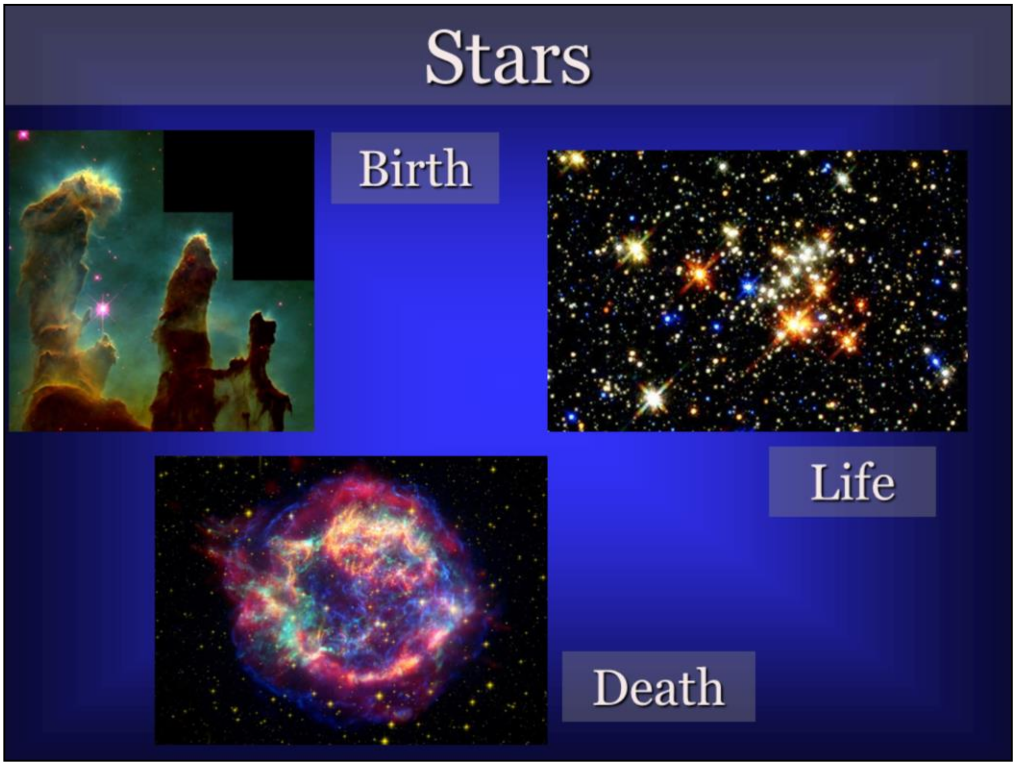


Stars

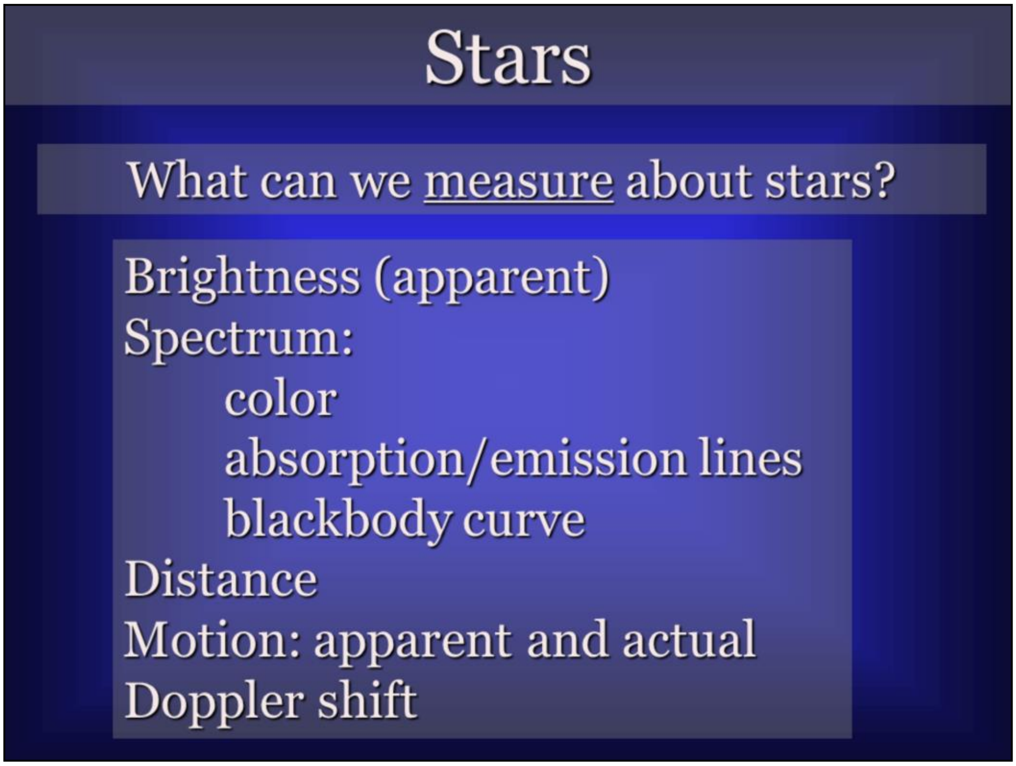
Birth

Life

Death

We are going to talk about

- how stars form
- how stars live and die
- how their mass relates to their temperature and their luminosity (intrinsic brightness).
- fusion of elements (we already covered H -> He)
- creation of elements greater (larger) than iron (Fe)



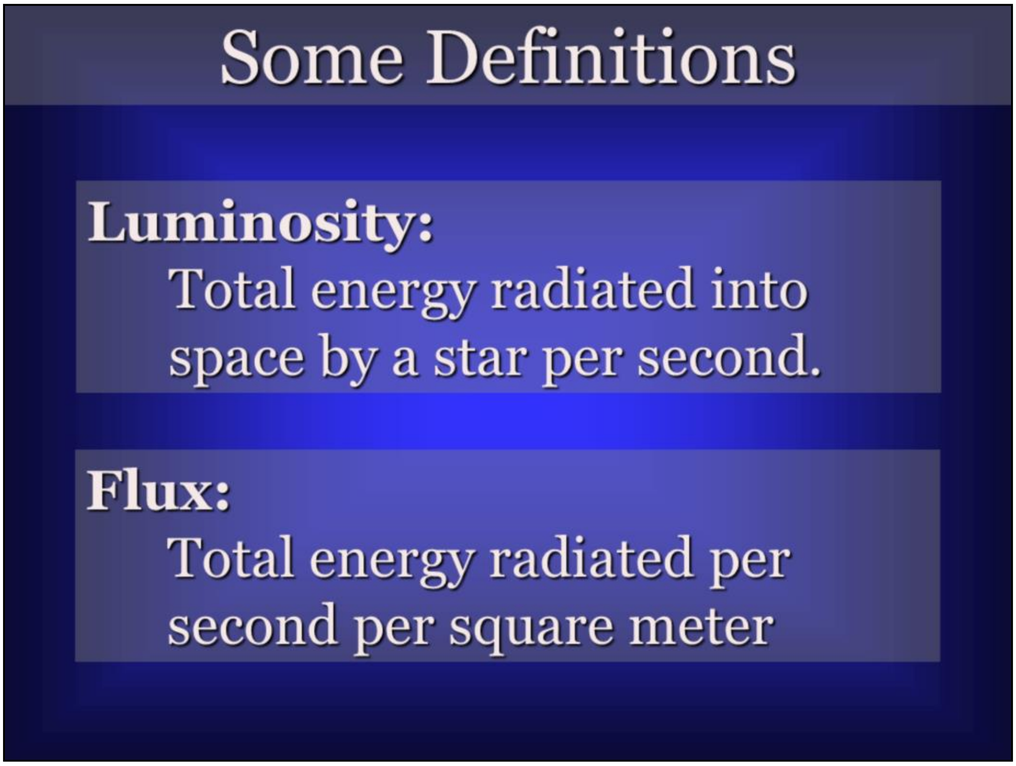
Stars

What can we measure about stars?

