The Celestial Globe

Laboratory 1

Astronomy 120. The Copernican Revolution

Purpose

To understand the concept of the celestial sphere, to learn how the Sun and stars move as seen from the Earth, and to use a (real or virtual) celestial globe to identify objects visible in the night sky.

The Celestial Globe

The stars we see change with time of day, day of year, and the position on the Earth from which the observations are being made.[1] Using the idea of the Celestial Sphere we can build a model that will take these factors into account in making predictions of what we can see in the night sky. This model is called the Celestial Globe. We will look at both a physical version and a virtual version of the celestial globe. Let's start with the physical version.

The globe consists of four parts: Earth, a small yellow ball representing the Sun, the transparent celestial sphere on which the stars are located, and the horizon ring. Note that the Earth is mounted on a rod about which it is free to rotate. This represents the celestial axis. The ends of the rod are the North and South poles. The sphere itself is marked with grid lines for the equatorial coordinates (RA and Dec). Make sure you can locate any given line of constant Dec or RA.

On the globe near, but not exactly at the North pole is a knob that controls the motion of the Sun. Try rotating this knob and watch the Sun revolve about the Earth. We all know the Sun doesn't revolve about the Earth (or does it? Aristotle thought it did.), but as we view the Sun from Earth, it moves against the starry background. The projection of this motion on the transparent globe is marked by a dashed line. The circle of this line lies in a plane called the *ecliptic plane*. Notice the plane of the ecliptic is not the same as that of the celestial equator.

Notice also that the plane of the orbit of the Sun crosses the celestial equator at two points, as the Sun appears to rotate about the Earth. These two points are called the *equinoxes*, and occur in March and September. This is the point at which the Sun passes directly overhead at noon on the equator, a time at which there are equal amounts of day and night. These are the *Vernal* (Spring) and *Autumnal* equinoxes. The right ascension on the celestial equator is measured eastward from the vernal equinox in hours.

Setting up the Globe

Now, let's set the sphere for our location. The first thing we need to know is where we are. We are located at Rome, Georgia, a spot on the surface of the Earth identified by the coordinates of latitude and longitude as: latitude $34°16'$, longitude $85°10'$.

Now rotate the sphere along the meridian until the angle between the North polar axis of the celestial sphere and the North direction on the horizontal or horizon ring is equal in magnitude to the latitude of Rome. (On the celestial sphere, the meridian is the north-south line through the zenith.) In practice, you should tilt the globe toward the North and make sure that the angular reading at the top of the globe is equal to the latitude of Rome. Now we must rotate the sphere to correspond to our longitude and the time of day. To do this we must take into account the fact

[1] There are a few other things that also affect the appearance of the stars, but these are small effects which we will not consider at this point.

that we set our clocks by reference to the Sun. This is because our sleep patterns are determined by when the daylight occurs, and this depends on the Sun. However, in so doing we have gotten out of synchronization with the celestial sky.

To set the date/time for the stars, look at the date/time values near the North Celestial Pole. Rotate the globe until the time you want is aligned with the date you want. Go ahead and try to set the globe up for right now (ie the current date/time). To get the sun in the right spot you should turn the sun knob until the sun is at the location on the ecliptic that corresponds to the date you want. Once you have the globe set up for right now in Rome, GA, ask your instructor to check your globe before moving on.

Azimuth and Altitude

Imagine a line through the center of the celestial sphere and perpendicular to the plane of the horizon. This line intersects the sphere in two points, the *zenith*, which is directly overhead, and the *nadir*, which is directly below.

The horizon circle is graduated into 360°. The *azimuth* of any point on the globe is determined from the horizon ring. Azimuth is measured from the North point on the horizon ring to the point where a vertical *great circle* through the star and the zenith, meets the horizon. The *altitude* is the angular distance of an object above (or below) the horizon plane defined by the horizon ring. A flexible scale will be needed to measure this angle, since, in general, there are no corresponding graduations on the globe. Now we have a rudimentary understanding of the celestial sphere as far as it is depicted by the celestial globe.

