STARS

Luminosity, Temperature, and Radius

Overview

This lesson will relate Luminosity to Radius to Temperature.

This assumes you have already viewed the lessons on the Magnitude, EM Spectrum, and Wien's Law.

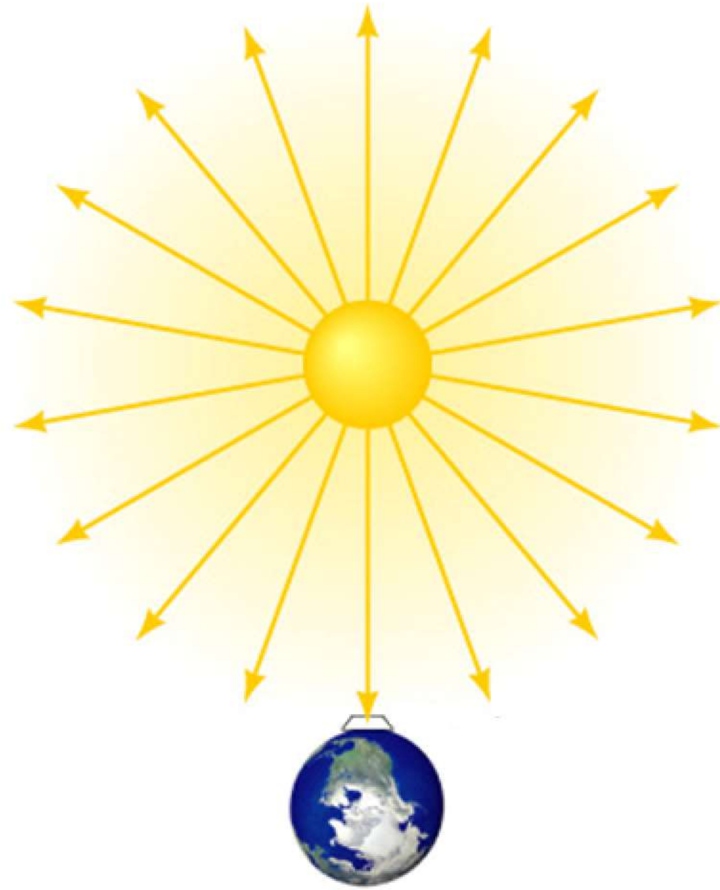
Stellar Properties Review

Luminosity (L): The total amount of energy produced in a star and radiated into space in the form of EM radiation each second. (NOTE: This is also known as Absolute Magnitude (M)

A typical unit of measurement for luminosity is the watt.

Compare a 100-watt bulb to the Sun's luminosity, 4×10^{26} watts

Knowing a star's luminosity will allow a determination of a star's distance and radius