Brightness (apparent)
Spectrum:
  color
  absorption/emission lines
  blackbody curve
Distance
Motion: apparent and actual
Doppler shift

Now wait one minute. We need to talk about this. We've been plotting luminosity and temperature. What do we really *measure*? Here are all the things we can measure about stars. Some of these we don't need right now but it's important to keep in mind.

We'll cover some of how we do this in future slides.



Some Definitions

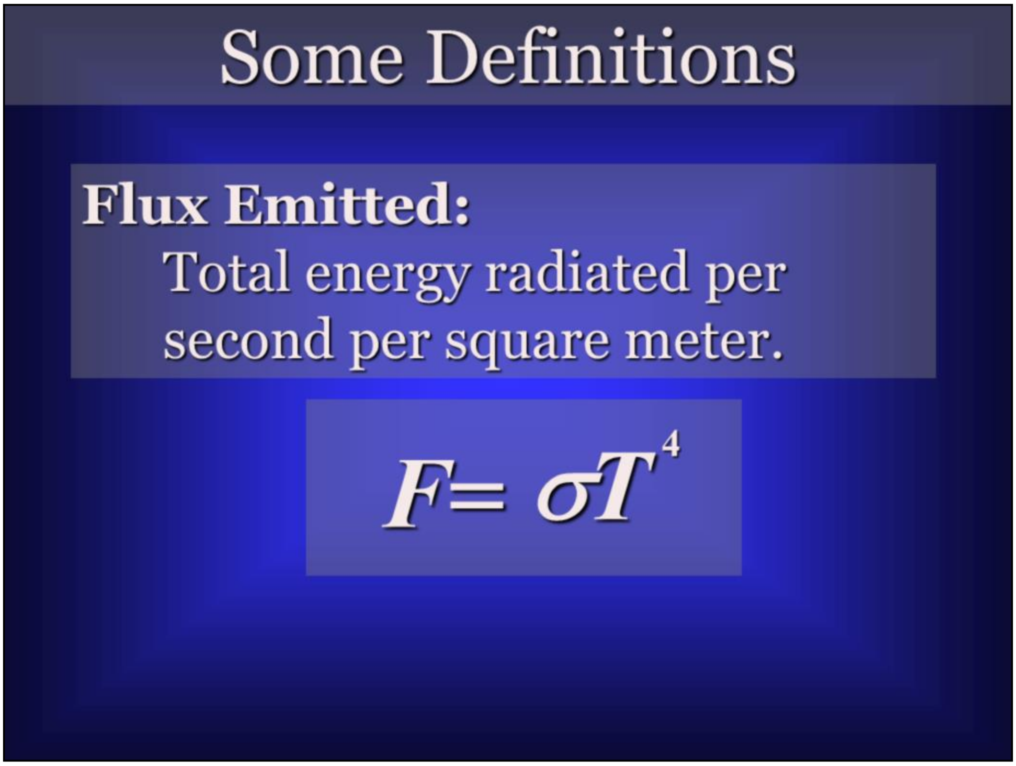
Luminosity:

Total energy radiated into space by a star per second.

Flux:

Total energy radiated per second per square meter

In order to get these we take the **apparent** brightness and correct for **distance**.



Some Definitions

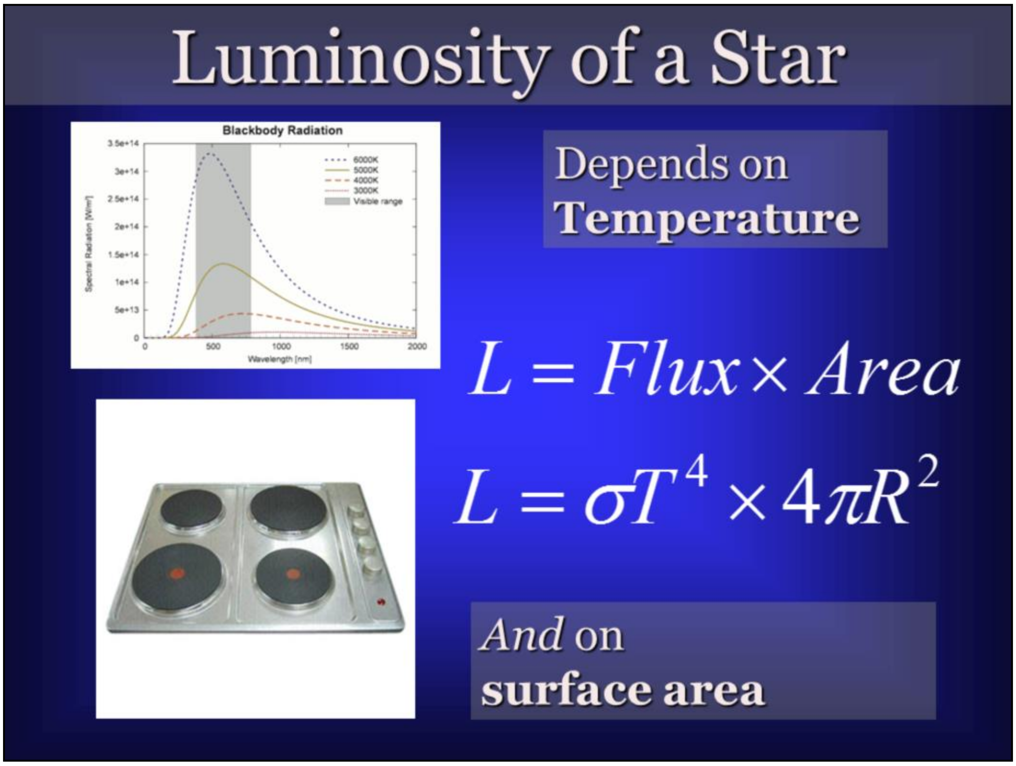
Flux Emitted:

Total energy radiated per second per square meter.

$$F = \sigma T^4$$

We've been talking about intensity so far! Intensity and flux have the *same units* (energy per area). In fact, they are essentially the same thing – so be careful *where* you are talking about the flux matters.

This is the flux *at the surface of the star.*



Luminosity of a Star

Depends on
Temperature

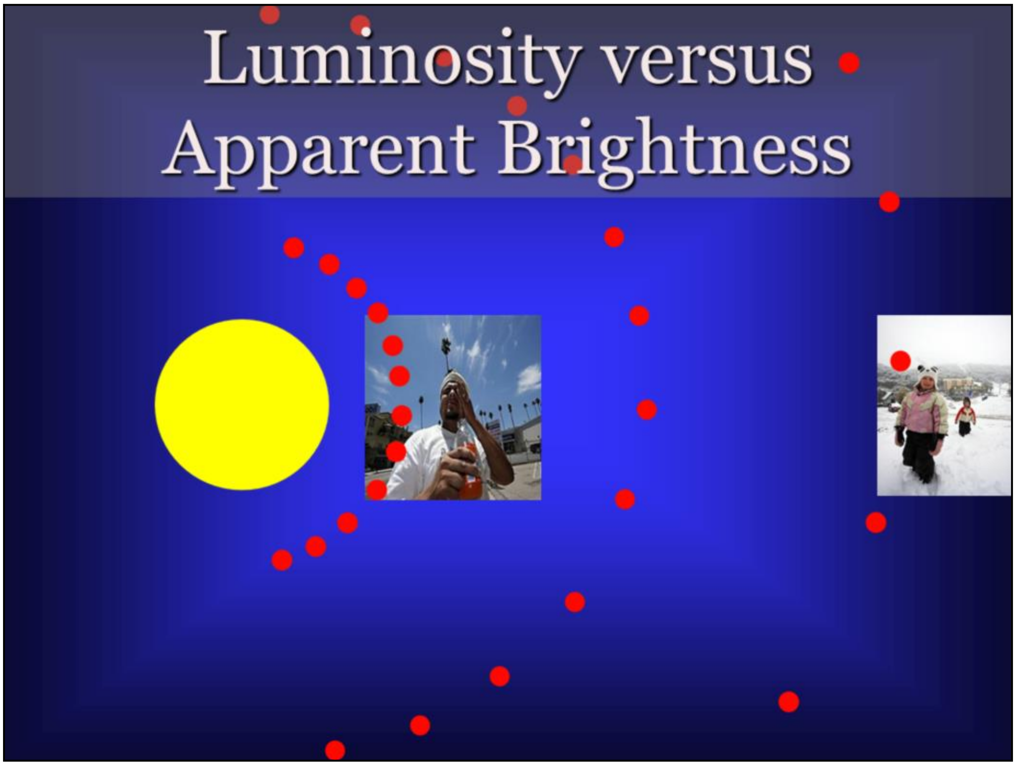
$$L = Flux \times Area$$

$$L = \sigma T^4 \times 4\pi R^2$$

And on
surface area

Luminosity from a star depends on temperature- Hotter objects are brighter
Luminosity from a star depends on surface area- Bigger objects are brighter

Luminosity is INTRINSIC to the star… independent of distance.

