

INSIDE LAB 1: Celestial Motions and the Celestial Sphere

OBJECT: To learn how to find objects in the sky and become familiar with some of the motions of the stars, Sun, Moon and planets as seen from the surface of the Earth.

DISCUSSION:

From our point of view on the Earth, it appears as if all celestial objects are attached to a giant sphere, which we call the *celestial sphere*. This fictitious sphere appears to rotate around the Earth once every sidereal day. The Sun, Moon and planets appear to move with respect to the stars on the celestial sphere. Over a human lifetime, the stars (at least to the naked eye observer) appear to be fixed in place on the celestial sphere. However, over longer periods they move around, in part due to a phenomenon called precession.

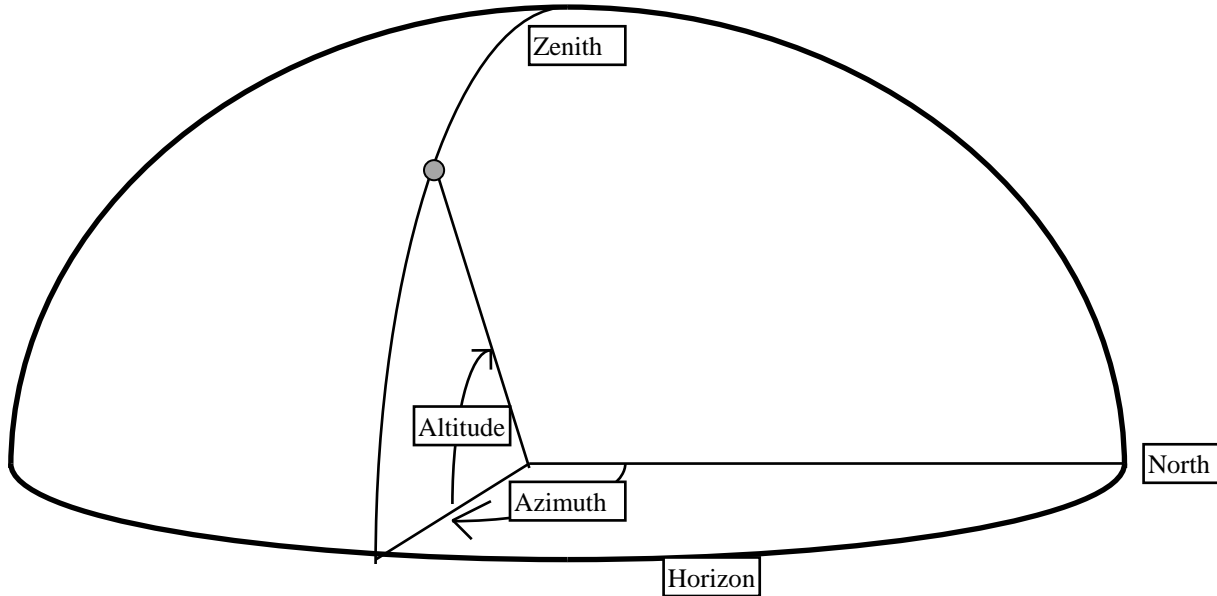
A *constellation* is a region of the sky characterized by a recognized grouping of stars. Each region of the sky is blocked off in right-angled sections and is called by the name of the constellation which dominates the section. There are 88 constellations. Forty-eight were recognized by the ancient Greeks, and forty more were added after the southern skies were observed during the age of discovery by Western Europeans.

Bright stars carry two names, one given to them by the ancients and the other the modern designation, which is determined by their visual brightness and the constellation in which they are found. The ancient name is usually Arabic in origin. For example, in the constellation *Orion*, the two brightest stars are *Betelgeuse* and *Rigel*. The first derives from the Arabic through French and means "the armpit of the giant". The second means "foot."

The modern designation of stars labels the brightest stars in a given constellation with the letters of the Greek alphabet, α usually representing the brightest star, β the next brightest, and so on. (However, there are many instances in which this convention is not strictly followed.) The letter name is followed by the Latin genitive form of the name of the constellation. Thus Betelgeuse is called α -Orionis (Alpha Orionis) and Rigel is called β -Orionis (Beta Orionis).