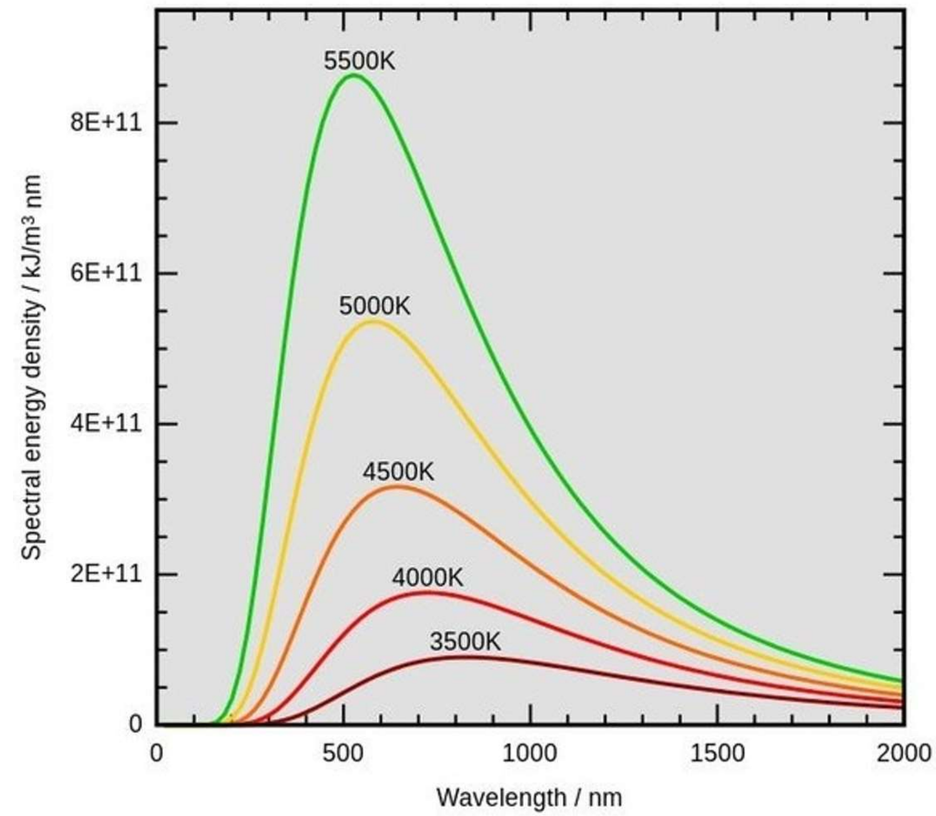


Apparent brightness/magnitude (m): Amount of starlight that reaches Earth (energy per second per square meter=$W\ m^{-2}$)

Wien's Law Review

The peak wavelength, is inversely proportional to a blackbody's temperature.

This implies that the warmer objects are more blue (blue is shorter wavelength) and cooler objects are redder (red is longer wavelength).



Stefan-Boltzmann Law

This builds on: the hotter an object is, the more energy it radiates outward.

Or, the flux (energy per unit time) is proportional to the fourth power of the temperature (in Kelvin).

$$F = \sigma T^4$$

F = flux of energy (W/m^2)
T = temperature (K)
$\sigma = 5.67 \times 10^{-8}\ W/m^2K^4$ (a constant)

Stefan-Boltzmann and Radius

To understand a stellar radius from Temperature and Flux output, we must look to a sphere.

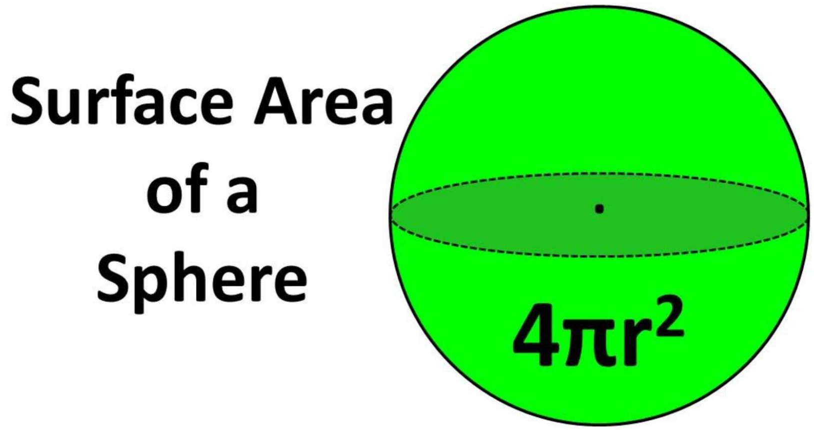
- The surface area of a sphere is: $A = 4\pi r^2$
- Combining this with Stefan-Boltzmann, we can determine the radius of a star.

Therefore, E= $4\pi r^2 \sigma T^4$

- The Energy/Flux can is related to the area of the star times temperature to the 4th power

Simplifying:

- 4, π, and σ are constants and can be dropped for illustration
- That leaves the variables: E= $r^2 T^4$



Summary

So, what does this say in plain English?

