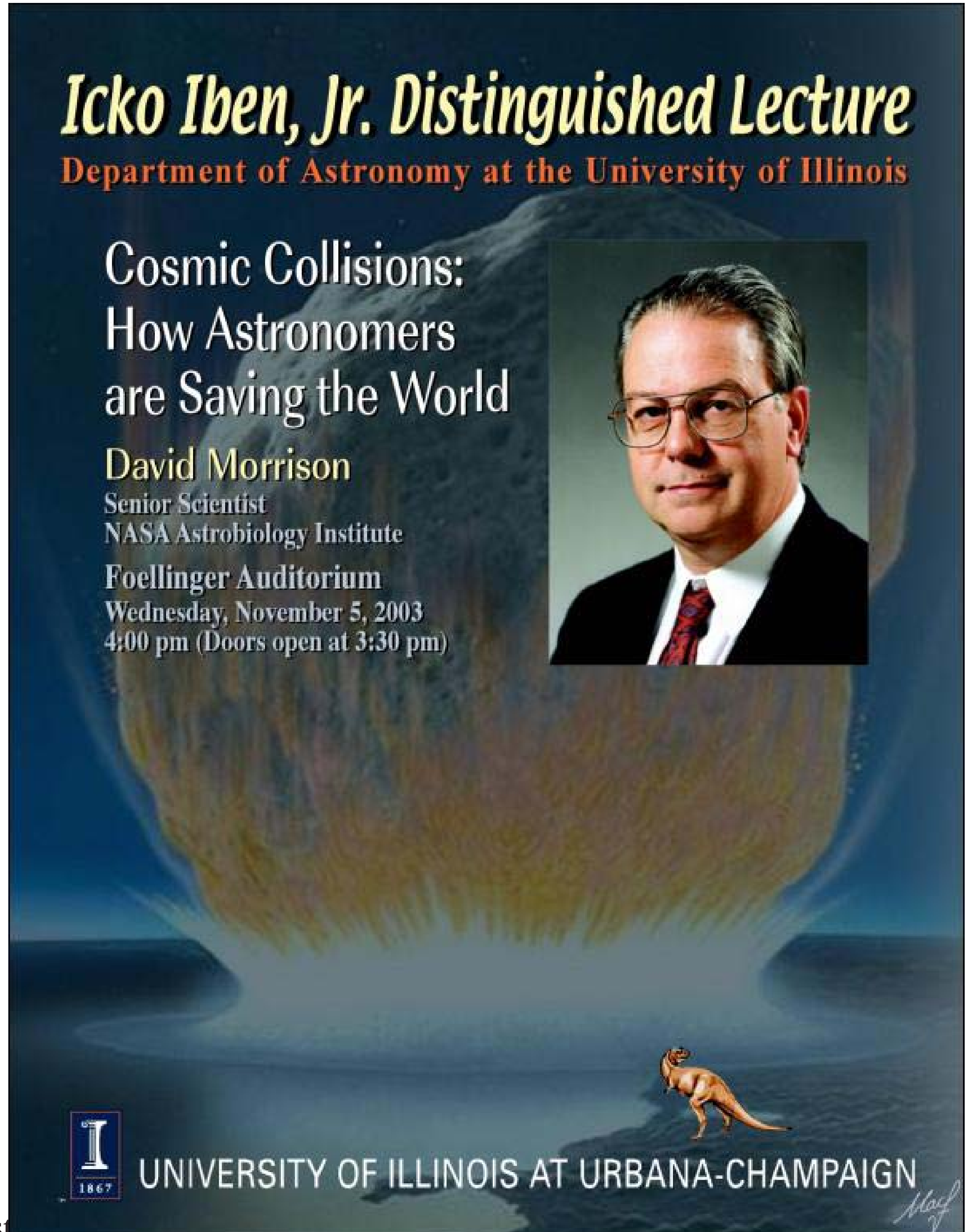
- Next homework is #6– due Friday at 11:50 am.

- There will be another make-up nighttime observing session on Thursday October 30th this week, with a cloud date of November 4th. Stay tuned to the webpage.

Want some extra credit?

