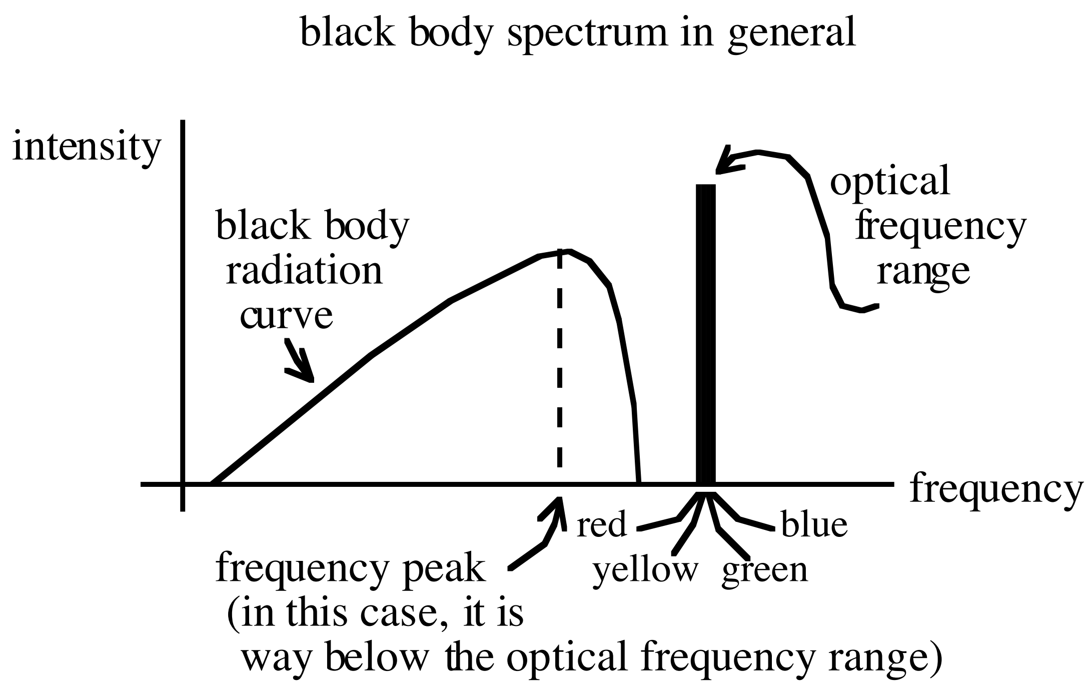
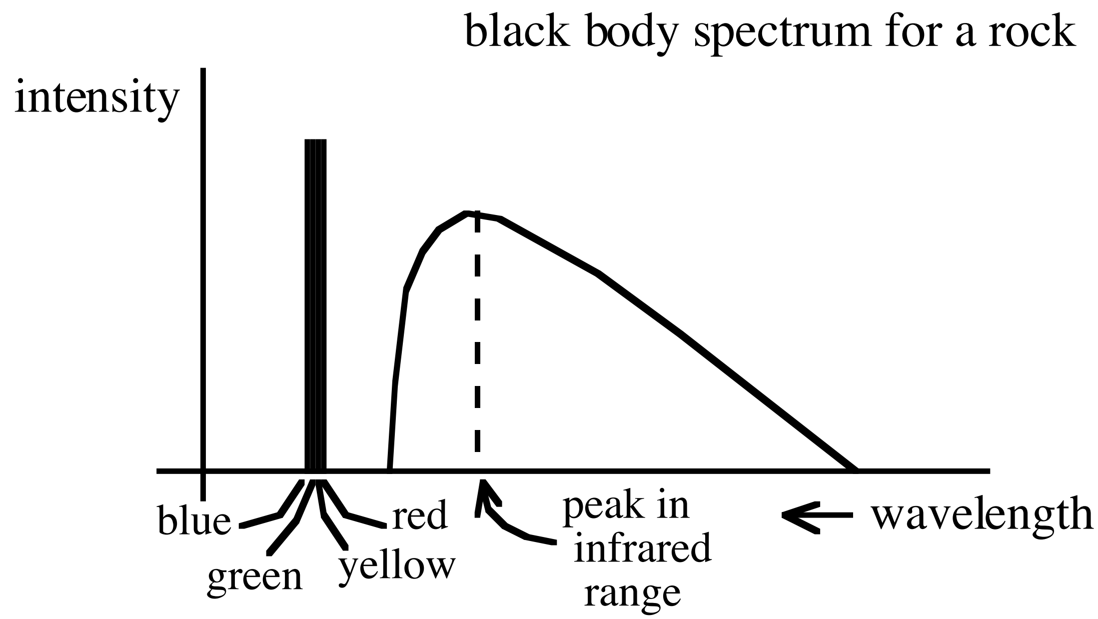
The atomic and molecular structure of all objects are always absorbing and emitting radiation due to electron transitions (and other energy state changes). In short, all objects radiate a spread of electromagnetic frequencies.