The Virtual Celestial Globe

Since you won't be able to take these physical globes home with you, you may want to make use of a virtual version. Run the EJS Celestial Globe program. One window displays a celestial globe much like the physical one we have just discussed. A small control window can be used to set the time of day and time of year for this globe, as well as adjust the latitude of the observer. Another window shows the sky as seen by the observer looking straight up. Take some time to make sure you see how this virtual globe relates to the physical one, then answer the questions below.

- The cyan line in the celestial globe represents the ____.
- The green disk represents the ____.
- The magenta (purple) disk represents the ____.
- The red disk represents the ____.

The Celestial Globe Worksheet

Answer the questions below. For most of these questions you will need to use the physical celestial globe, but feel free to use the virtual celestial globe any time you want/need to.

1. Locate the Sun for December 22 and rotate the Sun until it is just rising in the East (When it is appearing in the upper hemisphere of the globe on the eastern side). How many hours of daylight do you have on this date? In other words, what is the length of day on
   (a) December 22? ________________________
   (b) March 21? ________________________
   (c) September 21? ________________________
   (d) June 21? ________________________
2. What stars have the following coordinates?
   (a) R.A. $20^{\mathrm{h}}40^{\mathrm{m}}$, Dec. $+45°10'$ ________________________
   (b) R.A. $06^{\mathrm{h}}24^{\mathrm{m}}$, Dec. $-52°42'$ ________________________
   (c) R.A. $04^{\mathrm{h}}34^{\mathrm{m}}$, Dec. $+16°27'$ ________________________
3. Find the right ascension and declination of Vega (α Lyrae, the brightest star in the constellation Lyra).
   (a) R.A. = ________________________
   (b) Dec. = ________________________
4. On May 21, what is the
   R.A. of the Sun? ________________________
   Dec. of the Sun? ________________________
5. (a) On October 21 at latitude 40° N at 7:00 PM, which bright star in Taurus is about to rise? ________________________
   (b) At approximately what point on the horizon (degrees azimuth) will it rise?
   ____
6. Estimate the right ascension of and declination of the Large Magellanic cloud (LMC) near the south celestial pole.
   R.A. = ____________
   Dec. = ____________
7. What is the declination of the sun
   (a) At the summer solstice ____________
   (b) At the winter solstice ____________
   (c) At the vernal equinox ____________
   (d) At the autumnal equinox ____________

8. What would be the meridian (maximum) altitude of the Sun for an observer at Rome
   (a) at the time of the summer solstice? ___________________
   (b) at the time of the winter solstice? ___________________
   (c) at the the times of the equinoxes? ___________________
9. In what constellation is the Sun found:
   (a) in April? ___________________
   (b) in November? ___________________
10. For a Rome observer, at which point on the horizon (degrees azimuth) does the Sun rise
    (a) at the time of the vernal equinox? ___________________
    (b) at the summer solstice? ___________________
    (c) at the autumnal equinox? ___________________
    (d) at the winter solstice? ___________________
11. For an observer at the North geographic pole on what dates would the Sun appear to stay on the horizon all day long neither rising nor setting?
    _______________________________________ and _______________________________________
12. Between what two dates will the sun stay above the horizon all day long for the North pole observer?
    _______________________________________ to _______________________________________
13. From some locations certain stars can never be seen because they are always below the horizon. Other stars can be seen at any time because they are always above the horizon. Which stars are always above, or always below, depends on the latitude of the observer and the declination of the stars. For each location listed below, give the range of declinations for stars that are always above, and stars that are always below, the horizon.
    (a) The north geographic pole?
        always above the horizon: ___________________
        always below the horizon: ___________________
    (b) A point on the equator?
        always above the horizon: ___________________
        always below the horizon: ___________________
    (c) Rome, Georgia?
        always above the horizon: ___________________
        always below the horizon: ___________________
    (d) Buenos Aires (lat 35°S)?
        always above the horizon: ___________________
        always below the horizon: ___________________
14. In what range of latitudes would an observer need to be for the LMC to be above the horizon at all times? ___________________ to ___________________
15. Is there anywhere on Earth where you would expect to see all stars at some time during the year? ___________________
    If so, where? _______________________________________