Unlike the stars, the Sun does not appear to be fixed on the celestial sphere. It appears to move generally eastward among the stars on a great circular path, called the *ecliptic*, making one revolution of the celestial sphere, from vernal equinox to vernal equinox, in one tropical year of 365.25 days. The ecliptic intersects the celestial equator at two points, called the *vernal* and *autumnal equinoxes*. (These names apply to points on the sphere as well as to times of the year.) The angle between the ecliptic and the equator, called the *inclination of the ecliptic*, is approximately 23.5° . Thus, half the ecliptic is to the north of the celestial equator, and half is to the south. The northernmost point of the ecliptic, called the *summer solstice*, is the position of the Sun on the first day of summer (in the northern hemisphere of the earth). The southernmost point, the *winter solstice*, is the position of the Sun on the first day of winter. The Sun arrives at the vernal equinox around March 22, the summer solstice around June 22, the autumnal equinox around September 22, and the winter solstice around December 22.

There are several coordinate systems in use in astronomy by which we locate the positions of heavenly bodies. The two most important ones for our purposes are the *horizon system* and the *equatorial system*. The horizon system, locates these bodies relative to the celestial horizon and the direction of north. The equatorial system, locates them relative to the celestial equator and the vernal equinox.



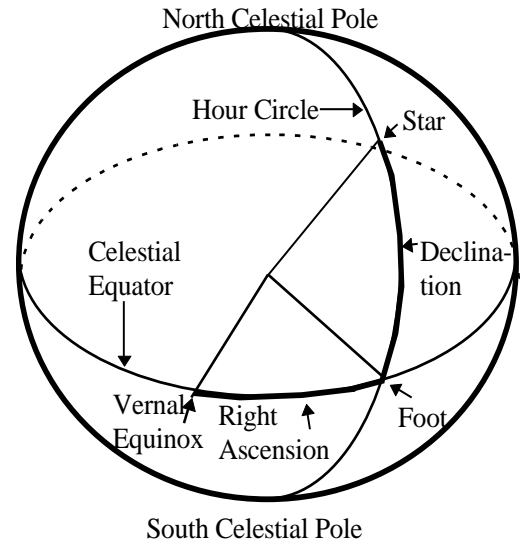
The horizon system measures the position a celestial object is at in the sky at a given time. This is done by using the coordinates altitude and azimuth. If an object is straight overhead its altitude is 90° and it is said to be at the *zenith*. Altitudes are measured by drawing a great circle (a circle centered at the center of the Earth) which intersects both the object and the zenith. The altitude is the angular distance along the circle from the horizon to the object. The azimuth is the angle measured along the horizon clockwise from due North to the point at which the great circle intersects the horizon. Thus altitude goes from 0° on the horizon to 90° at the zenith while azimuth goes from 0° at North to 360° which is again North. The direction East is 90° , South is 180° , etc.

Because of the Earth's rotation, the position of celestial objects in the sky is constantly changing. Thus it is useful to have a coordinate system which allows us to determine the location of the stars and planets with respect to each other. One very useful system is the equatorial system which is used by observatories around the world. It is based on a system identical to the latitude and longitude coordinate system that is used on the Earth. However this system is used on the celestial sphere.

The system is as follows: Just as the earth is girded by an equator, so also do we define a *celestial equator* girding the celestial sphere. This great circle lies on the celestial sphere directly over the equator of the earth. There is a point on the celestial equator, called the *vernal equinox*, at which the Sun is found on the first day of spring. The vernal equinox is the origin of coordinates in the equatorial system. The celestial equator has poles, just as does the equator of the earth. The *north celestial pole* is the point on the sphere which lies directly over the north pole of the earth, and the *south celestial pole* is the point on the sphere which lies directly over the south pole of the earth.

In order to locate a point on the celestial sphere, we first imagine drawing a great circle from pole to pole through the point. Such a circle is called an *hour circle*. This hour circle intersects the celestial equator at a point called the *foot* of the hour circle. We measure the angular distance eastward from the vernal equinox along the celestial equator to the foot of the hour circle through the point. This eastward angular position is called the *right ascension* of the point. Next we measure the angular separation of the point from the celestial equator along the hour circle through the point. This angle is called the *declination* of the point. It is the angular distance of the point north or south of the celestial equator.

