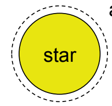
HOW DO WE GET DISTANCES OUT FARTHER THAN 1000 PARSECS?

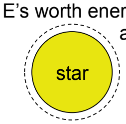
Think about the amount of energy a star gives off per unit time. In fact, let's define luminosity L as the amount of light energy *at all frequencies* and *in all directions* a star gives off *per unit time* (that means its units are joules per second).



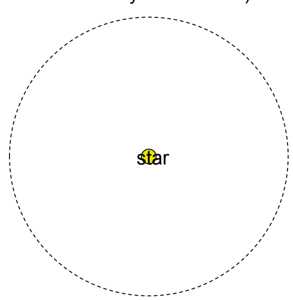
With that definition, we can say that over a 1 second period, our star will give off energy E = L (1 second)

We can additionally say that that energy will move out away from the star on a spherical surface traveling at the speed of light.

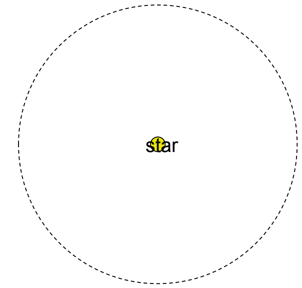
Let's assume that an hour passes after our 1 second of energy emission (obviously, the star has continued to put out energy--we are only interested in the amount given off during that 1 second period). During that hour, the sphere will expand growing quite large, but the amount of energy arrayed across its surface will NOT changed. No energy will be lost!



Total energy on sphere hasn't chanced even though the sphere's size has grown (sketch obviously not to scale)



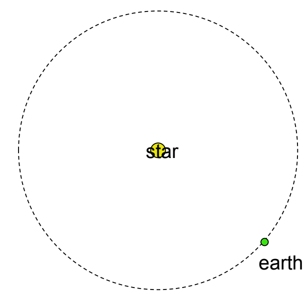
What *has* changed is the amount of *energy per unit area per unit time*, called the energy flux F, on the sphere (the units for energy flux are *joules per meter-squared per second*). That is, when the sphere was small, there was lots of energy packed into a unit area. But as the sphere got large, it's surface area increased and the energy per unit area got smaller.



What is interesting to note is that at any instance, the relationship between the energy flux on the spherical surface, the star's luminosity and the surface area S of the spherical surface upon which the energy resides can be mathematically presented as:

$$L_{\text{of star}}(\text{joules/sec}) = F_{\text{on sphere}}\left(\text{joules}/\text{m}^2\bullet\text{sec}\right) A_{\text{sphere}}(\text{m}^2)$$

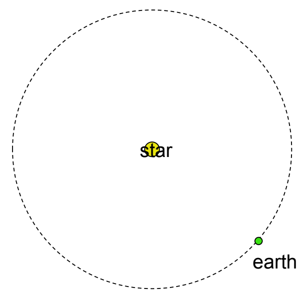
What this relationship implies is that if, at some instance, the spherical shell were to pass by the earth and a little bit of it captured by a telescope, we'd find ourselves in an interesting situation.



Assuming the telescope was fitted with a photosensitive plate, it would be easy to measure the amount of energy that impinges on the plate per unit time (that is, we could count the number of photons that strike the plate per unit time). We could then divide by the plate's area.

This number would be the *energy flux F on the sphere*--the amount of *energy per unit area per unit time* arrayed on the sphere as calculated on the earth's surface. That value is called the apparent brightness of the star.

Additionally, the radius R of the sphere would be the distance between the star and our solar system (or, more accurately, the earth). That means the surface area A of the sphere would equal:



$$A_{sphere} = 4\pi R^2$$

Putting this all together in our luminosity relationship yields:

$$L_{of\ star} = F_{known\ flux\ as\ measured\ on\ earth}(4\pi R^2)$$

The only things we don't know in this relationship are L and R.

In other words, if we can determine the luminosity L of a star, given we've taken the time to determine the star's energy flux as it exists here on earth, we can determine the distance R to that star . . . (or vice versa).

So how do we figure out a star's luminosity?

It turns out there are several ways to do this. In order of complexity, they are:

a.) If you are lucky and the star is a standard candle, it's average luminosity will be related to the rate at which its radius and, hence, luminosity varies.

b.) Find a star that has the same spectral signature as the star you are interested in, but that is near enough to use parallax to determine its distance. With its energy flux and distance known, you can determine its luminosity using our luminosity/flux/distance relationship. Because the two stars have the same spectral characteristics, they will have the same luminosity. (We'll talk more about spectral characteristics shortly). So knowing one, you know the other.