Luminosity of a star's surface area is equal to its Radius squared times it Temperature to the fourth power

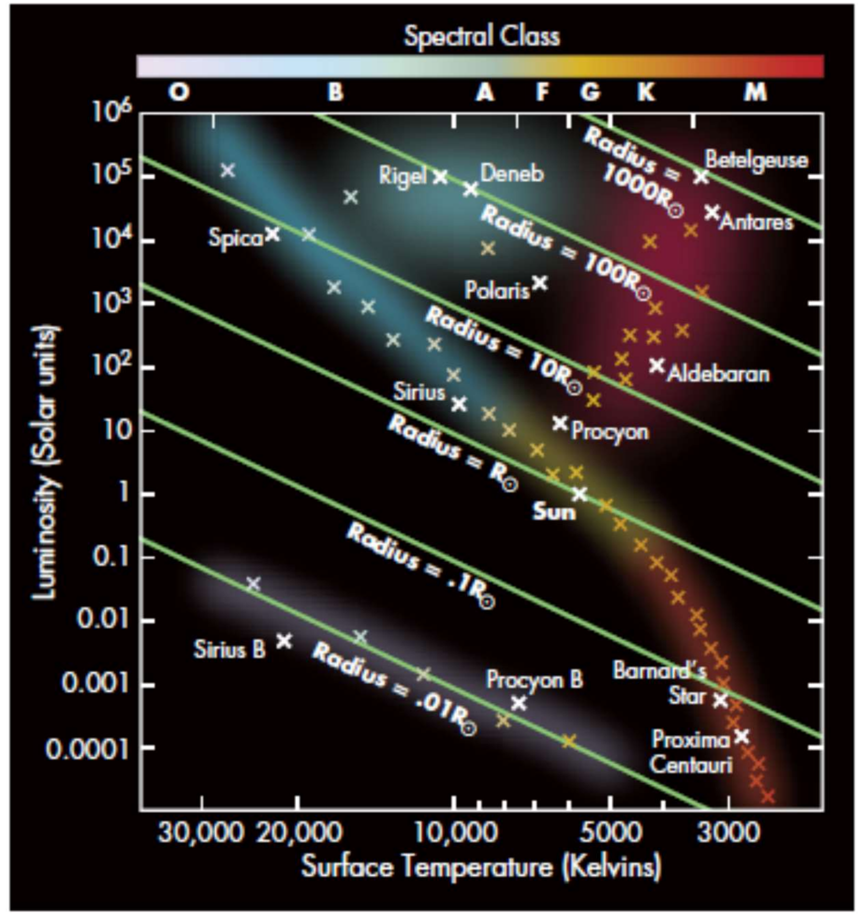
$$\boxed{L=R^2T^4}$$

If a star's luminosity stays the same, but its temperature increases, what must happen to the Radius?

$$\boxed{L={}_{R^2}T^4}$$

What if a star's luminosity stays the same its size increases?

$$\boxed{L=R^2{}_{T^4}}$$



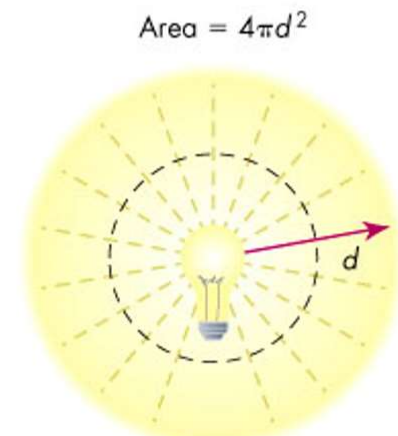
Questions?