Declination is measured in *degrees*, and is positive if the star is to the north of the celestial equator, and negative if to the south. Right ascension, however, is measured in *hours, minutes, and seconds*, where 24 hours is equivalent to 360°. That is, 1 hr equals 15°. For example, a star whose right ascension is 4 hr is at an angle of 60° to the east of the vernal equinox.



EXERCISE 1:

It is apparently a common misconception that the extra warmth that one gets from sunlight in the summer is due to that part of the Earth being closer to the Sun than the part which is experiencing winter. This is not true because the relative difference in distance between each hemisphere and the Sun is negligible compared to the distance that each is away from the Sun. One reason that it is warmer in the summer is that the Sun is higher in the sky at noon and thus shines more directly upon the Earth's surface than it does in the winter at noon when it is lower in the sky. A second reason is that the Sun is above the horizon longer in the summer than in the winter.

To demonstrate for yourself that direct light produces more heat than light that is more spread out go up to the lamp which in the front of the room. Your TA will show you how to hold your hand close to it in such a way that the light shines directly on the center of your hand. Then tilt your hand so the distance from its center to the light doesn't change but so that the angle between the light rays is no longer perpendicular to your hand. Concentrate only on the center of your hand, not your fingers or the part near your wrist and see what happens to the temperature of the center as you tilt your hand.

Briefly describe what you experienced in this simple experiment. How does it relate to the heating of the Earth during the summer and winter?

EXERCISE 2: Examine the celestial sphere which should be on your lab table. Find the north and south celestial poles and the celestial equator.

How are these positions on the celestial sphere defined?

From Winston-Salem can we see the stars near the south celestial pole? If so when can we see them? If not, why can't we see them?

EXERCISE 3: Find the position of the Sun on the celestial sphere today.

What constellation is it in? What is its approximate right ascension and declination?

Name two constellations which you would be able to see outside tonight if it was clear.

EXERCISE 4: Find the position of the Sun on the celestial sphere during the vernal and autumnal equinoxes and the summer and winter solstices. In each case state where on Earth it is directly overhead, what constellations it is in, and what its right ascension and declination are. Also what are two constellations that could be seen from Winston-Salem at night at each of those times?

Starry Night Exercises

First, your Lab TA will help you to load the software onto your computer if necessary.

You are now ready to use the computer program “Starry Night.” Notice the bar running across the top of the window. Toward the left is a section for the Time and Date. To the right of this is a section where you can set the Time Flow Rate. Next is your Viewing Location, followed by the Gaze and the Zoom. These last two indicate which way you are looking and how much of the sky you see. If you click anywhere on the “sky”, you will see information appear in the upper right hand of the window giving the altitude and azimuth for the point on the sky you selected. These coordinates correspond to the position of the “mouse”. By moving the mouse so it is on top of a celestial object and pressing the left mouse button, you can find the location of that object in the. Check to see that the date and time are correct. You can change the direction you are looking in either by using the arrow keys, by “grabbing” the sky and moving it with the mouse, or by typing n, s, e, w, or z for North, South, East, West, or Zenith. You can zoom in by typing +. You can zoom out by typing -.

EXERCISE 5: Find the altitude and azimuth and the right ascension and declination of each of the planets which is currently above the horizon. If you were to go outside right now, what direction (N, SE, etc.) would you have to look to see each planet? How high in the sky would it be (low, medium, etc.)? Determine which constellation each planet is in. [To find these objects more easily, type Ctrl-F, then double click on the name of the planet you want to see. If you place the cursor over the object, it will display a great deal of information. To obtain more information right click on the object and go down to “show info”. To see the names and official borders of each constellation, go to the “View” menu and under “Constellations” select both “Boundaries” and “Labels.”]

EXERCISE 6: Sketch the pattern of stars for each of the following constellations: Ursa Minor, Ursa Major, Cygnus, Scorpius [To see the classic “stick figure” for each constellation, go to the “View” menu and under “Constellations” select “Constellation Options...” and check the box for “Stick Figures.” All of these options can also be set under the “Options” tab to the left of the sky window.]

In your sketches point out the following stars: Polaris, Deneb, Antares.