Celestial Coordinates I

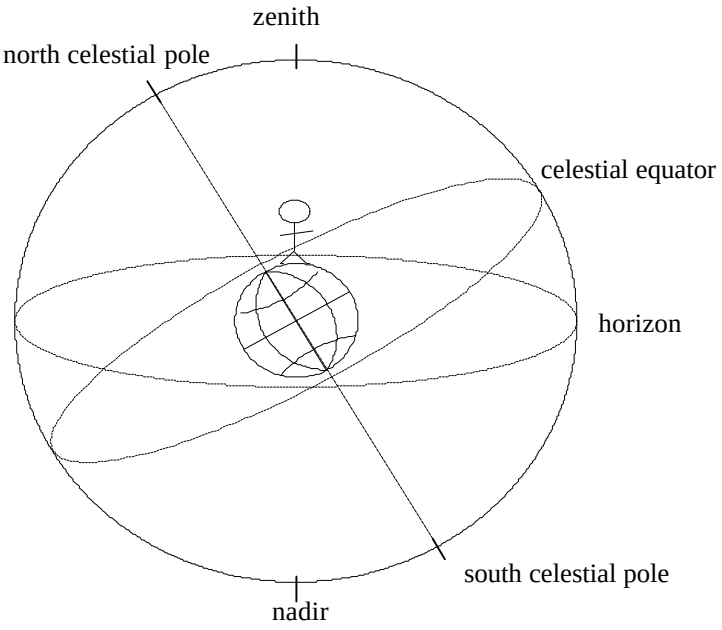
Equipment: Star Charts, Planisphere.

Objective: To become acquainted with basic navigation of the night sky.

Discussion: From our vantage point on Earth, the night sky has the appearance of the inside of a large sphere or bowl with us at the center of it. Astronomers need to be able to reference certain stars and patches of sky in order to quickly locate objects of interest. A traditional method of doing this is to identify groups of stars known as *asterisms* or *constellations,* i.e., patterns of stars that resemble familiar objects. An early astronomer might have given directions to an object by referencing a certain area of a constellation, the belt of the hunter Orion, for example. While this system works well for objects that can be seen with the unaided eye, *deep sky objects* (those too faint to be seen without a telescope) require a more exacting system of location.

Since the sky appears as a sphere surrounding us, it is natural to use the inside of a globe to represent the heavens just as we use the outside of a globe to represent the surface of the earth. If we wish to locate a point on the globe representing the earth, Pocatello or Idaho Falls for instance, we do so using a grid system known as *latitude* and *longitude* (in this case 42^0 52' N, 112^0 27' W for Pocatello and 43^0 29' N, 112^0 02' W for Idaho Falls). A similar system is applied to the sky.

In this exercise you will be introduced to the celestial globe. You will also learn to use *planispheres* and *star charts*. These are projections of the celestial globe onto flat surfaces (in the same manner as a map of the United States is a projection of a portion of a globe onto a flat surface). Anyone who is familiar with maps should also be familiar with the difficulties of projecting spherical objects onto flat surfaces. The result is some unavoidable distortion. But just as maps of the earth are widely accepted due to their ease of transport, maps of the heavens are widely used among astronomers.



The Celestial Globe

Zenith The point straight above you

Nadir The point straight below you

Horizon Basically 90 degrees below the zenith. The horizon is defined as the lowest point one can see in the sky because of trees, mountains, buildings, etc.

Meridian A line that goes through the northernmost point on the horizon, through the zenith, and through the southernmost point on the horizon. The meridian divides the sky into eastern and western halves.

Ecliptic The path through the sky that the sun and planets appear to follow.

Solstice The two points at which the celestial equator and the ecliptic are most widely separated.

Equinox The two points at which the celestial equator and the ecliptic cross.

Equatorial Coordinates

North Celestial Pole This is a point in the sky directly above the north pole on the earth. Since the earth rotates about an axis through the poles, the stars appear to revolve about the north celestial pole in the northern hemisphere.

South Celestial Pole The point straight above the south pole of the earth.