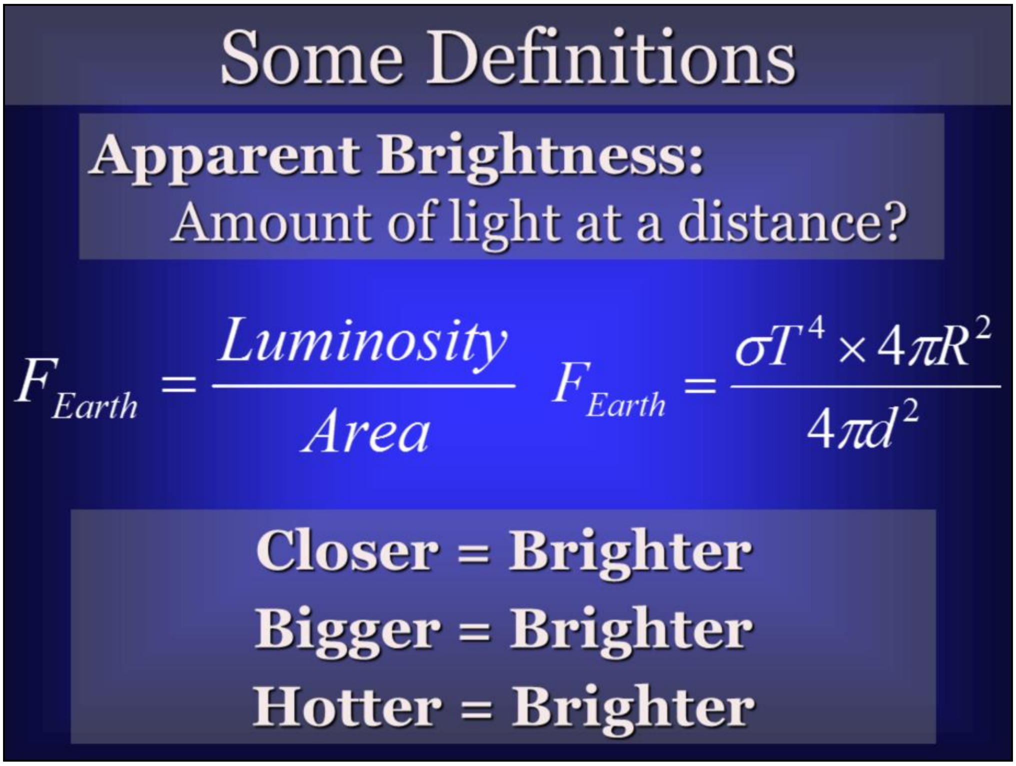


Luminosity versus Apparent Brightness

Imagine the light particles are little ping pong balls called “photons.”

The Sun spits photons in all directions. If you are standing very close, you will intercept many photons

If you are far away, you will intercept fewer photons.



Some Definitions

Apparent Brightness:
Amount of light at a distance?

$$F_{Earth} = \frac{Luminosity}{Area} \qquad F_{Earth} = \frac{\sigma T^4 \times 4\pi R^2}{4\pi d^2}$$

Closer = Brighter
Bigger = Brighter
Hotter = Brighter

Luminosity is the total number of photons leaving a star every second.

Luminosity is an intrinsic property of a star and is INDEPENDENT of its distance from us.

Flux is the number of photons crossing a square meter patch.

From our unit on light, we know that the flux from the surface of a hot object depends on its temperature.

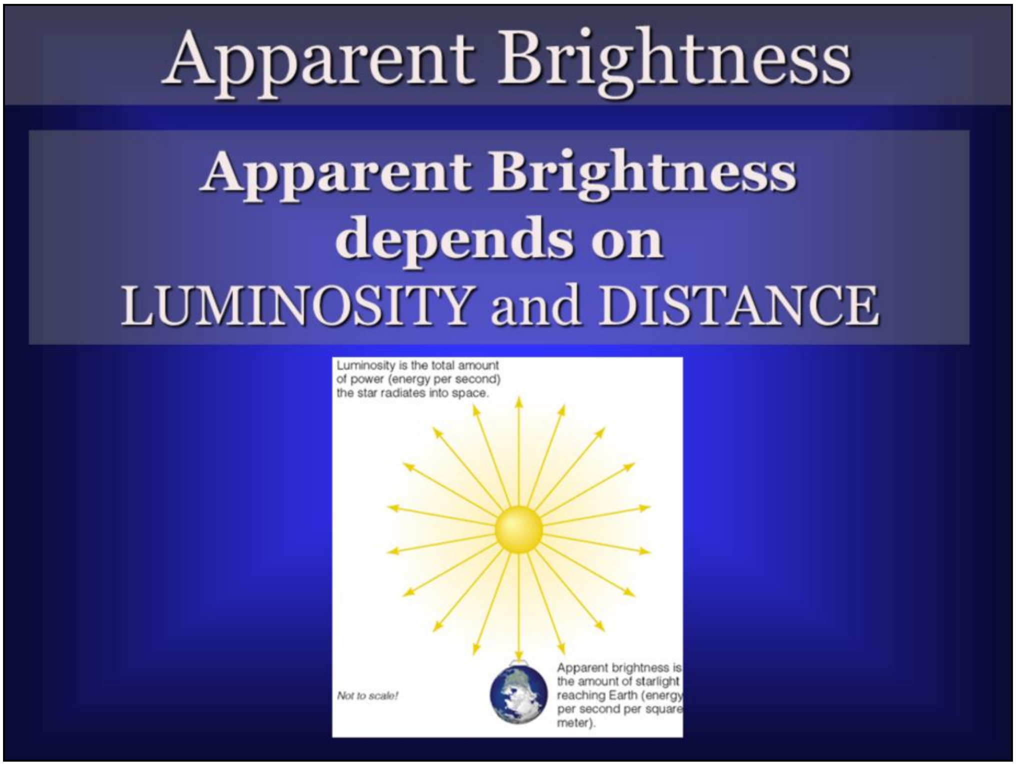
Therefore, the Luminosity of a star depends on its Temperature and its surface area.

A hot bowling ball emits more energy per second than a hot bb

Small hot plates emit less energy per second than a large hotplate.

The flux received by the Earth from a star is the total number of photons per meter at the distance that the Earth is from the star.

A LARGE solar collector collects more energy than a tiny one.



Apparent Brightness

Apparent Brightness depends on LUMINOSITY and DISTANCE

Luminosity is the total amount of power (energy per second) the star radiates into space.

Apparent brightness is the amount of starlight reaching Earth (energy per second per square meter).

Not to scale!