- Download and print report form from course web site
- Attend the Iben Lecture on November 5th
- Obtain my signature *before* the lecture and answer the questions on form. Turn in by Nov. 14th
- Worth 12 points (1/2 a homework)

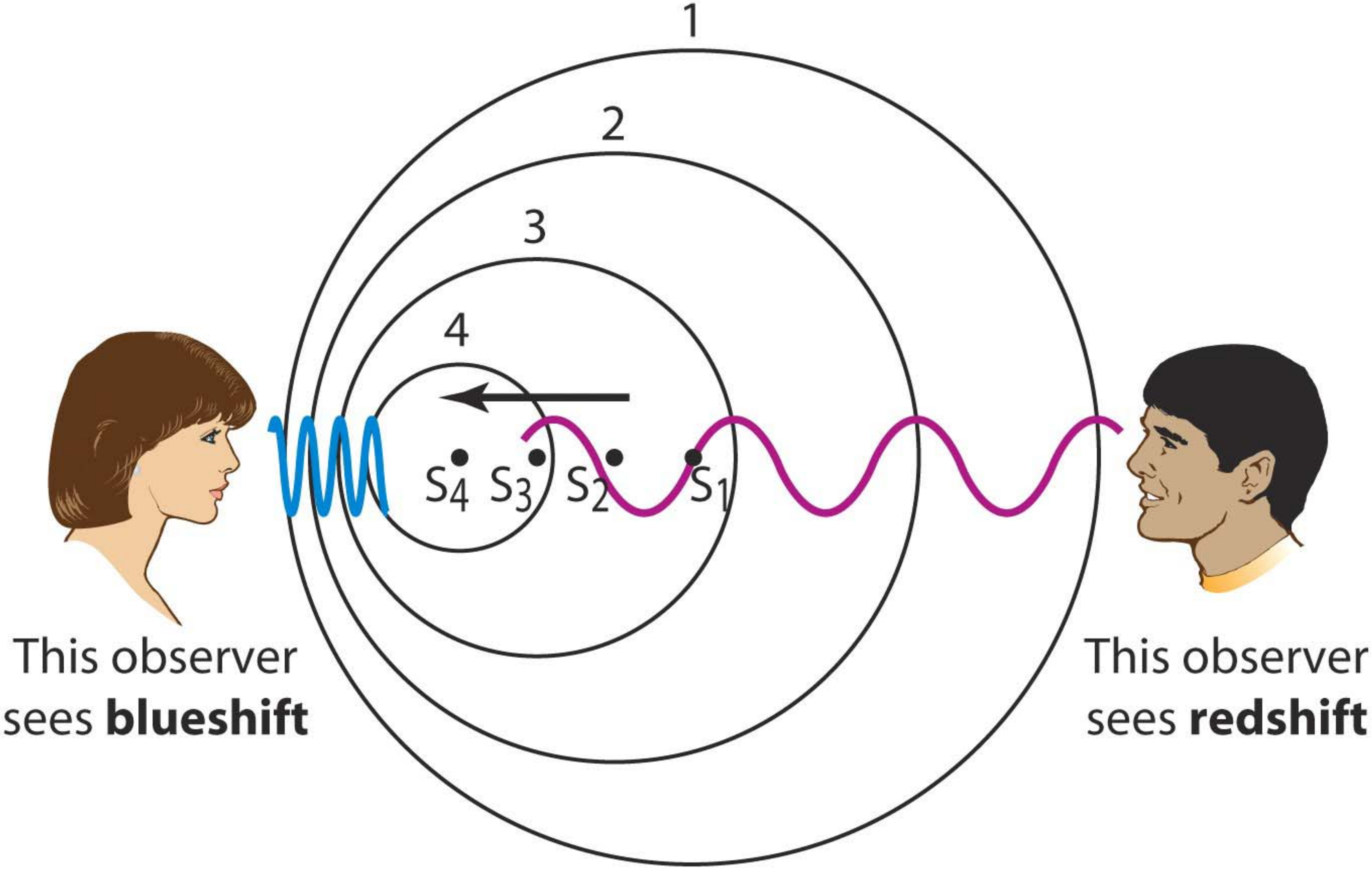


Outline

- Doppler shift– also shifts light
- Apparent Brightness compared to Absolute Brightness
- Move away from the Solar System– onto stars!
- How to tell how far away a star is– parallax.
- A stellar consensus
- The HR Diagram– it's your friend.
- Main Sequence Stars, Giants, Super Giants, White Dwarves, Red Dwarves, Brown Dwarves, and Black Dwarves