A graph of this spread is called a *blackbody radiation*.

The black body radiation curve (as a function of frequency) for a rock is shown above.

The black body radiation curve (as a function of wavelength) for a rock is shown to the right.



The shape of the curve is the same for all objects, but what determines where the curve sits along the wavelength (or frequency) axis is dependent solely on the body's temperature.

Put a little differently, if you can determine the *peak wavelength or frequency* (i.e., the most intense of the possibilities) of a black body radiation curve, you can determine the body's temperature.

The peak wavelength is λ_{peak} = .0029/T.

ENERGY FLUX "F" (sometimes called *energy* density*)* is defined as the amount of energy that passes through a surface *per unit area per unit time*.

The units of *energy flux* are *joules/second/(square meter)*.

From experimentation, we know that the energy flux from a radiating object is proportional to the fourth power of the object's surface temperature. The proportionality constant is called the Stefan-Boltzman constant. Its symbol is a sigma (σ). With it, we can write the flux relationship as

$$F = \sigma T^4$$

LUMINOSITY "L" is defined as the total amount of energy from all frequencies of radiation and in all directions given off by a star *per unit time*.

A star's luminosity is equal to a stars energy flux (energy per unit area per unit time) times its surface area.

In other words,

$$L = \text{(energy flux)} \ \text{(star's surface area)}$$

$$= [(\sigma)(T^4)] \quad (4\pi R_{star}^2)$$

In other words, in other words, if we can determine a star's temperature and luminosity, we can determine its radius.

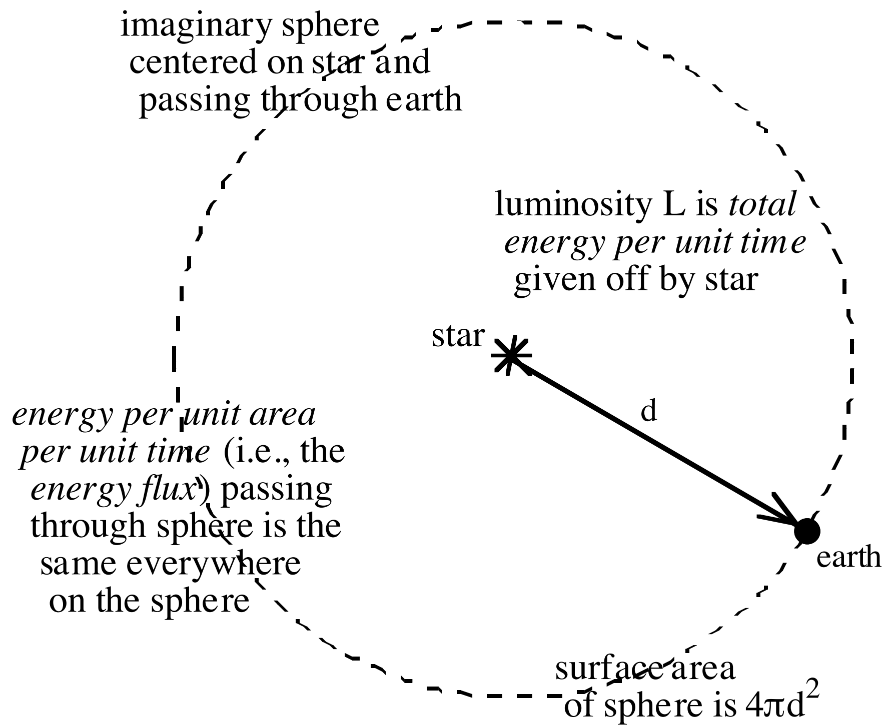
--How else is knowing a star's luminosity useful?