The **apparent** brightness of a star depends on its luminosity and its DISTANCE

So if I know the apparent brightness and the luminosity, I can get the distance

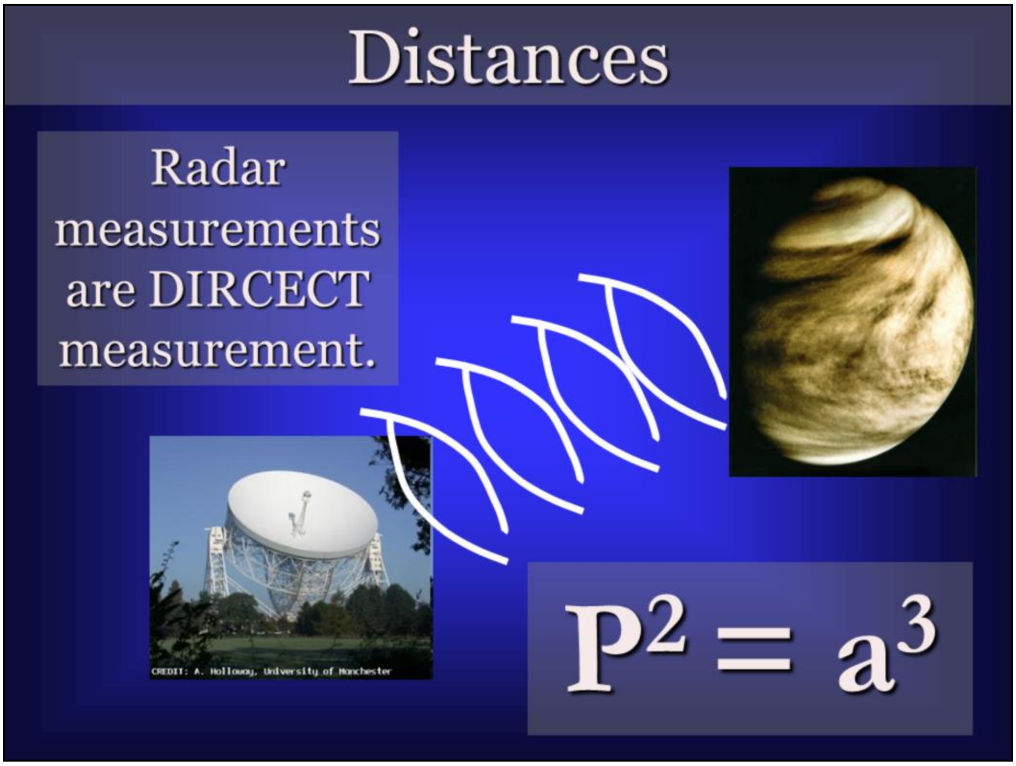
For luminosity, we need to know the stellar temperature AND the stellar radius

The temperature I can measure directly.

The radius is near impossible to measure directly.

OR, we can try to find the true luminosity of a star by knowing its distance and measuring its apparent brightness. Unfortunately, distances are hard to figure out. However if we can find distances to some stars, we can figure out characteristics and then make generalizations to stars that are similar*

*we'll talk about what this means later.



Distances

Radar measurements are DIRCECT measurement.

$$P^2 = a^3$$

CREDIT: A. Holloway, University of Manchester

We bounce radar signals off of Venus to measure our precise distance from it.

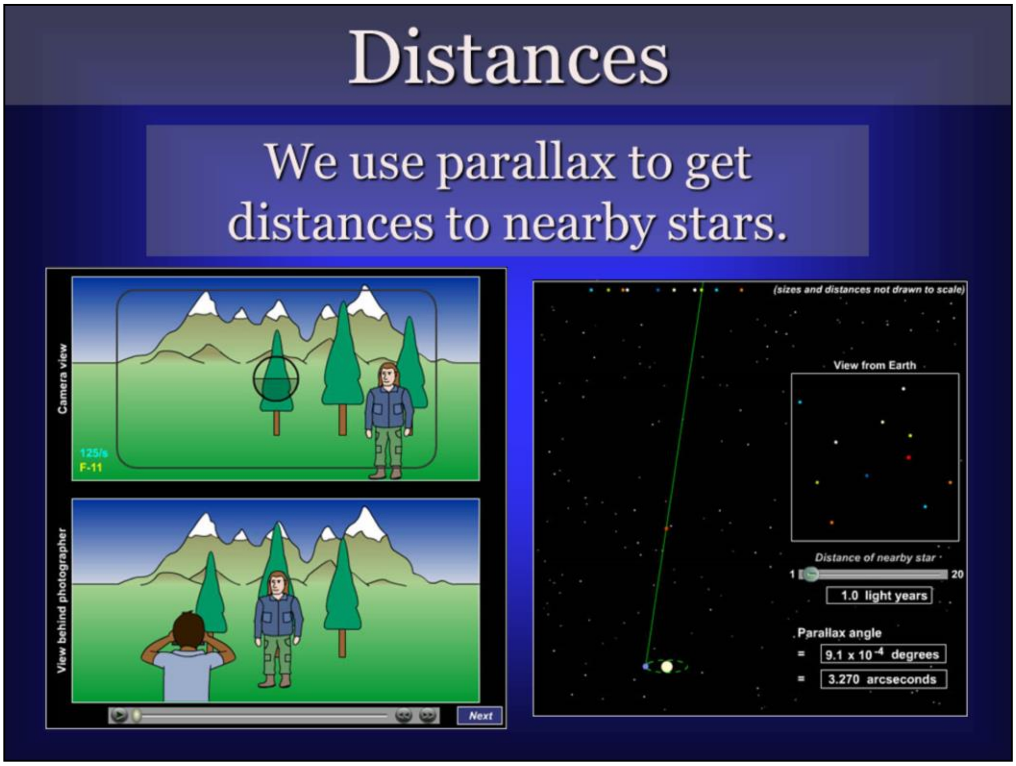
Remember Kepler’s Laws?

The third law relates orbital period to distance.

So, we have distances in terms of the AU, or the average Earth/Sun distance.

Once we know the distance between us and one other planet, we can calculate

the exact value of the AU and get the distance to the Sun



Distances

We use parallax to get distances to nearby stars.

Parallax is something the Greeks expected to see, but couldn't. That's why (one of the reasons) they decided that the Earth isn't moving.

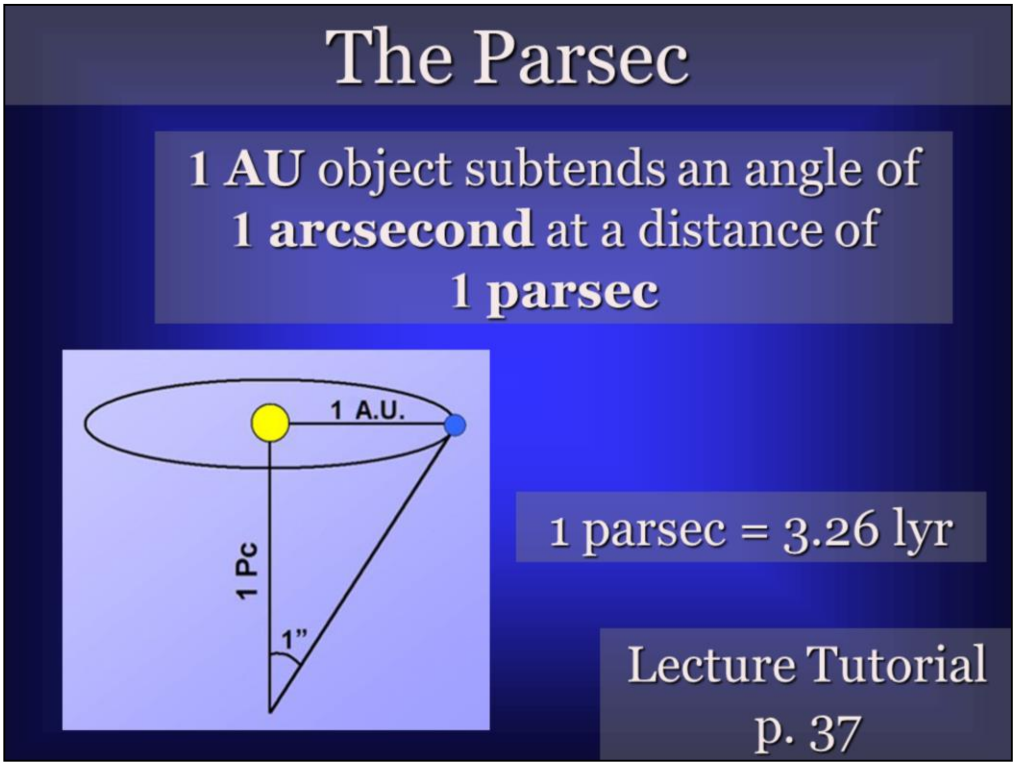
But stars are crazy far away, so their parallax is hard to measure.

