The Celestial Sphere

Adapted from `http://www.astro.lsa.umich.edu/Academics/Undergrad/labs.php`

Introduction

Here on Earth we have a coordinate system called latitude and longitude that allow us to pinpoint any location on the globe. Of course, this isn't always useful: giving the latitude and longitude of the grocery store won't help most people find it. Hence we also use local coordinates with instructions like "2.3 miles west of my apartment."

The **equatorial system** is analogous to the latitude and longitude system we use on Earth. To map out these lines, astronomers start by projecting the Earth's north and south poles and the equator onto the sky. Those projections are called the north and south celestial poles and the celestial equator. Lines of Right Ascention (RA) run through the north and south celestial poles, crossing the equator at right angles just like lines of longitude. Lines of declination circle the sky perpendicular to this like latitude lines. In fact, the declination lines match the latitude lines: the celestial equator is at 0° dec, the north celestial pole at +90° or 90° north dec, and the south celestial pole at -90° or 90° south dec. Since Ann Arbor is at a latiude of +42.3° the declination of zenith is +42.3°. Note the fractional degree may be given as a decimal, or in minutes and seconds of arc. There are 60 arcminutes in a degree, 60 arcseconds in an arcminute.

The right ascension is a little harder. On Earth, 0° longitude is measured from Greenwich, England. We set our watches by the motion of the sun (solar time) again using Greenwich as the standard (universal time) so the Sun should transit the meridian at roughly noon every day in Greenwich. We choose the vernal equinox to be our celestial "Greenwich," where RA is equal to zero. We measure RA in hours; that way, your local sidereal time is equal to the RA of an object transiting the meridian. For example, if your local sidereal time is 20:15, a star at 20h 15m 0s RA would be on the meridian. This also makes it convenient to figure out how long an object will remain visible. Coordinates are normally given with RA first, then dec: the summer solstice is located at 6h 0m 0s and 23° 30m.

Just as the latitude and longitude aren't always convenient on Earth, the equatorial system isn't always convenient for astronomers. So there is an alternate: the altitude and azimuth system. The altitude is ideally measured in degrees above the horizon. An object at zenith is at 90°, and object on the horizon is at 0°. (Be careful if you are on a mountaintop or in a valley!) In the field, altitude is usually estimated using your hands for reference. The Moon subtends an angle of 0.5°, which is about the width of your index finger held at arm's length. Three fingers take up about 5°, your fist is about 10°, and if you spread your hand out, from index finger to pinky is about 15° and from thumb to pinky is about 20°. However, in the planetarium we have projected scales we will use.

The azimuth is measured in degrees away from north. The system is the same as the markings on a compass: 90° is due East, 180° is due South, and 270° due West. Coordinates are usually give with altitude first, azimuth second: the position of the Sun on the summer solstice when it transits the meridian is 65.8° at 180°

As you work on this activity try to keep in mind that one of these coordinate systems is "global", completely independant of your location, while the other is "local", totally dependant on your location.

Important Elements of the Celestial Sphere

Your GSI will point out components of the celestial sphere. As she does so, note the following elements: the zenith, the horizon, the celestial north pole, the celestial equator, the ecliptic, and the equinoxes. In your notebook, record some observations regarding these elements. More detailed observations will better help you to answer questions later.

Alt-Az: Altitude and Azimuth

Make a table as follows:

Star Name	Position	Altitude (deg)	Azimuth (deg)

Your GSI will set the planetarium to display the stars tonight at 8 PM and point out a star to watch north of the equator. Record the star's name as well as the altitude and azimuth for position 1 in your table.

Your GSI will move the projector until the star transits the meridian. Record the altitude and azimuth under position 2 for the first star.

Your GSI will again move the planetarium back to 8 PM and point out a star south of the equator to watch. Record its name and the altitude and azimuth for position 1 in your table. Your GSI will move the planetarium again until the second star transits. Record the altitude and azimuth for position 2 for this second star.

Finally, think about how accurate your measurements are. Could you numbers be 1 degree off? 2 degrees? 10? Determine the maximum amount by which your measurement of the position could vary, and record this as your uncertainty.

1. Does the altitude of most of the stars remain constant or change throughout the night? Does the azimuth? Make sure to take the uncertainty in your measurements into account when answering this question.
2. What object(s) has/have (roughly) the same alt-az all the time? What are its coordinates or their range of coordinates?
3. What is the possible range of altitude in degrees in the planetarium (look carefully at the meridian markings!)?
4. What is the possible range of azimuth in degrees in the planetarium?

Equatorial: Right Ascension and Declination

Now you will observe the same 2 stars you did in part 1, but this time measure their Right Ascension and declination. Record your results in a second table:

Star Name	Position	RA (hours)	Dec (deg)

Once again, determine the uncertainty in your measurements.

5. Does the RA of most of the stars remain constant or change throughout the night? Does the dec? Make sure to take the uncertainty in your measurements into account when answering this question.
6. What object(s) has/have (roughly) the same RA and dec all the time?
7. What is the possible range of RA in hours visible from Ann Arbor? Why do we use hours instead of degrees?
8. What is the possible range of dec visible in Ann Arbor?

Thinking Problems

9. What is the altitude and azimuth of Polaris (as viewed from Ann Arbor)? What is its RA and dec?
10. On what date is the longest day in Ann Arbor? In Sydney, Australia? Near Quito, Ecuador?