Topics: Moon phases, more angular measure, parallax

Reading:

- Skim the beginning of Ch. 2, through the end of §2.1 and then read carefully about *parallax* on pp. 37 and 38 (Fig. 2.5 is key).

Recall that there are multiple copies of the textbook on reserve behind the front desk at Cornell Library.

Summary of work to submit:

- You will hand in your answers to the two Moon-related problems I have out in class on Tuesday, and which are repeated here, in this assignment. Bring your solutions to class, we'll go over them, and then you'll hand them in.

Overview:

We'll start class on Thursday with our hands-on Moon phases activity and then we'll get back to discussing angular measure and use the two Moon problems to motivate a derivation of the very useful size-angle-distance relationship. We'll remind ourselves about *radians* and other angle units.

Commentary on the reading, viewing, and other preparation:

(This is just about the new reading, about parallax; see the previous assignment – the last paragraph – for guidance on thinking about Moon phases.)

The ancient Greeks (Ch. 2) had an interesting mix of surprisingly sophisticated (even "scientific") ideas – see Eratosthenes's measurement of the size of the Earth – and totally incorrect, non-evidence-based ideas (the Earth is at the center of the universe). Interesting! Trigonometry and geometry was a forte of the ancient Greeks and those are useful tools for determining the size scale of the nearby universe.

Please bear in mind that the ancient Greeks built on knowledge generated by Sumerians and other, still older civilizations in the Near East (and indeed, the Egyptians thought the Sun was the center of the Universe – not accepted by the Greeks because they did not see the stellar parallax you'd expect if the Earth moves...do you understand *why* they didn't see parallax?).

And bear in mind also that a big part of the reason Greek astronomical knowledge was still going strong in the Middle Ages was because scholars in the Arab world preserved and enhanced Greek astronomy in the 9th and 10th Centuries. You may have noticed that most stars have Arabic names (and our constellations are taken from the Greeks).

Problem 1

You bounce radar (light in the form of radio waves, traveling at $c = 3.00 \times 10^8$ m s^{-1}) off of the Moon and find that it takes the light 2.6 seconds to make the Earth-Moon-Earth round trip.

Based on that measurement, how far away from the Earth is the Moon?

This radar method is used today to measure the distances to planets and other Solar System objects to within centimeters. But the ability to control radio waves was really only developed around WW II. Before the mid-twentieth century, parallax was the most direct way to measure distances. And once you know the distance to an object, simply measuring its angular size leads easily to a calculation of its actual size.

Problem 2

Given the distance to the Moon you found in the previous problem AND its angular size (0.5 degrees), what is the radius of the Moon (2 sig figs, please)? *Hint*: Draw a sketch of the observer and the Moon and show two rays going from one edge of the Moon into the person's eyes. That half-degree angle is the angle at the person's eyes, made by the two lines, which then compose a triangle (with the short side of the triangle being the Moon's diameter. Now...bisect that triangle and you can use some trigonometry to solve the problem.

If you already know/still remember the *small angle approximation*, remind yourself of what it is, what units have to be used to make it valid, and think about how simply you can express the key equation you had to derive to solve problem number 2 if you were to employ the small angle approximation. ...we will go over this explicitly in class, so if you don't recall the approximation, don't worry.

As you think about parallax, and study Fig. 2.5, think about what an observer on the Earth actually sees when they make this parallax measurement. The key is to convince yourself that the small angle at the "nearby star" is the same as the apparent shift in the nearby star's position seen by the two different observers. Think about the role played by the "distant stars."

For your convenience, here is the Moon phase reading guide from the last assignment:

The Moon – like planets and indeed all objects in the Solar system – is visible only by virtue of its ability to reflect sunlight. (That's true at least as far as visible light goes; later we'll see that objects emit infrared light simply by virtue of their non-zero temperature.) Changes in Moon phases are caused by our changing view of the Moon as it makes its approximately month-long orbit around the Earth. When you look at Figure 4.10, think about how the top part of the figure is a "top view" (as seen from above) of the Earth and Moon (with the Sun off the right side of the figure). Note that the Sun is so far away from the Earth and Moon that its rays of light are *parallel*. Stop and think about that. What would those rays (arrows) look like if the Sun were just barely off the right side of the image? The bottom part of the figure shows the view of the Moon from the perspective of an observer on the Earth. Think about how you could describe to someone who had no idea how Moon phases work what the process is for going from a given (labeled with a capital letter) Moon phase in the top part of the figure to the corresponding view in the bottom part. You might think about the fact that from the Earth, you can always see exactly half of the Moon. And that the Sun always lights up exactly half of the Moon. Think about where you'd put a stick figure representing yourself on the Earth at the time around dusk you observed the Moon. What direction along its orbit in that figure is the moon moving? How does the *angular separation* between the Moon and Sun as seen from the Earth change from night to night when there's a waxing Moon?