We are able to detect the parallax of the nearest stars, within a few hundred light years.

Remember that the Milky Way galaxy is 100,000 light years across.

Parallax is a geometric measurement! Accurate to within detection limits (how well we can resolve the motion). In the late 90's Hipparcos satellite recalibrated all our distance measurements.

Note: This depends on having an accurate measurement of the A.U. – which we got from radar measurements!



The Parsec

1 AU object subtends an angle of **1 arcsecond** at a distance of **1 parsec**

1 parsec = 3.26 lyr

Lecture Tutorial p. 37

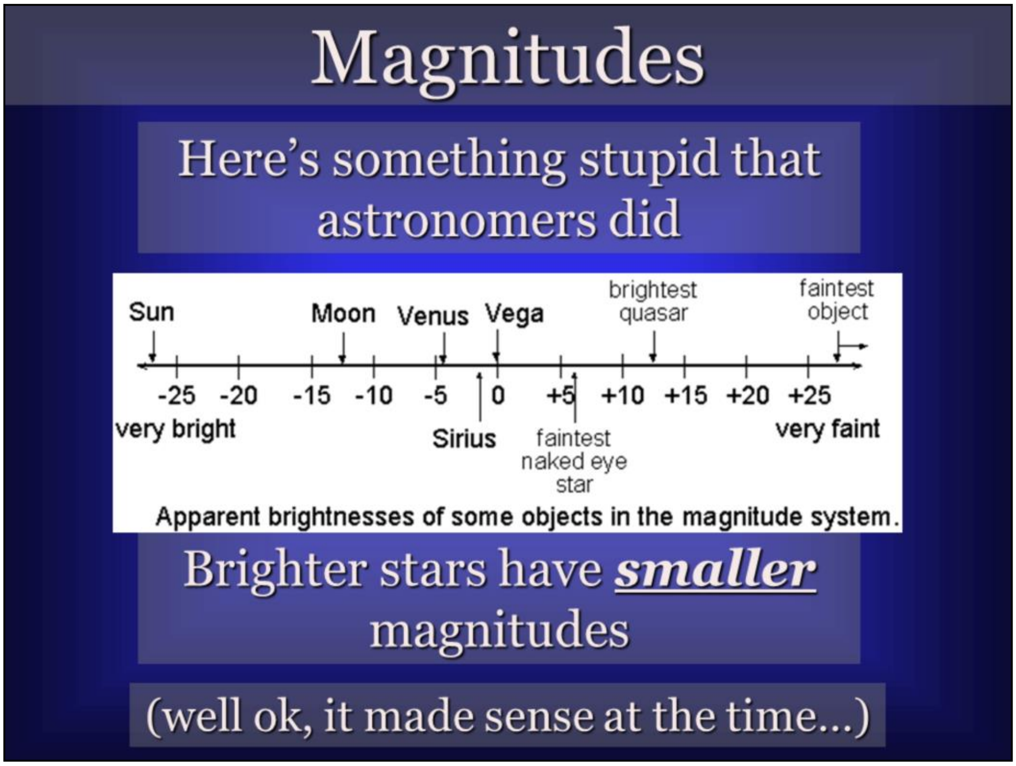
Lecture Tutorial: Parsec p 37 (after talking about below)

Stars

What do we want to know about stars?

Luminosity
Mass
Size (radius)
Temperature (surface, interior)

→ Fusion / physical processes



Magnitudes

Here's something stupid that astronomers did

Apparent brightnesses of some objects in the magnitude system.

Brighter stars have ***smaller*** magnitudes

(well ok, it made sense at the time…)

The magnitude system dates back to Hipparchus.

The brightest stars were called ‘Stars of the First Magnitude’

Next came stars of the second magnitude and so on.

Our eyes respond logarithmically… So the magnitude system is logarithmic.

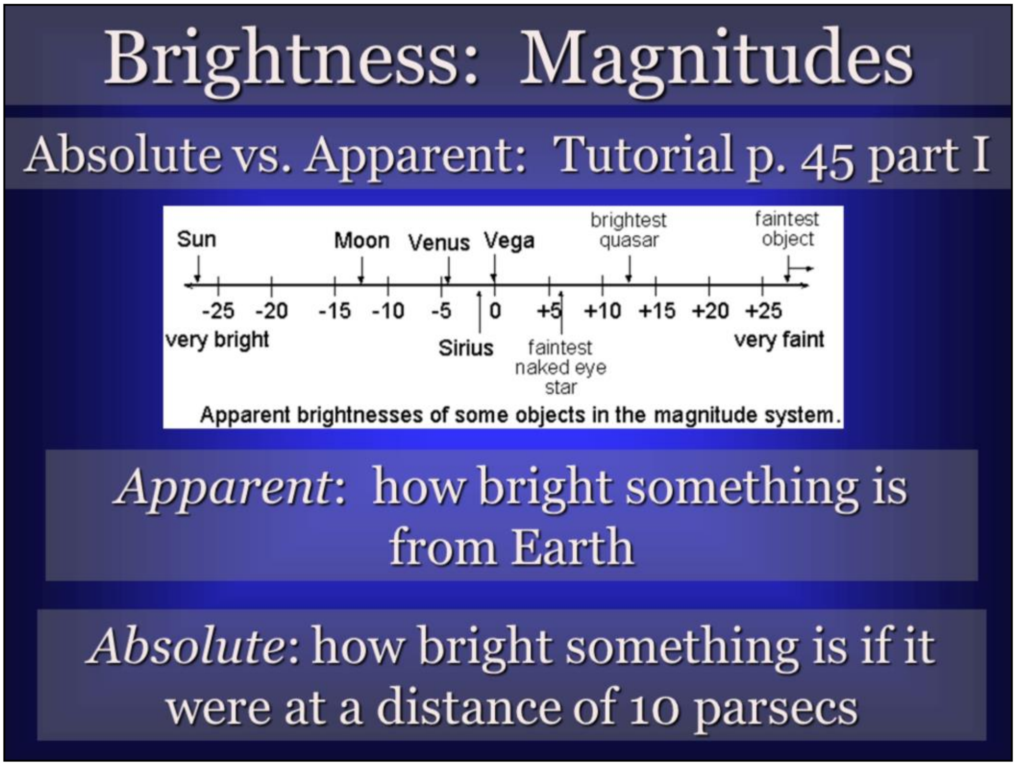
It’s also backwards.

It’s also ‘unitless’, It’s based on the log of the ratio of fluxes.

The flux in the bottom is called the ‘zero point’, as it defines where zero is on the scale.

Vega is the zero magnitude star.

Absolute magnitude is the magnitude that a star WOULD have if it were 10 parsecs away. It is a measure of *intrinsic* brightness.