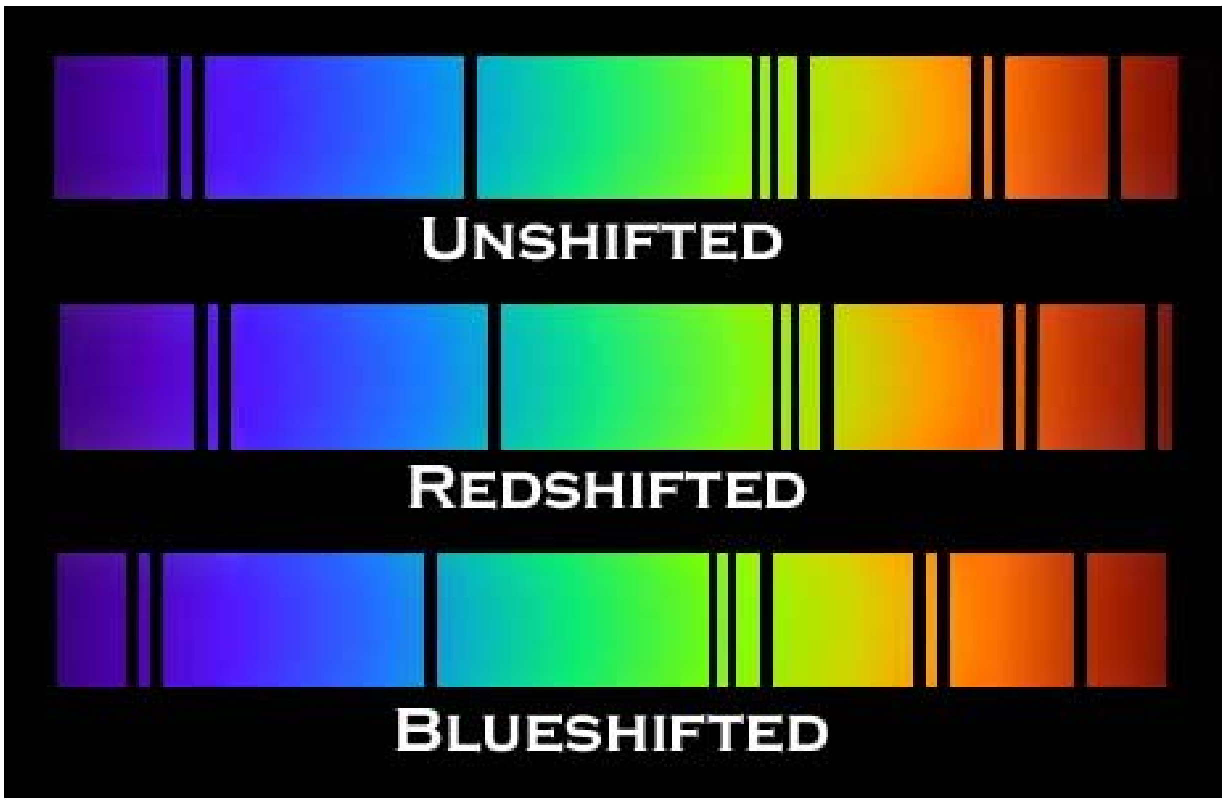
The Doppler Effect

The amount of the shift in wavelength depends on the relative velocity of the source and the observer

