Topics: (revisit) Eratosthenes; parallax – how far away are the stars?; the inverse square law of light; revisiting orbits and Kepler's laws, the gravity simulator, and also the virial theorem

Reading:

- Greek idea of parallax, pp. 37-38
- Evidence for the Earth's motion, including parallax: pp. 52-59
- Parallax and the inverse square law of light, pp. 307-310

Remember: The textbook is on reserve behind the front desk at Cornell.

Summary of work to submit:

- Bring your solution to problem 1 embedded here in this assignment to class on Tuesday, and hand it in when you arrive.

We've seen how some important astronomical quantities can be measured, including the Earth-Moon distance, and the size of the Moon and the Sun. Now we'll see how *parallax* is used to measure the distances to planets (and indirectly the size of the AU) within our own Solar System and also, remarkably, to the distant stars. Well, only the relatively nearby stars, actually. And we'll discuss how Eratosthenes measured the size of the Earth 23 centuries ago.

Recognizing the vast distances to stars motivates us to understand how the brightness of stars is related to their distances, and so we'll discuss the inverse square law of light, which, when combined with a parallax distance measurement enables us to measure the luminous power output (luminosity) of stars. Ultimately, the inverse square law can be used to estimate the distances of the most distant objects in the universe if we can estimate their luminosities by other means.

We'll also use part of class 3 to finish up our brief study of gravity and orbits. So come to class with questions about orbital energetics and about the virial theorem. And about Kepler's laws...or anything else.

Commentary on the reading:

The ancient Greeks had good reason to believe that the Earth was at the center of the universe and did not move – they didn't notice any parallax shift of the stars as the Earth (allegedly) moved around Sun. Make sure you can describe what that parallax shift would look like, given the Greek's belief that all the stars were at the same distance from the Earth, fixed to the celestial sphere. ...why didn't the Greeks actually see stellar parallax? Hint: It's not because the Earth isn't moving.

Related to this brief bit of material from Ch. 2, you might review Eratosthenes's measurement of the circumference of the Earth plus the evidence Aristotle presented for the spherical shape of the Earth. We'll discuss these things in class on Tuesday.

The Earth moves! Surprisingly hard to prove... read about the Coriolis effect (don't sweat the vector calculus, but maybe just focus on understanding the Foucault pendulum – easiest is when it's on the North pole; be ready to describe what its motion over many hours would look like as seen from outer space and as seen from the surface of the Earth). Aberration of starlight – pretty interesting, but hard to measure given its small magnitude. Are you comfortable with Fig. 2.22 and the analogy of someone running through a rain storm? Focus mostly on parallax in the pp. 52-59 reading. Make sure you are very comfortable with eq. 2.33 – it is just the angle-size-distance relationship but with weird units. We'll be using it quite a bit.

Parallax is again introduced at the beginning of Ch. 13, where the important unit of length, the *parsec*, is defined. Is it a coincidence that the number of AU in a parsec is equal to the number of arc seconds in a radian? Be ready to use eq. 13.3 and to draw a sketch explaining how stellar parallax works, with the relevant lengths labeled.

Problem 1

If the Cassini spaceship, now in a close orbit around Saturn made a parallax measurement of Proxima Centauri, what parallax (in arc seconds) would it find for that nearest-by of stars? If the actual shift measured by the spaceship were to be maximized, how much time would pass between the two measurements? (Hint: The Appendix of the textbook has some useful information about Saturn's orbit.)

Read through the bottom of p. 310. Here too, get comfortable with the simple, but useful governing equation (13.7) including the units of each term. Does it make sense that flux, F, which we colloquially call *brightness*, has units of energy per time per area? How do you think about that *per area*? Below is a sketch showing the geometrical argument motivating the inverse square law.

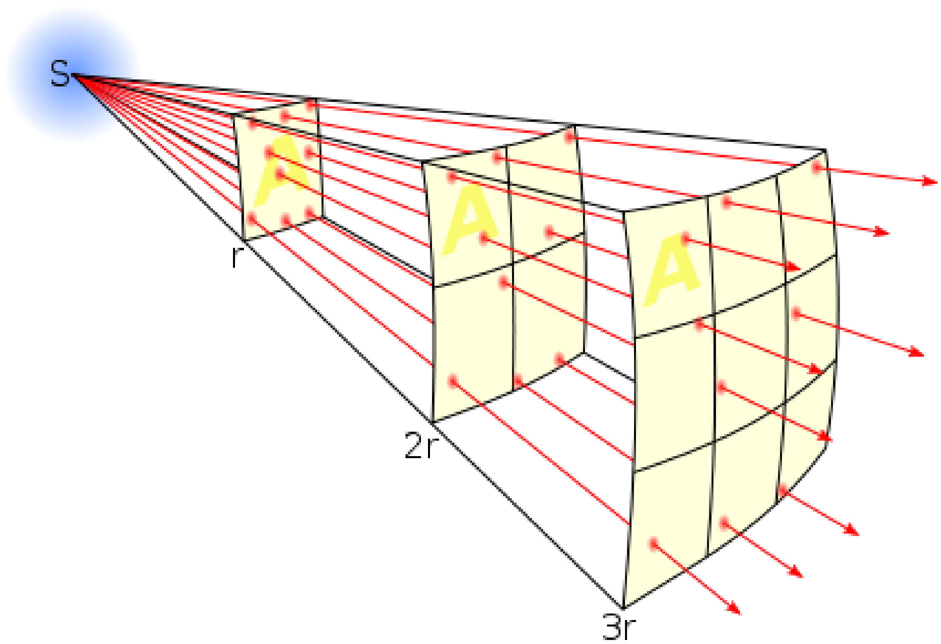

Fig. 1 Light rays from a source (S) diverge as the emitted light fills the three-dimensional volume surrounding the light. If you take the number of rays passing though a unit area square as a measure of the observed brightness, or flux, than you can see that the brightness diminishes as $1/r^2$ (just like gravity). Note that each of the light yellow array of squares represents a section of a sphere centered on the light source. And the second and third spheres are, respectively, two and three times bigger (in radius) than the first one.