Brightness: Magnitudes

Absolute vs. Apparent: Tutorial p. 45 part I

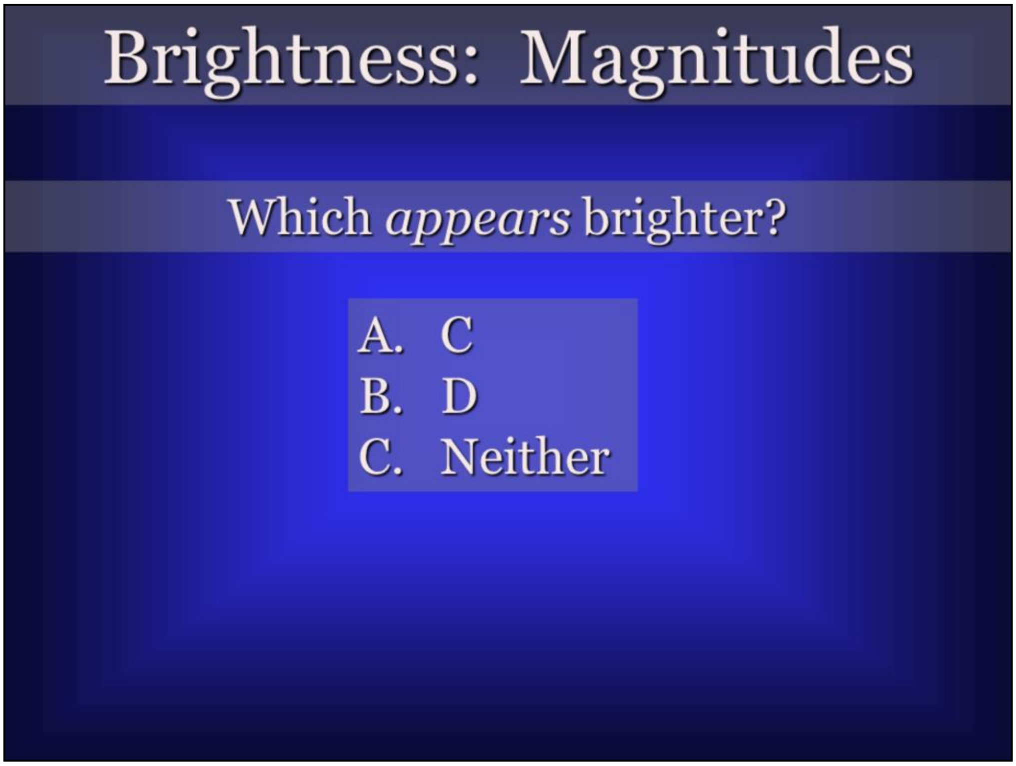
Apparent brightnesses of some objects in the magnitude system.

Apparent: how bright something is from Earth

Absolute: how bright something is if it were at a distance of 10 parsecs

Lecture Tutorial: p45 (questions 1-5 of apparent & abs magnitude of stars)

Absolute is a way to measure how intrinsically bright something is. Why 10 parsecs? Because that's pretty easy to calculate, since the magnitude scale is a logarithmic scale (base 10). It's a convenient choice, just as Vega is our convenient choice for an apparent magnitude of zero.



Brightness: Magnitudes

Which *appears* brighter?

A. C
B. D
C. Neither

Lecture Tutorial: p45 (questions 1-5 of apparent & abs magnitude of stars)

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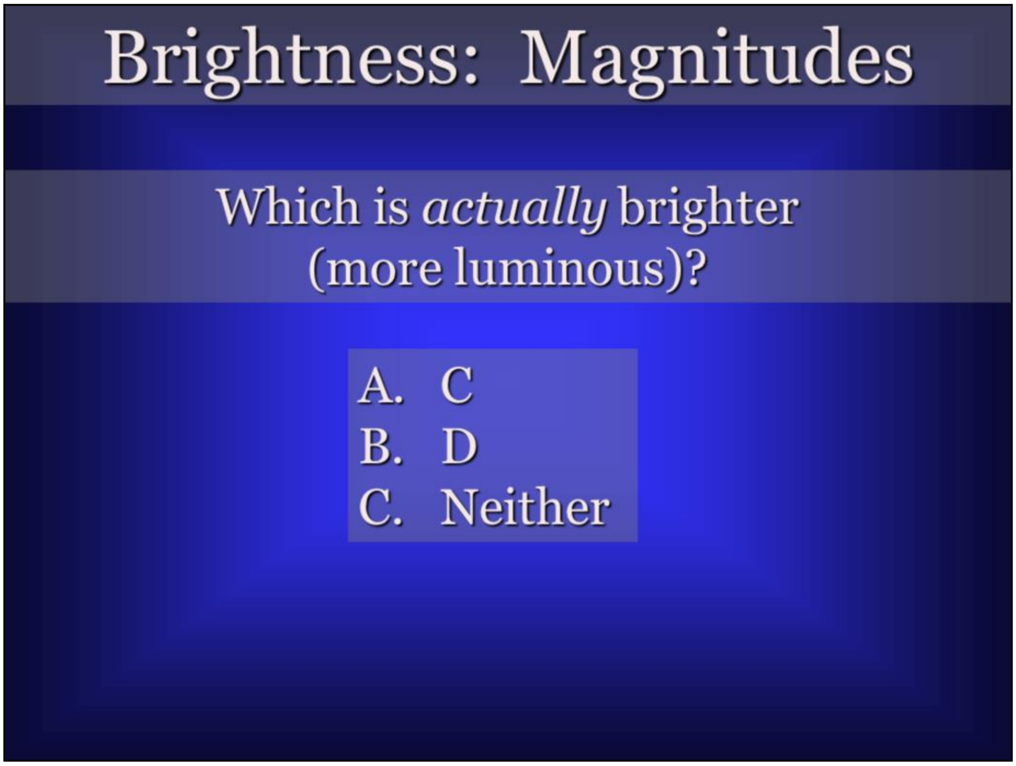

Brightness: Magnitudes

Which is *actually* brighter (more luminous)?

A. C
B. D
C. Neither

Lecture Tutorial: p45 (questions 1-5 of apparent & abs magnitude of stars)

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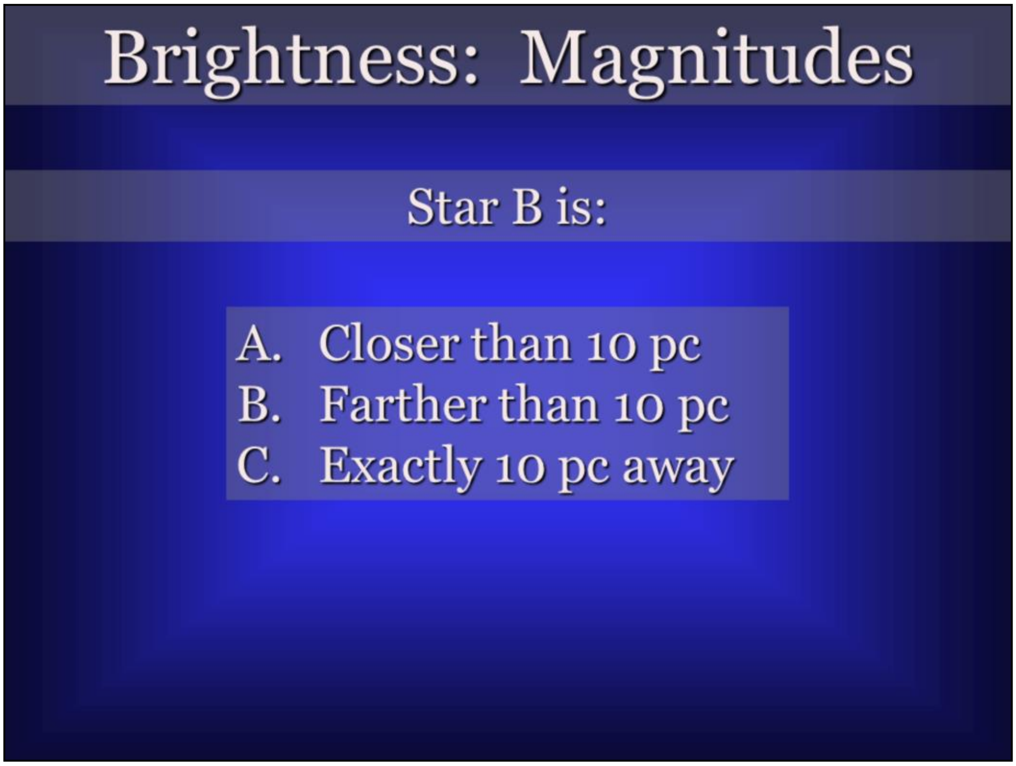


