Day Lab 2 - Measuring the Distance to the Moon

This lab attempts to measure the change in the apparent size of the Moon during the course of a day, and to use this information, plus a knowledge of the size of the Earth, to determine how far away the Moon is. The Earth is spherical and rotates; thus during a day (or night) when the Moon is visible, the Earth's rotation moves our position on the surface of the Earth closer and then farther from the Moon. This change in distance between us and the Moon results in a change in the apparent size of the Moon. We will work out the geometry to get the equation that expresses the distance to the Moon in terms of things we will measure. The measurements themselves will come from images we obtain with a digital camera and a telephoto lens.

Part 1 - Build a Model of the Current Earth - Moon - Sun System

* The direction towards the light bulb is the direction towards the Sun. Orient the globe of the Earth such that the direction of its axis of rotation is correct with respect to the direction towards the Sun. To do this, you will need to know the day of the year and how the seasons work.

* Knowing the date of the last new Moon, and today's date, place the model of the Moon at its proper position.

* Knowing the time of day, rotate the globe to the current orientation.

* Use the model to predict when the Moon will be highest in the sky

* When will the Moon set?

* How many kilometers closer to the Moon are we when the Moon is highest in the sky compared to when it sets (or rises)? This is a value we can call D2- D1.

* When we are closer to the Moon, it appears to be larger (we say that its apparent size is larger, or that its angular size is larger). Let's say that we measure its apparent size to be A1 when we are closest to it (the Moon is highest in the sky), and A2 when we are farthest from it (the Moon is low in the sky). How are these two values of the apparent size related to the actual size of the Moon and its distance from us at those two times (call these two distances D1 and D2)?

* What is the ratio D2/D1?

* Since you have determined the values of the difference D2 - D1 and the ratio D2/D1, it is now possible to solve for D1 or D2. This is the formula for the distance to the Moon that we will use later.

* Again using your model, what is the phase of the Moon? If you stepped outside, in what direction would you look to see the Moon?

* Roughly speaking, how will all of these things be different tomorrow?

Part 2A - Measuring the Distance to the Moon Using an Astronomical Ephemeris

The position of the Moon in the sky (or any other celestial object) at each time is called an *ephemeris*. The excel file you will be working with is an ephemeris table for the moon for the Yerkes Summer Institute week. The columns are as follows.

date - date in Greenwich, England

time - time in Greenwich, England (UT means Universal Time) - to get our local time Central Daylight Time (CDT), subtract 5 hours

right ascension - sky equivalent of longitude, in degrees

declination - sky equivalent of latitude, in degrees

ecliptic longitude - number of degrees measured along the plane of the ecliptic

zenith angle - number of degrees between straight up, termed zenith, and the Moon

azimuth - direction around the horizon, where N = 0 deg, E = 90 deg , S =180 deg, and W = 270 deg

fraction illuminated - the fraction of the lunar disk this is illuminated by sunlight

diameter - predicted apparent size of the Moon in degrees

* What specifically do the numbers in the columns mean?

* Plot time on the x-axis and right ascension on the y-axis. What is going on?

* Plot fraction illuminated on the x-axis and right ascension on the y-axis. What is going on?

* Plot zenith angle on the x-axis and diameter on the y-axis. What is going on? (It might make the analysis of the plot clearer to make it for a single 24-hour period.)

* Plot time on the x-axis and diameter on the y-axis. What is going on?

* Make a similar plot, but this time do so only for today's date, and only for the time interval between moonrise and moonset.

* From analysis of this plot, measure the distance to the Moon in kilometers.

Part 2B - Measuring the Distance to the Moon by Change in Apparent Size

If the day is clear, we will use a digital camera and a telephoto lens to obtain images of the Moon and to make precise measurements of its apparent diameter.

* Print out excel table and determine, for today's date, at what time the Moon will be 15 deg above the eastern horizon (rising) and when it will be 15 deg above the western horizon (setting). Also determine when the Moon will be highest in the sky.

* Obtain digital images at intervals between these times with the date and time as the file name.

* Copy files to Macs in the Battleship computer lab

* Use CCDOPS or HOU to open and display the images. Measure the diameter in units of pixels.

* Derive a formula for determining the distance to the Moon, where D2 - D1 is the difference between the distance to the Moon for the images when we were farthest from it and the distance to the Moon when we were nearest to it, A1 is the apparent size of the Moon (measured in pixels) when it is closest (highest in the sky), and A2 is the apparent size of the Moon when it is farthest (low in the sky). A1 and A2 are measured in pixels, and D2 - D1 is measured in kilometers. Why is it not necessary to convert from pixels into degrees?

* Use your formula and your data to measure the distance to the Moon in kilometers.

* In the above analysis, we needed to know the size of the Earth in kilometers. Invent a practical method for measuring the size of the Earth that could be used (for example) in a Yerkes Summer Institute lab.