charts and atlases and planetarium computer applications are based on visual magnitudes. Absolute magnitude is the apparent magnitude an object would have if it were 10 *parsecs* from Earth. One parsec is equal to about 3.26 light years. This allows astronomers to compare the relative brightness of stars and other objects. For instance, the Sun has an apparent magnitude of -26 because it is so close to us. However, its absolute magnitude is about 4.

Converting Sexagesimal Coordinates to Decimal Values

RA to Decimal = hours + (minutes / 60) + (seconds / 3600)

If you need to represent RA in degrees rather than time, multiply RA by 15.

DEC to Decimal = sign * (|degrees| + (arc-minutes / 60) + (arc-seconds / 3600))

Equinoxes and Solstices

The intersections of the ecliptic with celestial equator marks the *equinoxes*. At 0h is the *vernal equinox* and at 12h is the *autumnal equinox*. If you live in the northern hemisphere, the vernal equinox marks the transition to the summer months and the autumnal equinox marks the transition to the winter months. The highest and lowest declinations of the Sun are the *solstices*. When the Sun reaches a declination of +23.5°, it has reached the *summer solstice*. The *winter solstice* occurs when it reaches -23.5°. On the Earth, the area between the latitudes that correspond to the solstices is known as the tropics.