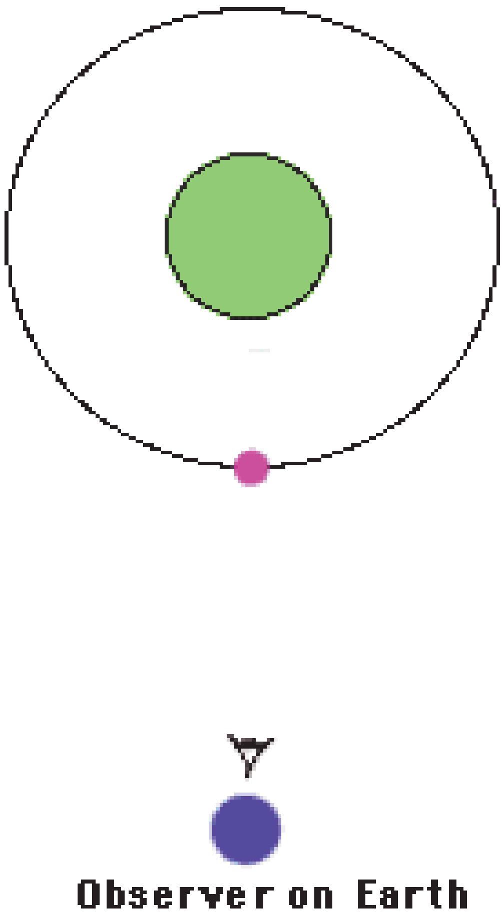


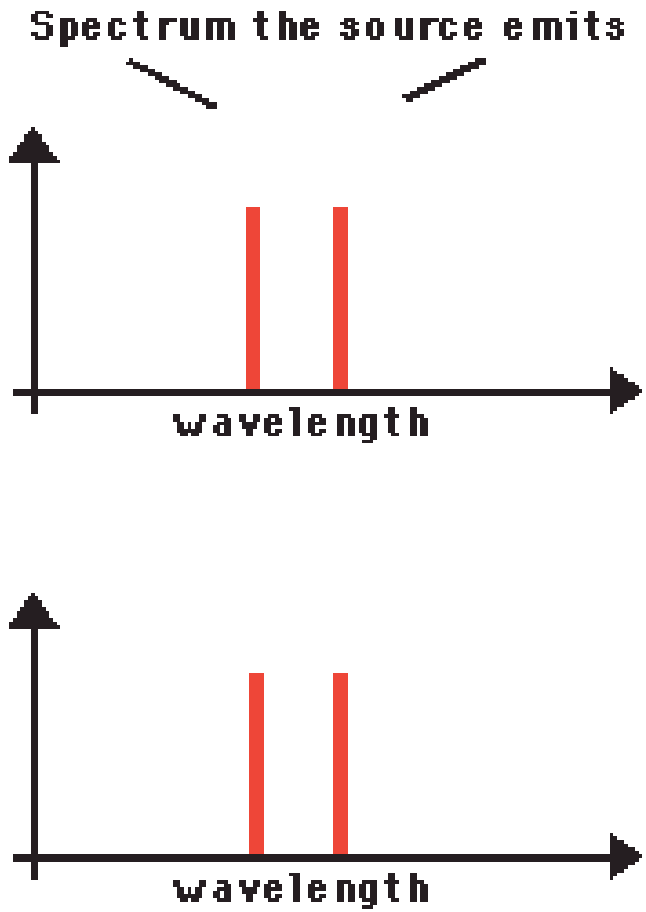
Applying Doppler Shift to Light

We can use the Doppler shift as a shift in the wavelength of spectral lines to determine the speed of the source of light– either **toward** or **away** from us.