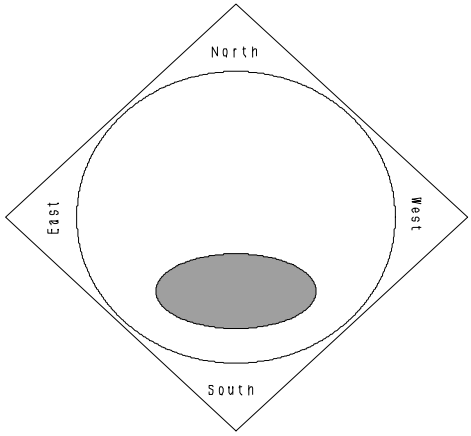
Celestial Equator This is a line in the sky directly above the equator in the earth. If you were to extend a plane through the earth's equator it would intersect the sky at the celestial equator.

Right Ascension Analogous to *longitude* on the earth, i.e, the long lines or *meridians* that pass through the north and south poles (great arcs). Right Ascension (RA) is obtained by projecting these lines of longitude into the sky. Unlike longitude, which measures displacement from the meridian that runs through Greenwich, England, RA gives the displacement eastward along the celestial equator from a reference point in the sky known as the vernal equinox, the point at which the ecliptic crosses the celestial equator. Right ascension is measured in hours and minutes.

Declination This is analogous to latitude on the earth, i.e., the horizontal lines on the globe. Declination is a measure of how far an object is above or below the Celestial Equator. Declination (DEC) is measured in degrees.

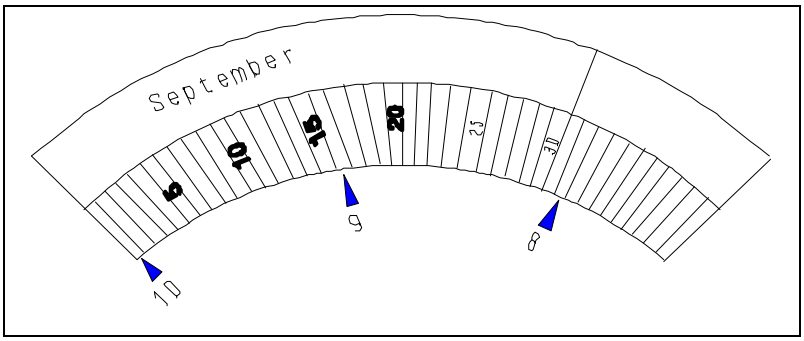
With this introduction to the celestial globe you should be ready to begin exploring projections of the sky onto flat maps.

Planispheres



The planisphere is an extremely useful aid for finding stars and constellation in the sky. If used properly, it will allow one to find not only what is currently in the sky but will even allow one to predict rising and setting times of various objects. Stars are depicted by circles with increasing brightness represented by increasing diameter. Constellation names are capitalized. Star names begin with a capital letter. Hold the planisphere so that the blue oval containing the sky is facing towards you. Orient it so that north is up and the blue sky oval is at the lower center of the device.

Setting the Date and Time



The outer rim of the planisphere disk has calendar dates along it. Find the current date and match it with the current time on the planisphere body.

A protocol must be observed in order to obtain reasonable accuracy on the planisphere. First, only standard times should be used. If daylight savings is in effect (April through October), you must subtract an hour when using the planisphere. Second, you must correct for your longitude. To do this you need to know your longitude (L) and the longitude of the meridian of your time zone (L_{tz}). The correction may then be made as follows:

$$Correction = \frac{(L_{tz} - L)}{15} hours$$

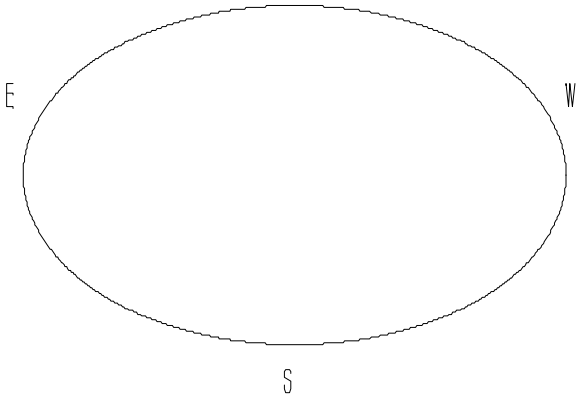
Example: For Pocatello, Idaho Falls, Blackfoot, etc., the longitude is about $112^0.5$ W. The central meridian for mountain standard time is near Denver Colorado and is $105^0.0$ W. The correction for eastern Idaho is therefore:

$$Correction = \frac{(105 - 112.5)}{15} = -0.5 hours$$

So for more accuracy one would subtract 30 minutes from mountain standard time for observations in the eastern Idaho area.

Let's set the planisphere for midnight on September 15th in eastern Idaho. Daylight savings time is in effect so we must adjust midnight to local standard time, i.e., 11 p.m. Next we must apply the longitude correction for eastern Idaho. We have already computed this to be minus 30 minutes. The time we should set on the planisphere is therefore 10:30 p.m. Set the line for 10:30 p.m. so that it lines up with the line for September 15. The stars in the oval will now be the ones in the real sky for 12 a.m. local daylight savings time.

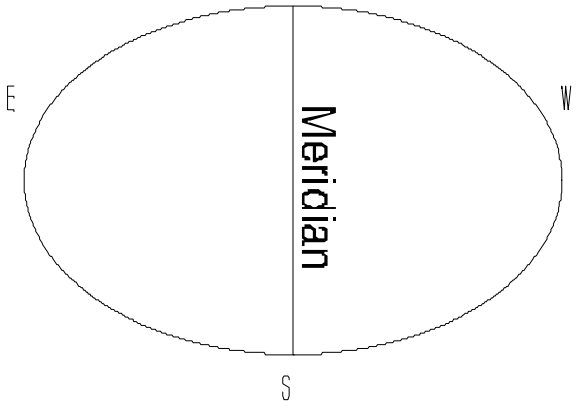
The Horizon on the Planisphere



The perimeter of the sky oval represents the horizon. The upper part of the oval is the northern horizon, the lower part is the southern horizon, To the right and up a little is the western horizon, and to the left and up a little is the eastern horizon.

Example: What stars are rising in the east at 12 a.m. on September 15th in the sky above eastern Idaho? Looking to the left side of the sky oval, we see the constellations of Cetus, Taurus, and Auriga. Note that a small star cluster called the Pleiades is low in the east at that time.

The Meridian on the Planisphere



The meridian can be represented on the planisphere by an imaginary line running vertically through the sky oval and cutting it in half.

Example: Which constellations are near the meridian on September 15th at midnight in the sky above eastern Idaho? From north to south they are: Ursa Major, Ursa Minor, Cepheus, Lacerta, Pegasus, Aquarius and Piscis Austrinus.

Holding the Planisphere Against the Night Sky

If you were to lay on your back with your head pointed north, the stars near the center of the sky oval will be straight above you. In this orientation the planisphere is a miniature map of what lies above.

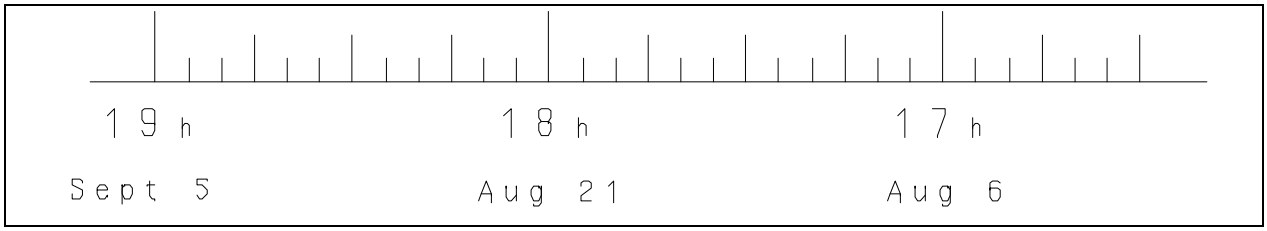
Star Charts

Because of the difficulty in projecting the spherical sky onto a flat map, there are two separate star charts used to cover the stars seen from southeastern Idaho. One is for the stars near the north celestial pole. The other chart is for the stars near the celestial equator. There are charts for the stars below the southern horizon as well, but since we cannot observe them from this latitude we shall not concern ourselves with these charts.