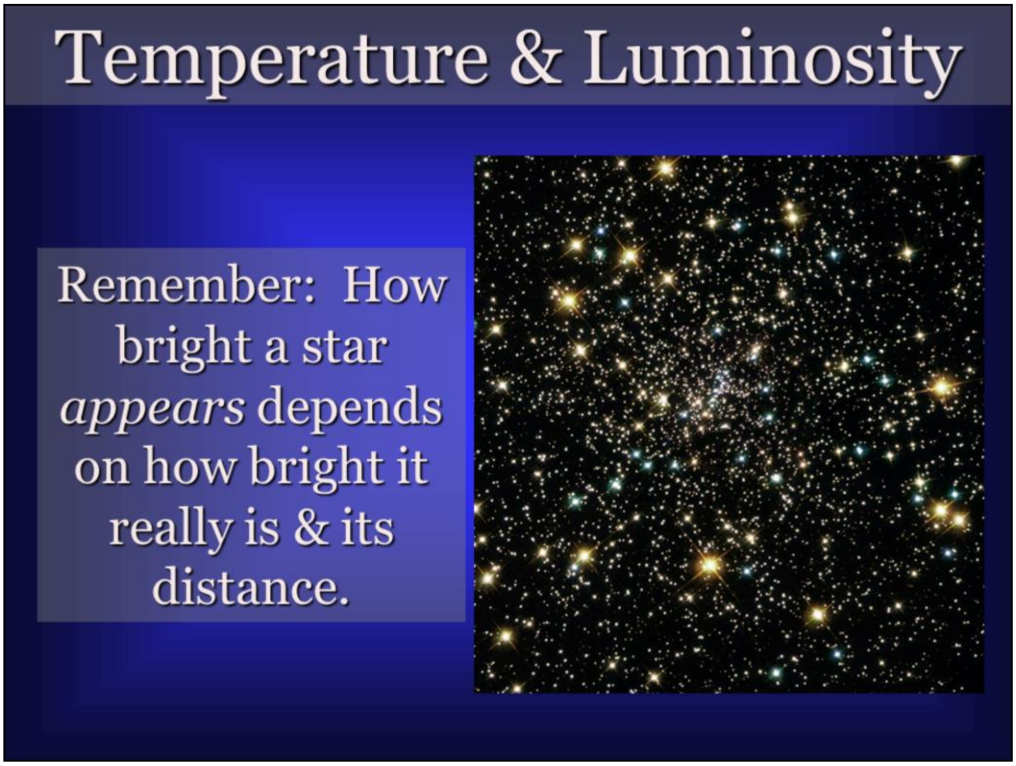
Brightness: Magnitudes

Star B is:

A. Closer than 10 pc
B. Farther than 10 pc
C. Exactly 10 pc away

Lecture Tutorial: p45 (questions 1-5 of apparent & abs magnitude of stars)

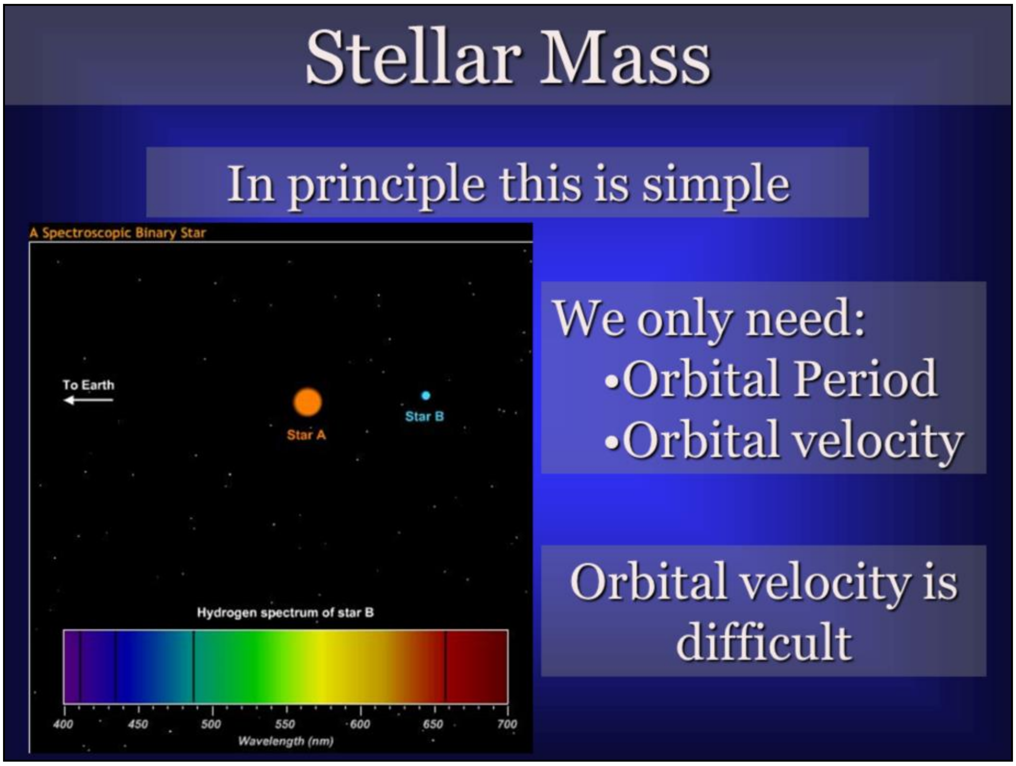
Absolute is a way to measure how intrinsically bright something is. Why 10 parsecs? Because that’s pretty easy to calculate, since the magnitude scale is a logarithmic scale (base 10). It’s a convenient choice, just as Vega is our convenient choice for an apparent magnitude of zero.



Temperature & Luminosity

Remember: How bright a star *appears* depends on how bright it really is & its distance.

But how do we figure out how bright something really is, if we can't get actual distances through parallax?



Stellar Mass

In principle this is simple

We only need:

- Orbital Period
- Orbital velocity

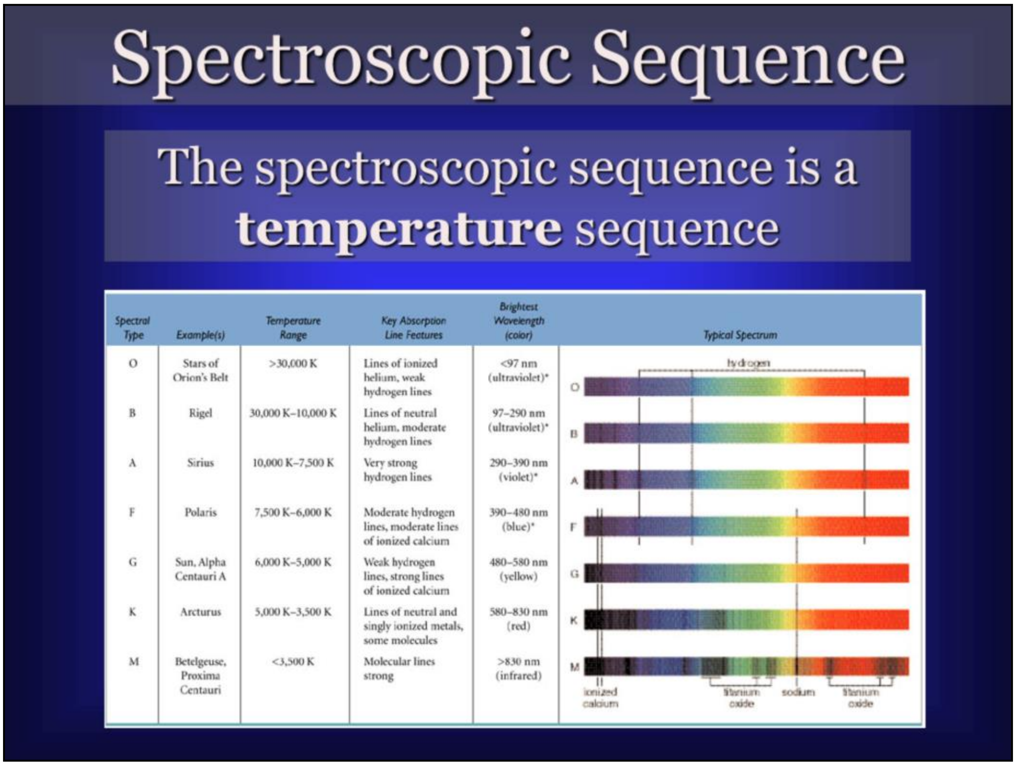
Orbital velocity is difficult

With the orbital period and the orbital velocity, we can apply Newton’s version of Kepler’s third law. This is the same thing that we do for the sun, or for determining Jupiter’s mass using its moons. But we have a slight added complication because you can’t ignore one of the star’s masses.