--Knowing a star's luminosity allows us to determine the distance to the star.

--How so?

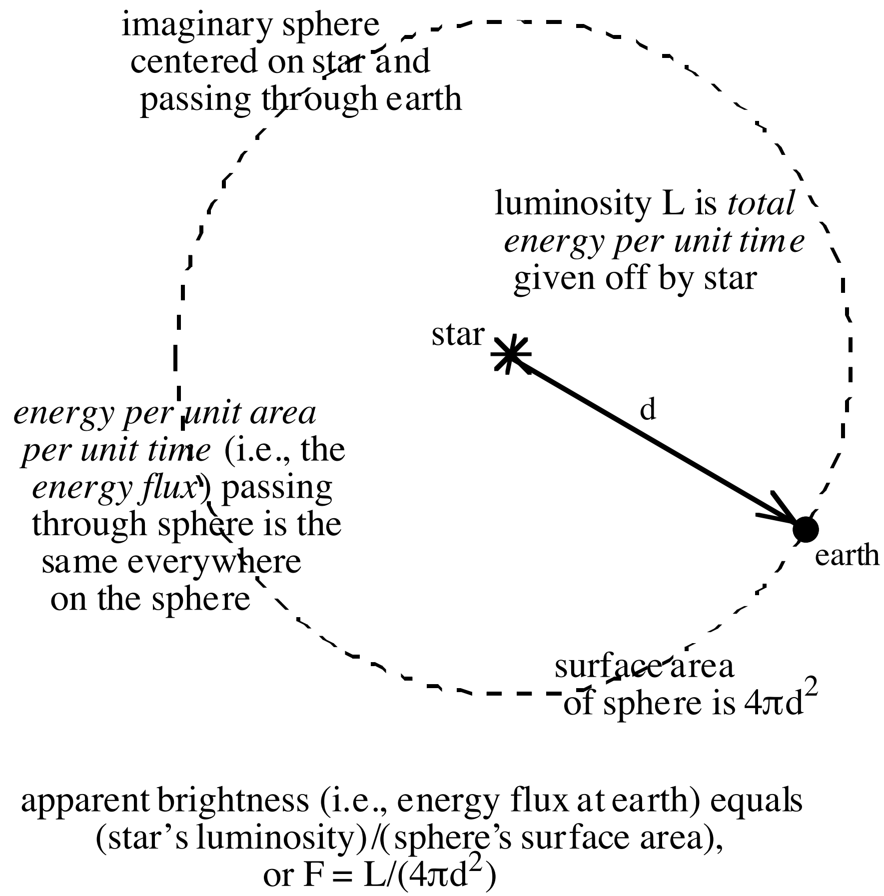
--The luminosity is the total energy per unit time given off by the star.

--Imagine the earth sitting on a sphere that is centered on the star.



apparent brightness (i.e., energy flux at earth) equals (star's luminosity)/(sphere's surface area), or $F = L/(4\pi d^2)$

--The energy flux through the sphere per unit time must equal the amount of energy coming out of the star per unit time



