Prelab for Coordinate Systems

1. Define the 3 major coordinate systems used in astronomy (Complete sentences):

Horizon:

Equatorial:

Ecliptic:

2. What defines the origins (zero points) for these coordinate systems? (CS)

Horizon:

Equatorial:

Ecliptic:

3. Are the coordinate systems static or do they move relative to astronomical objects (stars)?
    Horizon (circle one):   Static   Variable
    Equatorial (circle one):   Static   Variable
    Ecliptic (circle one):   Static   Variable

4. Which is the most natural system to use for the casual observer? Why?
     Hint: Read carefully in your lab script. Use complete sentences.

COORDINATE SYSTEMS

What will you learn in this Lab?

This lab is designed to introduce you to some of the coordinate systems used by astronomers. The coordinate systems to be introduced are Longitude and Latitude, Horizon Coordinate System, Equatorial Coordinate System and the Ecliptic Coordinate System.

What do I need to bring to the Class with me to do this Lab?

For this lab you will need:

- A copy of this lab script
- A pencil
- SC 001/002 star charts
- Audubon Guide
- Star Wheel
- Red Flashlight

Maps of the Earth

As a starting point for finding your way in the night sky, we first review maps of the Earth and how they were established. A coordinate reference frame is essential so that the location of remote places can be identified, such as islands at sea, cities, towns, mountain tops, etc. On the Earth the coordinate system employs **latitude** and **longitude**.

Latitude: is measured in *degrees*, *arcminutes* and *arcseconds*, *north* or *south* of the Earth's Equator. The zero point in latitude is naturally established by how the Earth rotates on its axis. The Earth's Equator is at a latitude of 0º, while the north pole is at a latitude of 90º N = +90º. Similarly, the south pole is at a latitude of 90º S = -90º. Tempe, Arizona is at a latitude of +33º.

Longitude: is measured in *degrees*, *arcminutes* and *arcseconds*, but unlike latitude there is no natural or physical characteristic of the Earth from which to set the zero point in longitude. As a result of global navigation, and what is now history, the British established a zero point in longitude, used primarily by the British Royal Navy (the Office of the Admiralty). The location of the zero point of longitude is in Greenwich, England. The Royal Observatory at Greenwich was established in 1676 for purposes of worldwide navigation.

Longitude and time, measured with clocks on board ships, was established as ships set out to sea on the Thames from London. A ship's navigator checked the time from clocks at the Royal Observatory that could be seen from the Thames. Then at sea the navigator would measure the position of the sun at noon (according to the shipboard clock). The angular amount that the sun was east of the local meridian[1] at noon for a westward moving ship would give a measure of the ship's longitude west of Greenwich.

Historically various countries established their own zero point of longitude, which is given the name: zero meridian.   National observatories were established in Paris, London, Berlin, Leningrad, Madrid, and other major capitols with the purpose of determining longitude. By 1889, through international agreement, most countries adopted the *Greenwich Meridian* as a standard of longitude.

Maps of the Sky: Celestial Coordinates

Horizon Coordinate System: Before introducing the principal celestial coordinate system, it is useful to discuss a more local coordinate system. This coordinate system, *established with natural reference to the observer and his/her location*, has two coordinates both measured in *degrees*, *arcminutes* and *arcseconds*:

Azimuth: Angular distance measured along the horizon from 0° to 360°, measured north through east, just like a clock. For example, an azimuth of 90° corresponds to the east point on the horizon (3 o'clock), while 270° points towards the west point on the horizon (9 o'clock).

Altitude: This coordinate is measured as an angular distance from the horizon toward the point directly overhead, called the *zenith*. Thus the zenith is at an altitude of 90°, whereas the horizon is at an altitude of 0°. Since we cannot use linear dimensions on the sky, all positions must be measured as angles.

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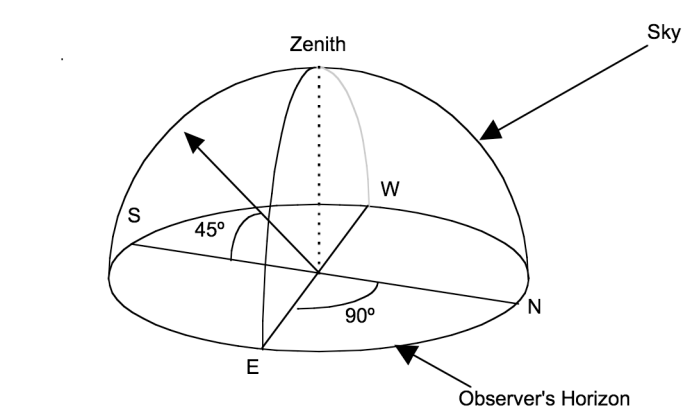
[1] A meridian is a circle on the Earth's surface that has its center at the center of the Earth and passes through the north and south poles.