We can get velocity through doppler shift… but that only gets one component of the velocity.

If the orbital plane is parallel to our line of sight, then we have the entire velocity.

Only a few systems are arranged like this. We can use them to *calibrate* the other stars.



Spectroscopic Sequence

The spectroscopic sequence is a **temperature** sequence

Spectral Type	*Example(s)*	*Temperature Range*	*Key Absorption Line Features*	*Brightest Wavelength (color)*	*Typical Spectrum*
O	Stars of Orion's Belt	>30,000 K	Lines of ionized helium, weak hydrogen lines	<97 nm (ultraviolet)*	
B	Rigel	30,000 K–10,000 K	Lines of neutral helium, moderate hydrogen lines	97–290 nm (ultraviolet)*	
A	Sirius	10,000 K–7,500 K	Very strong hydrogen lines	290–390 nm (violet)*	
F	Polaris	7,500 K–6,000 K	Moderate hydrogen lines, moderate lines of ionized calcium	390–480 nm (blue)*	
G	Sun, Alpha Centauri A	6,000 K–5,000 K	Weak hydrogen lines, strong lines of ionized calcium	480–580 nm (yellow)	
K	Arcturus	5,000 K–3,500 K	Lines of neutral and singly ionized metals, some molecules	580–830 nm (red)	
M	Betelgeuse, Proxima Centauri	<3,500 K	Molecular lines strong	>830 nm (infrared)	

The spectroscopic classification is a temperature sequence. O stars are HOT. M stars are cool.

Why… Bit of history

Edward Pickering was working on stellar spectra. He had an assistant… who didn't do good work. So, he hired his housekeeper, Williamina Fleming.

Williamina Fleming classified the spectra based on the strength of their hydrogen lines. A being the strongest to O for the weakest.

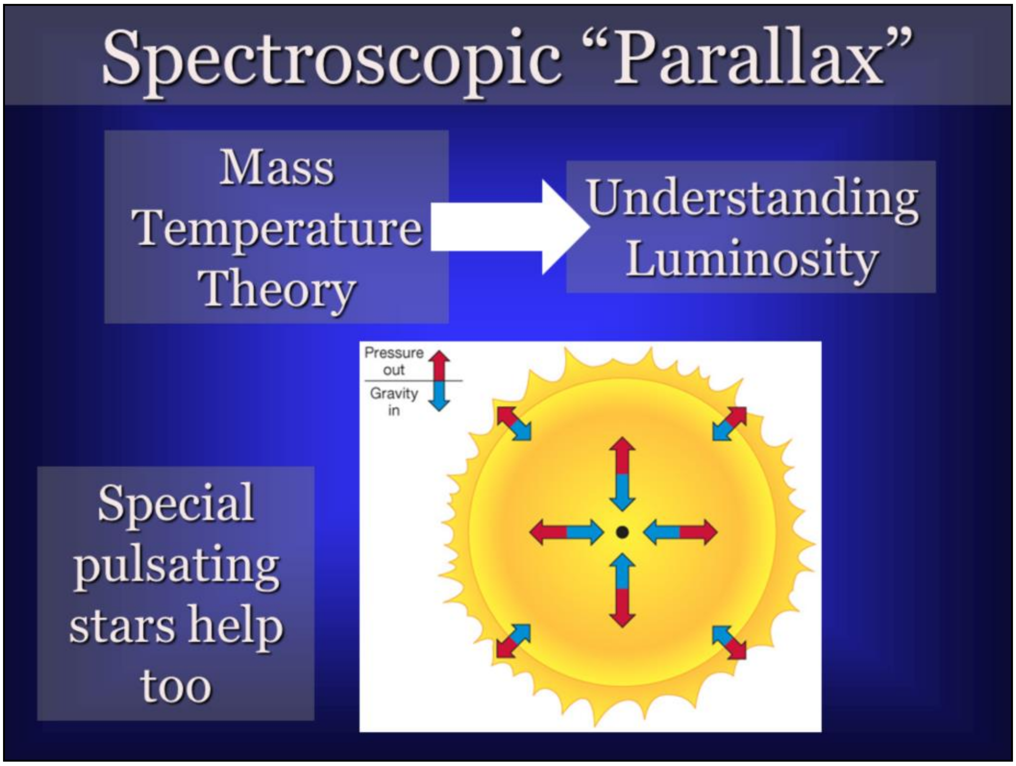
The hydrogen line classification was inadequate

Annie Jump Cannon realized, by looking at other lines, that the classification scheme actually should be in the order OBAFGKM order, eliminating some classifications.

Many astronomers thought that the different sets of lines were dependent on the composition of the star.

Cecilia Payn-Gaposchkin realized that it's a temperature sequence.

Hydrogen reaches a maximum and then goes away due to ionization in the hottest stars. This later led to the realization of the meaning of the underlying blackbody curve. Now we have an easy way to determine temperature.



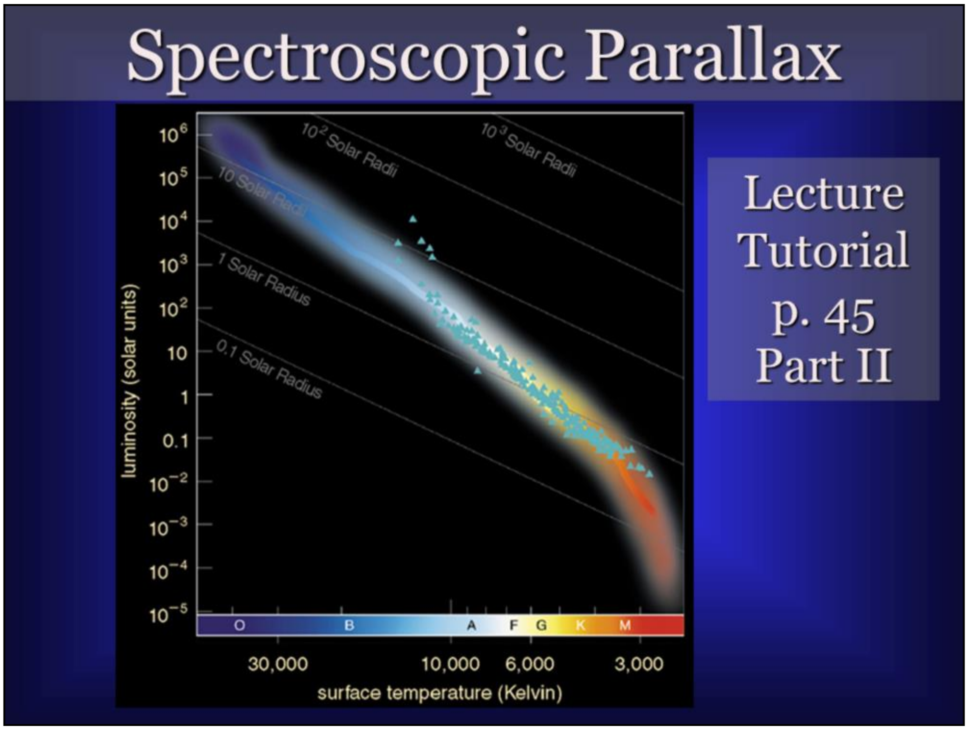
Spectroscopic “Parallax”

Mass
Temperature
Theory

Understanding
Luminosity

Special
pulsating
stars help
too

Cepheid variables have helped us calibrate star luminosities as well. These stars pulse with a very specific period-luminosity relationship. (This is different from the *small* pulsations that most stars undergo)



Spectroscopic Parallax

Lecture Tutorial
p. 45
Part II

Lecture Tutorial: Spectroscopic Parallax, p 45

The technique of using spectroscopic sequence to determine actual luminosity is based on understanding the HR diagram. You get the spectral type of the star in question (take its temperature) and look up what its luminosity should be. Note that the main sequence on the HR diagram has some thickness. (recall that main sequence stars get more luminous as they age)

This causes the distance measurement using a single star to be somewhat inaccurate. *This has nothing to do with geometric parallax.* It's just another stupid name astronomers use.