--That is

$$F_{\text{at surface}} = \frac{\text{(energy per unit time per sphere)}}{\text{(sphere's area)}}$$

$$= \frac{L}{(4\pi R^2_{\text{to star}})}$$

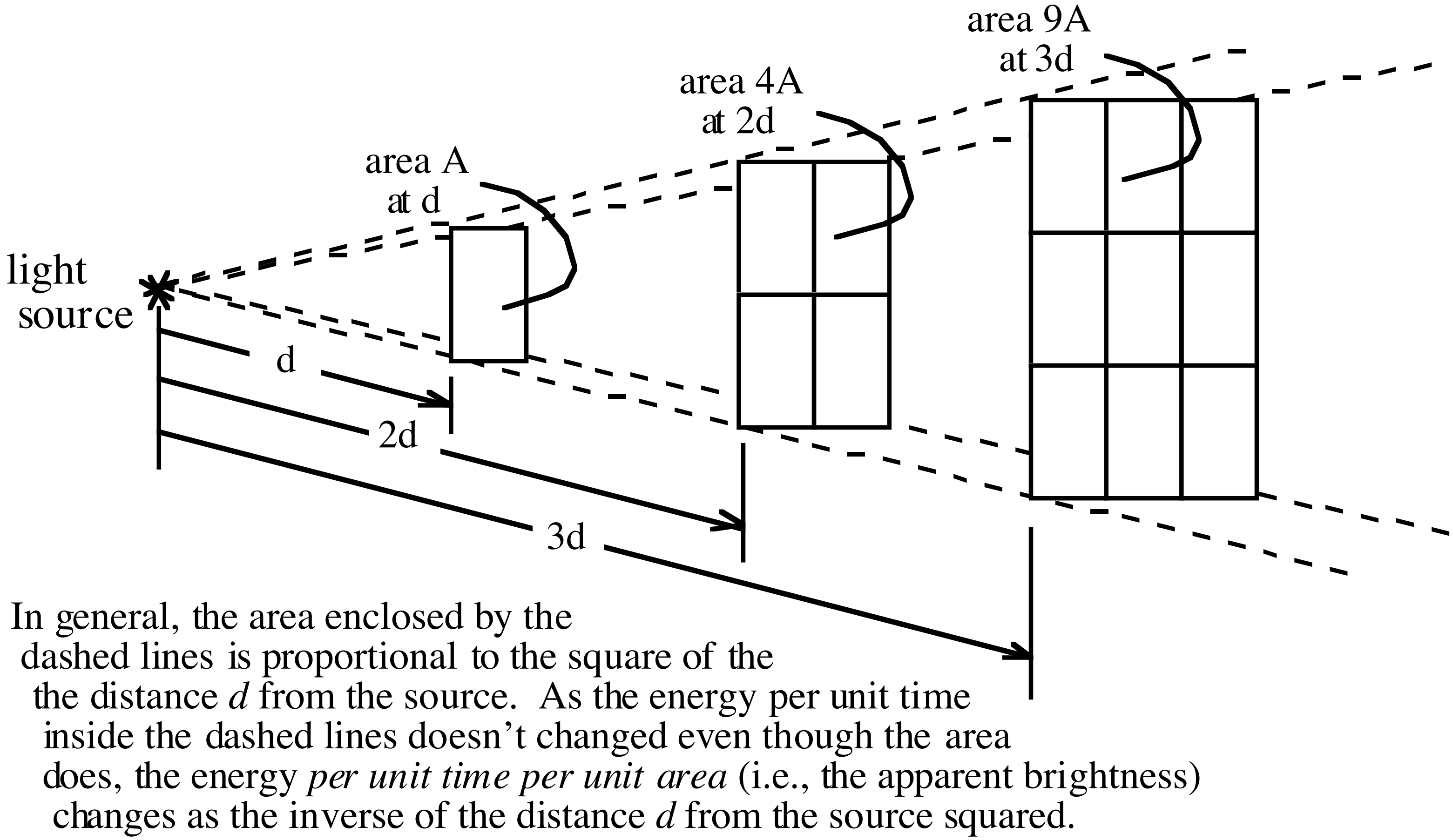
--How do we get the energy density (for situation like this, this is also called *apparent* brightness) at the surface of the sphere?

--We determine the energy density as it strikes the earth. That is, we take the light that comes in from the star, measure its intensity on a photosensitive plate, then divide by the area of the plate.

--And how does this help us?

--Light intensity (energy flux, luminosity, whatever) drops off as the square of the distance from the source. This is called the "inverse square law."

--With it, if we know the actual luminosity of a star, and the apparent brightness as measured on earth, we can work backwards to determine how far the star is from the earth.