Unfortunately we cannot use altitude and azimuth coordinates to find the same object in the sky every night. The Earth rotates on its axis and revolves around the Sun and consequently we cannot map positions on the sky as simply as we would map positions on the Earth. Since the Earth gradually orbits around the Sun, the direction that we look out from the Earth into the night sky gradually shifts day by day, changing by about 1° per day, which corresponds to 4 minutes of time. In the course of a year, the Earth moves through 360°. Most of the newly built large telescopes use this system for pointing and fast computers to make sure the telescope moves in the correct direction at the correct rate of motion.

Equatorial Coordinate System: As an extension of our Earth-based coordinate system (latitude and longitude), there is a similar set of coordinates on the sky that has some subtle but significant differences. Corresponding to the Earth's Equator is the **Celestial Equator**, which is simply a projection of the Earth's Equator on the sky. Directly above the Earth's north pole is the **north celestial pole** (NCP), while directly "below" the south pole is the **south celestial pole** (SCP). The celestial coordinates that are analogous to longitude and latitude (on the Earth) are called: **Right Ascension (RA)** and **Declination (Dec)**. **RA** is normally measured in units of time: *hours*, *minutes* and *seconds* of time, whereas **Dec** is measured in *degrees, arcminutes* and *arcseconds*. On the celestial equator one hour of RA corresponds to 15°, thus 4 minutes of time corresponds to 1°. RA is measured in an eastward direction, starting at 0 hrs and going through a full circle to 24 hrs or 360°.
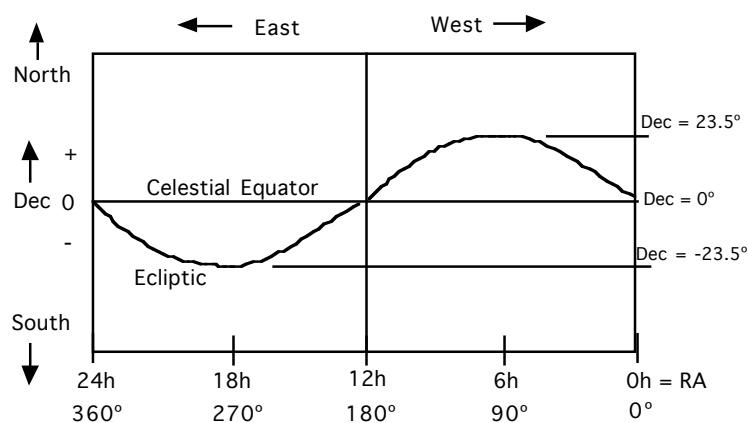

The zero point of RA is established by the point where the Ecliptic[2] crosses the celestial equator. This is the point where the Sun crosses the celestial equator, moving northward. As seen from the Earth, the Sun reaches this position on March 21st. The

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[2] The ecliptic is the apparent path of the Sun, Moon, and planets as seen from the Earth. In another sense, the ecliptic is the path of the Earth's orbit projected onto the sky. The orbits of the Earth and most of the other planets move in a relatively flat plane around the Sun.

direction in the sky at RA=0hr, Dec=0º is called the Vernal Equinox. Since the Earth's axis of rotation is tilted by 23.5° relative to the direction perpendicular to the Earth's orbital plane, the Sun, Moon and planets appear to move north and south of the celestial equator by as much as 23.5º.

Ecliptic Coordinate System: The other celestial coordinate system we will be discussing is the ecliptic coordinate system. Whereas, the equatorial coordinate system was based on the surface of the Earth, the ecliptic coordinate system is based on the orbit of the Earth. The units of the ecliptic coordinate system are degrees and the two coordinates are ecliptic latitude and longitude. Since the Earth revolves around the Sun once a year, it appears that the Sun travels once around the sky with respect to the background stars in the same time. This path of the Sun is called the **ecliptic**, and represents the "equator" described by the plane of the solar system. It runs all around the sky and so traces out a **great circle**. The ecliptic latitude is simply measured in degrees away from that great circle. The ecliptic longitude much like the longitude on Earth and Right Ascension in the equatorial coordinate system does not have a very obvious origin. The origin chosen was the same one as that for the equatorial coordinate system. The **vernal equinox** is the 0° longitude point in this system as well as the equatorial system. The longitude is then measured along the path of the Sun in the same direction that the Sun appears to be moving around the ecliptic. The ecliptic coordinate system is a very useful system to measure the location and motion of solar system objects since their apparent motion in the sky follows it.

