EVOLUTION OF SCIENTIFIC THOUGHT
LABORATORY I
THE TWO SPHERE UNIVERSE

In this experiment we will become familiar with the "two sphere universe," a concept first introduced by the ancient Greeks. The claim, which we will investigate, is that this model explains most common celestial phenomena very well indeed—the Navy still uses it to teach navigation! We will also learn how to use a contemporary star chart.

Use the following list as a guide as you examine our models of the celestial sphere. Record your observations in your laboratory notebooks as you make them. Your notebooks should be fairly detailed—include enough so that someone else could understand what you are saying, or so that you could understand it yourself if you look back at your notebook in six months! Be sure to raise questions if there is anything you don't understand.

1. Examine the (model) universe! Identify the earth and the celestial sphere; note that the North and South celestial Poles are directly over the earth's poles, and that the celestial equator is concentric with the earth's equator. Be sure that you can adjust the horizon. Initially, adjust the horizon to its appropriate location for central Minnesota.

2. Find the ecliptic (path of the sun) on the celestial sphere. Look at the zodiacal constellations, and see how the sun moves through them over the course of the year. Pick out the position that the sun will have at the summer and winter solstices, and at the fall and spring equinoxes.

3. Set the horizon for central Minnesota, and set the sun to its position for the summer solstice. Where on the horizon does the sun rise and set? Repeat this part for the winter solstice, and for the equinoxes.

4. You have probably noted the long summer twilight periods we have in Minnesota. If you have traveled to the north or south of here, you may have noticed that summer twilight periods are longer the farther north you go. They become quite short as you get close to the equator.

   By adjusting the horizon for positions north and south of us, see if you can explain these observations.

   HINT: This question can be a little tricky. Look, for example, at the angle the sun makes with the horizon at different times of the year, and at how far the sun goes below the horizon.

5. Set the horizon as it would be for someone at the North Pole, and confirm that for part of the year the sun will never rise, and for part of the year it will never set. How would the sun seem to move through the sky during one of the days on which it never sets.

6. We will need to learn how to specify the positions of stars and planets on the celestial sphere. The set of coordinates we use to map the celestial sphere is very similar to the terrestrial latitude and longitude we use on earth. Remember that the North and South Celestial poles are directly above the earth's poles, and that the celestial equator is concentric with the earth's equator. We make the following identifications:

   - We use **declination** instead of latitude, and + or − instead of N or S. Thus, the celestial equator is at 0° declination, and (for example) the declination of the star Betelgeuse in the constellation Orion is $+7^\circ\ 24'$. The "+" means Betelgeuse is north of the celestial equator.

     Remember that 1 degree $= 60'$ (minutes), and $1' = 60''$ (seconds). We can if we wish use decimal degrees instead of degrees, minutes, and seconds; thus $+7^\circ\ 24' = 7\frac{24}{60}^\circ = 7.4^\circ$. Today astronomers use both, more or less interchangeably. Note, however, that decimal degrees were *not* used either by the ancient Greeks or by the "early modern" astronomers we are studying in this course.

   - We use **right ascension** instead of longitude, and it is customary to measure right ascension in hours instead of degrees. (One full circle corresponds to 24h or 360°; Thus, one hour of right ascension corresponds to 360/24 or 15°.)

     Just as 0° Longitude is taken by convention as the meridian that passes through Greenwich, England, so we take it as a convention that 0h RA is the meridian that passes through the Spring Equinox, which is the one of the two points on the celestial sphere where the ecliptic and the equator intersect. Note that this convention implies that right ascension and declination are defined with respect to the seasons, and *not* with respect to the "fixed stars;" hence the coordinates of a given star will change slowly over time. Most tables of star coordinates will list the year (or "epoch") for which the positions given in the table are valid. Of course, over short periods the corrections required by precession are small, and the differences between, say, epoch 1950 and epoch 2000 will be very small.

   Pick a few stars on the celestial sphere and see how closely you can identify their coordinates. Then, set the sun to its approximate position **today**, and estimate its coordinates.

   Historical note: This coordinate system is a modern one—it was not used either by the ancient Greeks or by Copernicus. Instead, astronomers in earlier times used a coordinate system based on the eclipic: The longitude of a planet was measured along the ecliptic, and the latitude was measured north and south of the ecliptic. We will use the modern system as a matter of convenience—all modern star charts use it! But you should be aware that earlier astronomers used a slightly different system.

7. Examine one of the star charts and be sure you see how the chart and the sphere are related—it can sometimes be a little tricky to see the connection.

8. Now try to locate some of the planets. On 1 February 2010, Saturn will be located at 12h 19 m right ascension, $+0°34'$ declination.

   Mars will be located at 8h 50m right ascension, $+22°26'$ declination.

   Jupiter will be located at 22h 21m right ascension, $-11°15'$ declination.

   And Venus will be at 21h 18m right ascension, $-17°6'$ declination.

   Locate these positions on the celestial sphere. Will any of these planets currently be visible in the night sky? in the early morning sky?