--All we need is the luminosity and everything unfolds from there.

--For close stars:

--If you can find a close star with the same color and spectrum as that of a distant star of interest, you can use parallax to determine the distance to the close star, then measure the apparent brightness.

--With the star's distance *d* and apparent brightness *F*, you can use

$$F_{\text{at surface}} = \frac{\text{(energy per unit time per sphere)}}{\text{(sphere's area)}}$$

$$= \frac{L}{(4\pi\, d^2_{\text{to star}})}$$

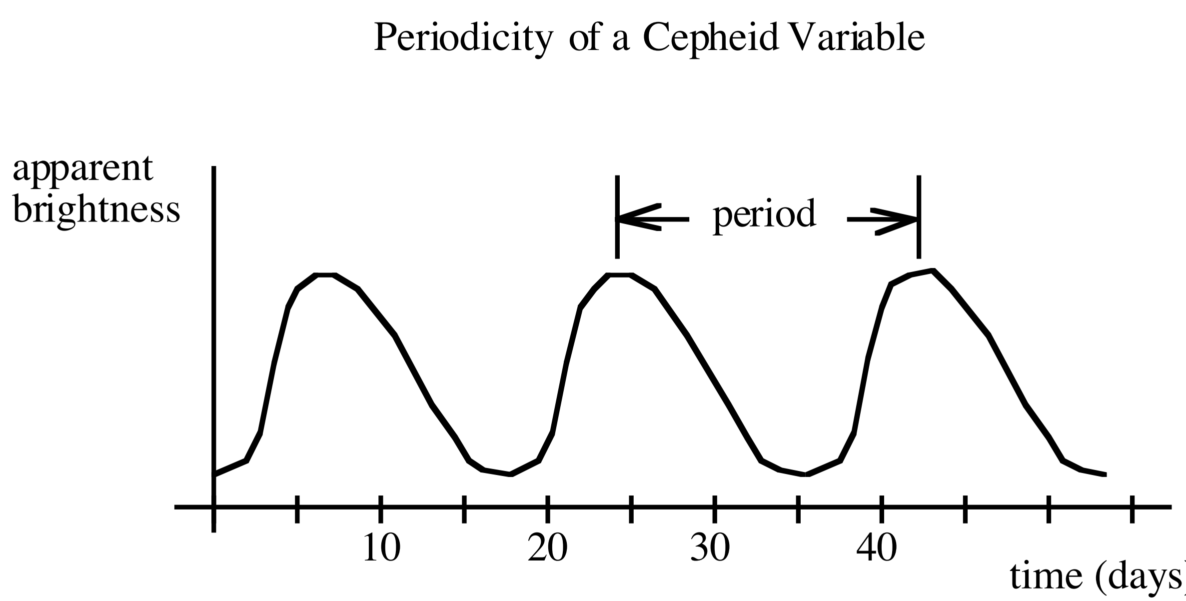
to determine *L*.

--As the two stars are the same, you then have *L* for the far star.

--For far stars, we have to be a little more clever:

--It turns out that there are stars whose luminosity and radius change in a periodic way. Of the two most often quoted (RR Lyrae and Cepheids), we will concentrate on Cepheid.

--Cepheid stars are relatively massive stars whose *frequency* of luminosity variation, measured between 1 and 100 days, is related to the their actual luminosity.



--We have plotted the *apparent brightness* versus *pulsation frequency* graph for a number of Cepheids, we can get an uncalibrated curve relating these.

--If we know the luminosity of just one of those Cepheids, we can calibrate the curve and have, in effect, a *pulsation frequency* versus *luminosity* curve.

--There is exactly ONE Cepheid within 3000 light years of us. Using the parallax approach of determining its luminosity, we have that calibration factor.

--In other words, if we are looking at a star cluster or galaxy, even, and we can find one variable Cepheid in its midst, all we have to do is measure its pulsation frequency and we will know its luminosity.

--Minor side point: There is one class of supernova that can also be used as a "standard candle" for luminosity measurements. We will talk about that later.