These charts don't have a horizon on them to help you know what is up at a given time, so more skill is required to interpret them. They are, however, quite useful for learning the spatial relationships between the constellations.

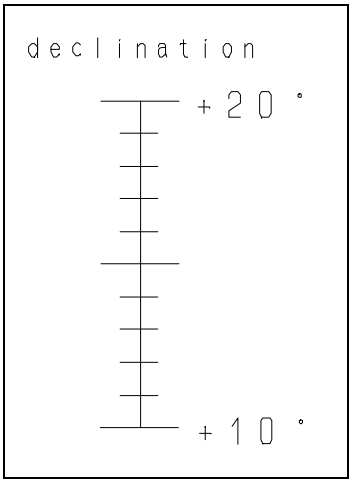
Orienting the Star Chart

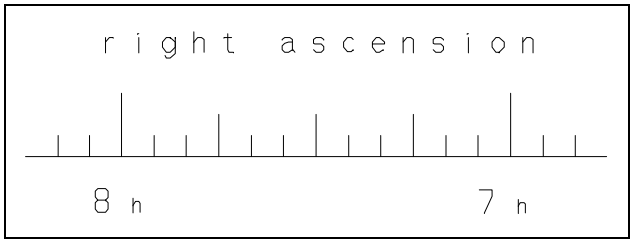
At the bottom of the equatorial star chart in very small letters are a series of dates. These represent the date at which the stars above on the chart are at the meridian at 9 p.m. (standard time) in the evening.



Find the current date, then face south and hold the star chart above your head. The constellations above the current date should be very near the meridian, those to the left of the date should be in the eastern sky and those to the right should be in the west at about 9 p.m. The stars near the current date and near $+40^0$ on the chart should be almost straight above you in the night sky.

This is probably the first time that you have seen stars mapped out with explicit right ascension and declination values marked on a map. Along the top and bottom of the chart there are hours of right ascension (e.g., 3^h or 16^h). Along the left, middle and right parts of the chart you will find degrees of declination. These are written as $+30^0$ or -10^0, etc. With these coordinates one may locate where any galaxy, nebula, or star would be on this map.





Example: Identify the very bright star to the south and east of the constellation of Orion. Orion is located at approximately 5 hours and 30 minutes of right ascension (5^h 30^m RA) and -9^0 declination (-9^0 DEC). Locate Orion on the star chart, then look south and east for a bright star (larger diameter circle). The star you are looking for is Sirius which is in the constellation of Canis Major. Note that east and west on a star chart are opposite of east and west on a map of the earth. On a star chart, east is left.

Example: Rigel is a bright star in the SW corner of Orion. What is its right ascension and declination? From the star chart one finds that Rigel is near 5^h 15^m RA and approximately -8^0 DEC.

Exercises

1. If the sun is in the constellation of Libra, what month is it?

2. What type of star is β Perseus?

3. What constellations are setting in the west on the evening of July 4th at about 10 p.m?

4. Which star is the sun near on October 19th?

5. What constellation is near $20^h\ 45^m$ RA and $+15^0$ DEC? What is the brightest star near this location?

6. What time of the year will you find Orion on the meridian around 9 p.m. in the evening?

7. What does the solid line on the Star and Planet locator represent?

8. On September 1st at about 9:30 p.m., which star would you expect to find near your zenith?

9. Set the planisphere for December 24th, 8 p.m. What constellations are near the meridian?

10. What is a great arc?

11. What does the dashed line on the Star and Planet locator represent?

12. What are the dates of the vernal equinox, the autumnal equinox, winter solstice, summer solstice?

13. What constellation is near the zenith at midnight on the date of the vernal equinox.

14. What is the magnitude of the star Fomalhaut?