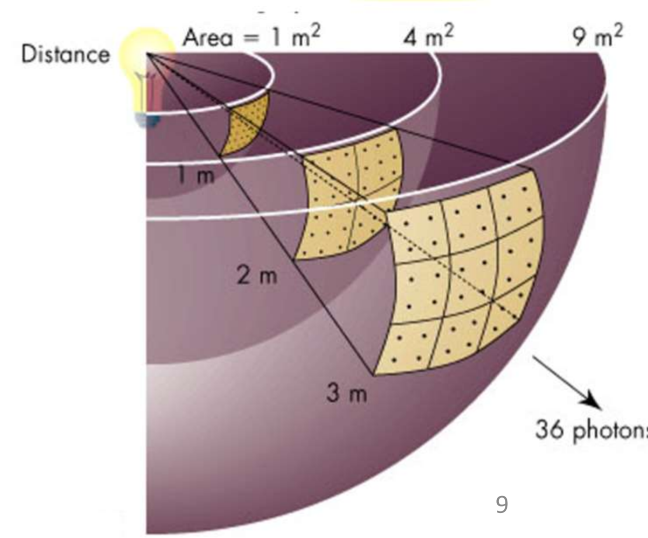
Stellar Properties: Luminosity & The Inverse Square Law of Brightness

The *inverse-square law* relates an object's luminosity to its distance and its apparent brightness (how bright it appears to us).

This law can be thought of as the result of a fixed number of photons, spreading out evenly in all directions (a sphere) as they leave the source

The photons have to cross larger and larger concentric spherical shells.
For a given shell, the number of photons crossing it decreases per unit area





Stellar Properties: Luminosity & The Inverse Square Law of Brightness

$$B = \frac{L}{4\pi d^2}$$

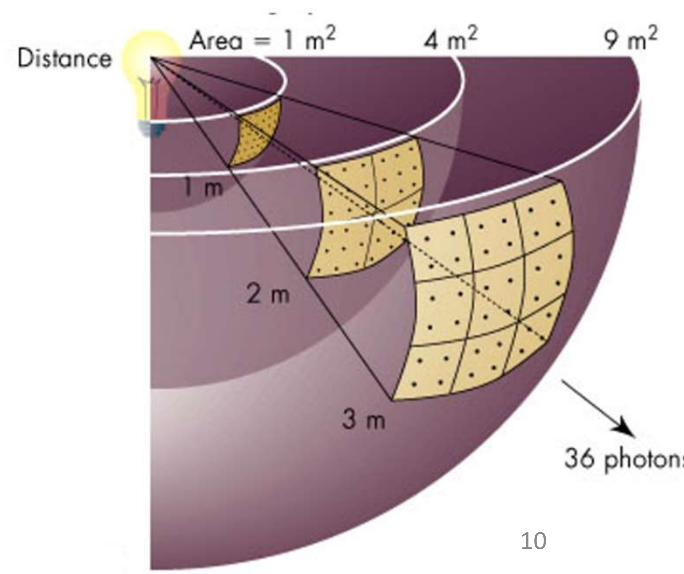
B (the *apparent brightness, also known as m*) at a distance ***d*** from a source of luminosity ***L*** (is the absolute magnitude, also known as M)

The formula states that the apparent brightness (B) we see is proportional to the total power of the star (L) divided by its distance away from us squared (d^2*).*

The 4π represents the surface area of the sphere that the light has created as it spreads. As it is a constant, if you remove it, you are left with L/d^2

Given d from parallax measurements, a star's *L* can be found (A star's *B* can easily be measured by an electronic device, called a photometer, connected to a telescope.)

Or if *L* is known in advance, a star's distance can be found



Stefan-Boltzman: Power Output related to Temperature

OK, from the study of Wien's Law, we know that a hot blackbody emits more energy per second than a colder black body. *Remember: Hotter objects are Brighter.*

Stefan-Boltzman defined: Energy emitted is directly related to temperature to the fourth power

$E = \sigma T^4$

E is Energy (or Flux)emitted per unit area/per second

T is the surface temperature in kelvins

σ is a constant known as Stefan-Boltzman constant