Sun's Location through the Year (on the Ecliptic)
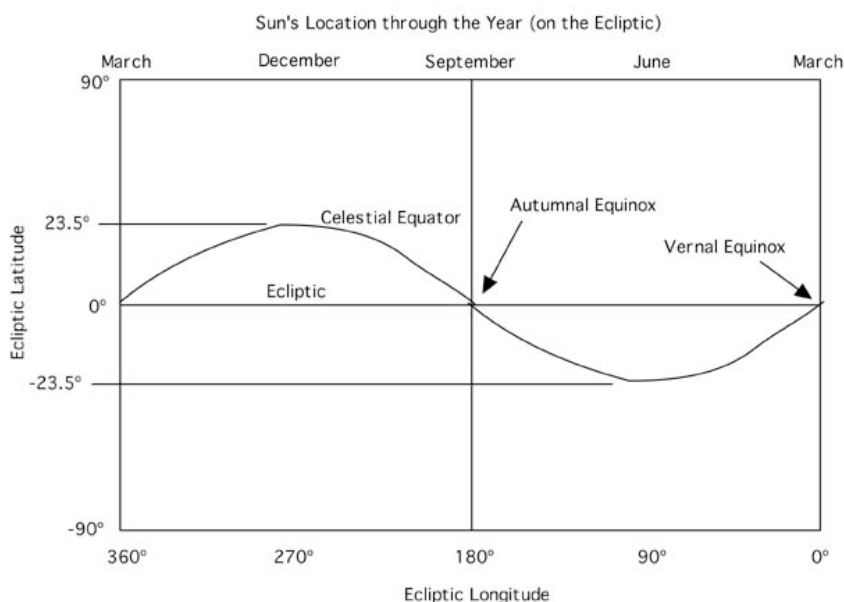
Observations

Before either the outdoor or indoor portion of this lab, you will be taken to the department Planetarium for a quick introduction to coordinate systems. In this environment we have

the capability of drawing the critical lines and axes on the sky for you to see. Then you can hold these in your mind's eye when you subsequently look at the night sky outside.

Procedure – A table is provided below in which you should record the observations.

1. Measure the altitude and azimuth of 5-10 (number determined by your TA) bright objects in the sky. Record the name of the object next to the object number in the table (if not provided). Record the time of these observations as well.

    There are a variety of methods to measure the altitude and azimuth of objects. In this lab, you will use a protractor and a plumb bob to measure altitudes and knowledgeable estimation to measure the azimuths. Take one of the protractors and attach the string with the bob on it. Look along the long flat edge of the protractor and line it up with the object that you are looking at. Hold down the location of the string and read off the larger angle given by the protractor – THEN SUBTRACT 90°, this will be the altitude of the object. Note you cannot use it to measure altitudes of greater than 90° and you cannot read off the smaller angle. The method to measure azimuth takes advantage of the fact that you already know the specific azimuths of a variety of locations, or the 4 cardinal directions. First, locate due north (which is 0° or 12 o'clock), then locate the point on the horizon directly below the object you are interested in. From this point, estimate what "time" your object is closest to, to the nearest "hour". Multiply that number by 30° and that is your azimuth (Example: A star looks to be at 4 o'clock from due north, so the azimuth is 120°).

2. Inside of the classroom, using your SC charts, determine the RAs and declinations of the stars and other objects you observed tonight. Put them in the table as well.

3. Using your SC charts, estimate the ecliptic longitude of each of the objects you just measured. It might be a good idea to first locate the ecliptic line (looks like a sine curve with markings from $0-360^\circ$ all along it). In order to determine the ecliptic longitude, you must draw a line from the object to the ecliptic line that makes a right angle. The point at which the lines intersect will have some degree associated with it – that is the ecliptic longitude. The ecliptic latitude is the same as the equatorial Dec.

4. Then, about an hour after your first observation, measure the altitudes and azimuths of the same 5-10 stars you measured earlier. Include in the table you started previously.

Additional Questions (After completing the chart, answer in complete sentences.)

5. What was the zodiacal constellation on the meridian tonight (Hint: see the bottom left-hand corner of your star charts)?

6. How did the RAs and Decs of your observed objects change tonight?

7. Will the ecliptic coordinates of these objects change tonight? Why or why not?

8. How many <u>degrees</u> of the ecliptic longitude does the Sun change <u>per day</u>? (calculation)

9. What effect will this change have on the sky you see from night to night? Why or why not?

10. a) How many RA-hours does the Sun travel through per year?

    b) How many RA-mins per day does the Sun travel through (take the previous answer and convert)? (calculation)

11. Why are the Moon and planets not located on the SC charts or starwheel?

Conclusion:

Indoor alternative:

1. Choose 5-10 bright stars (number determined by the TA) from locations all around your SC charts. Where on Earth could you go to see each of these stars at the zenith? You will need one location for each of these objects.

2. Using your SC charts, record the ecliptic longitude and latitude, Right Ascension and Declination of the Sun for the 20th of every month. What correlations between these values do you see? What phenomena does this correlation create?

3. Find a cluster, nebula, galaxy, variable star, AND double star on your SC charts. What are ALL OF THEIR RAs and Decs? What day of the year would they be on the meridian at about 8pm?

4. Using the Audubon guide, what other information can you give about each of these 5 objects?

Object	Time: Alt(1)	Az(1)	RA	DEC	Ecl Long	Ecl Lat	Time: Alt(2)	Az(2)
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								