Topics: many of the radiation topics from last assignment, the inverse square law of light

Reading:

- Review the last assignment (and the reading in it, as needed – including the Doppler shift).
- Read about the inverse square law of light on pp. 309-310 (the first four paragraphs of §13.2).

Summary of work to submit:

- Bring your solution to problem 1 to class on Thursday.

Overview:

The inverse square law is fundamental, and broadly useful both for measuring things and understanding things. It is important that you are comfortable with the meaning/definition and especially the units of flux and luminosity. The origin of the law is simple: space is three dimensional. Light expanding from a source has to fill a volume that increases with radius as r^2 (think about differentiating the formula for volume with respect to r). Note that gravity has the same dependence. Is that also simply because space is three dimensional?

Commentary on the reading, viewing, and other preparation:

Inverse Square Law of Light: the apparent brightness of an object falls off as the square of its distance.

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? The Sun's flux here on Earth is 1370 W m^{-2}. How do you think about that *per area*? Below is a sketch showing the geometrical argument motivating the inverse square law.

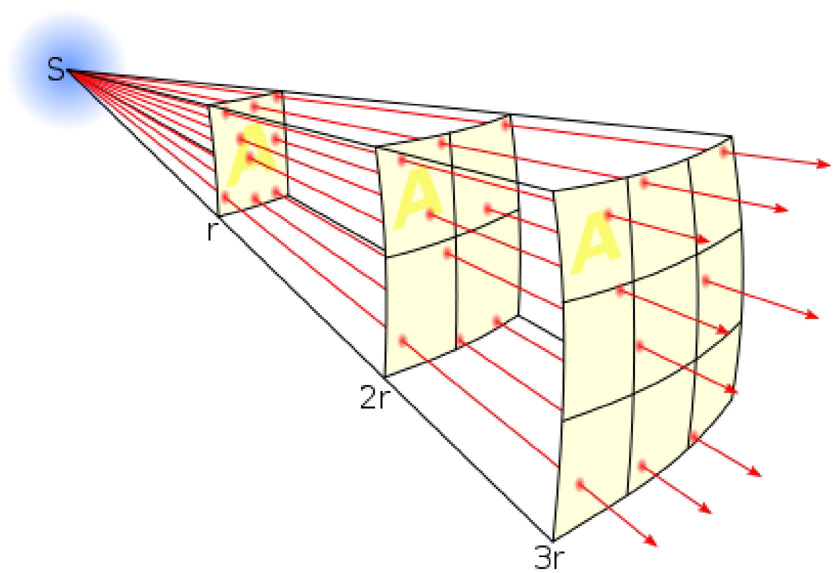

Fig. 1 Light rays from a source (S) diverge as the emitted light fills the three-dimensional volume surrounding the light. If you take the number of rays passing though a unit area square as a measure of the observed brightness, or flux, than you can see that the brightness diminishes as $1/r^2$ (just 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.

The argument is more straightforward if we draw the full depiction of the concentric spheres centered on the light source and note that all the light that passes through the first, smallest sphere in a given time interval will pass through the second, larger one in the same time interval (energy is conserved). But that light energy has to spread out to fill the larger surface area of the larger sphere. So it gets "diluted" according to the increasing surface area of the spheres, which again, go as the square of the radius of the sphere.

In practical terms, the per unit area can help you figure out how much power is delivered to something like a telescope or a human eye. If you know the energy per unit time per unit area (W/m^2) from a light source at your location, and if your telescope has an area, say, of 0.37 m^2, you can multiply those two quantities together to find the energy per unit time entering your telescope. And if you multiply by the exposure time, you have the total energy entering your camera in one observation. ...note (from last class's material) that if we have light of a single color – each photon has the same energy – we can divide that energy hitting our detector by the energy of one photon and find the number of photons in our detector. We'd also have to multiply by a unitless efficiency factor between 0 and 1 that accounts for dust on our telescope mirror, photons that hit the detector but aren't detected (both these effects are probably 0.8 for our telescope).

In practice, the new thing the inverse square law allows us to find out about the Sun is its luminosity – its intrinsic power output – which is, of course, huge. We already knew its distance and can measure its flux.

Problem 1

Jupiter is 5.2 AU from the Sun. What is the flux of sunlight on Jupiter? You might just scale the flux of sunlight here on the Earth by an appropriate factor.

By the way, measuring the flux of the Sun here on Earth in the late 19th Century, physicists discovered infrared light (a significant fraction of the Sun's output is in the infrared). They dispersed sunlight with a prism and then measured the heating of a thermometer with different colors of light. When they put the thermometer beyond the red, it still showed an elevated temperature.