Using Spectral Lines to Detect Line-of-Sight Motion

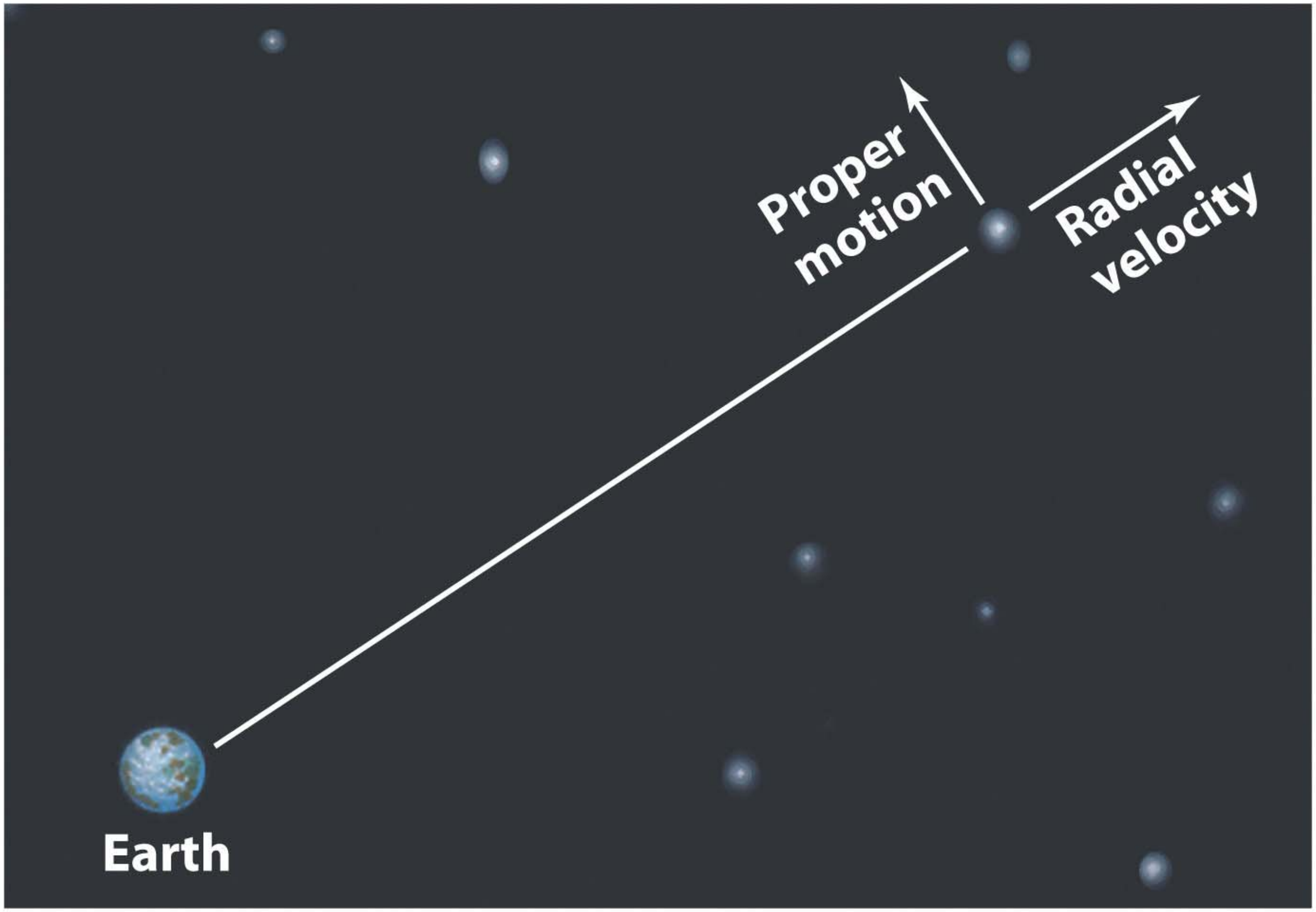




http://cosmos.colorado.edu/astr1120/lesson1.html

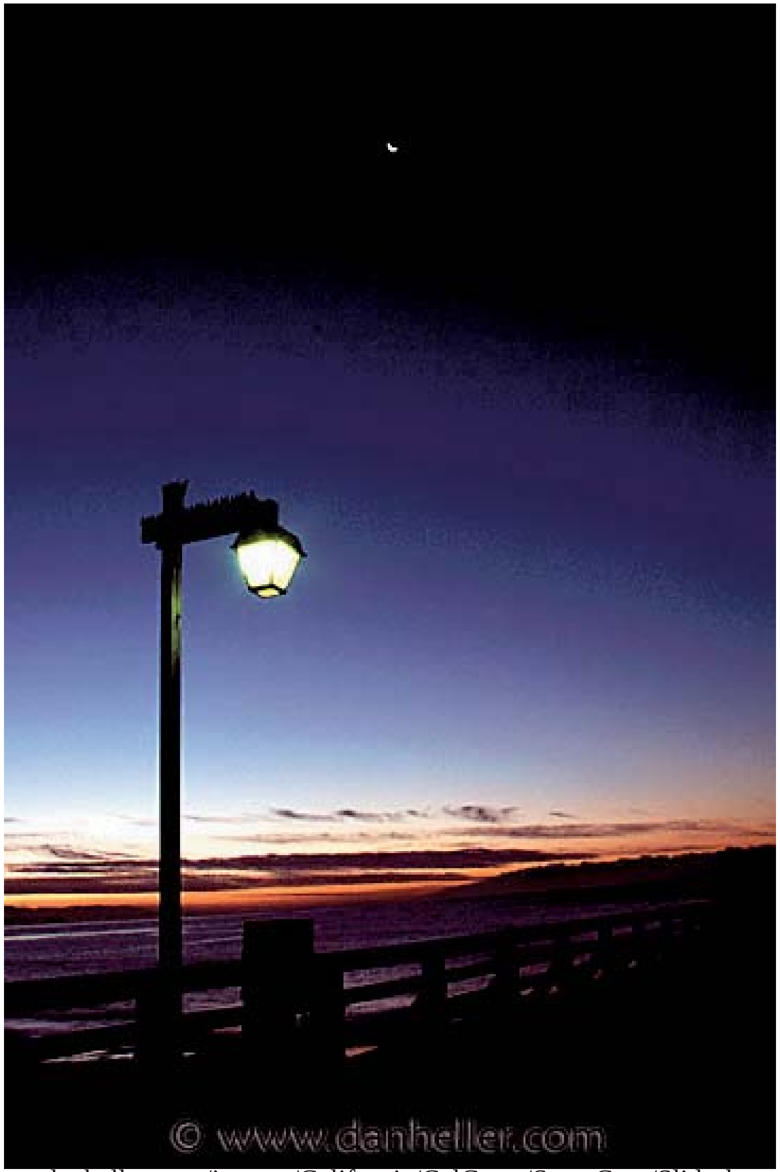
Proper Motions vs. Radial Motions

- **Proper motion** is the part of an object's velocity perpendicular to the line of sight
- The Doppler shift only gives us the line-of-sight motion, not the proper motion



Which is Brighter?

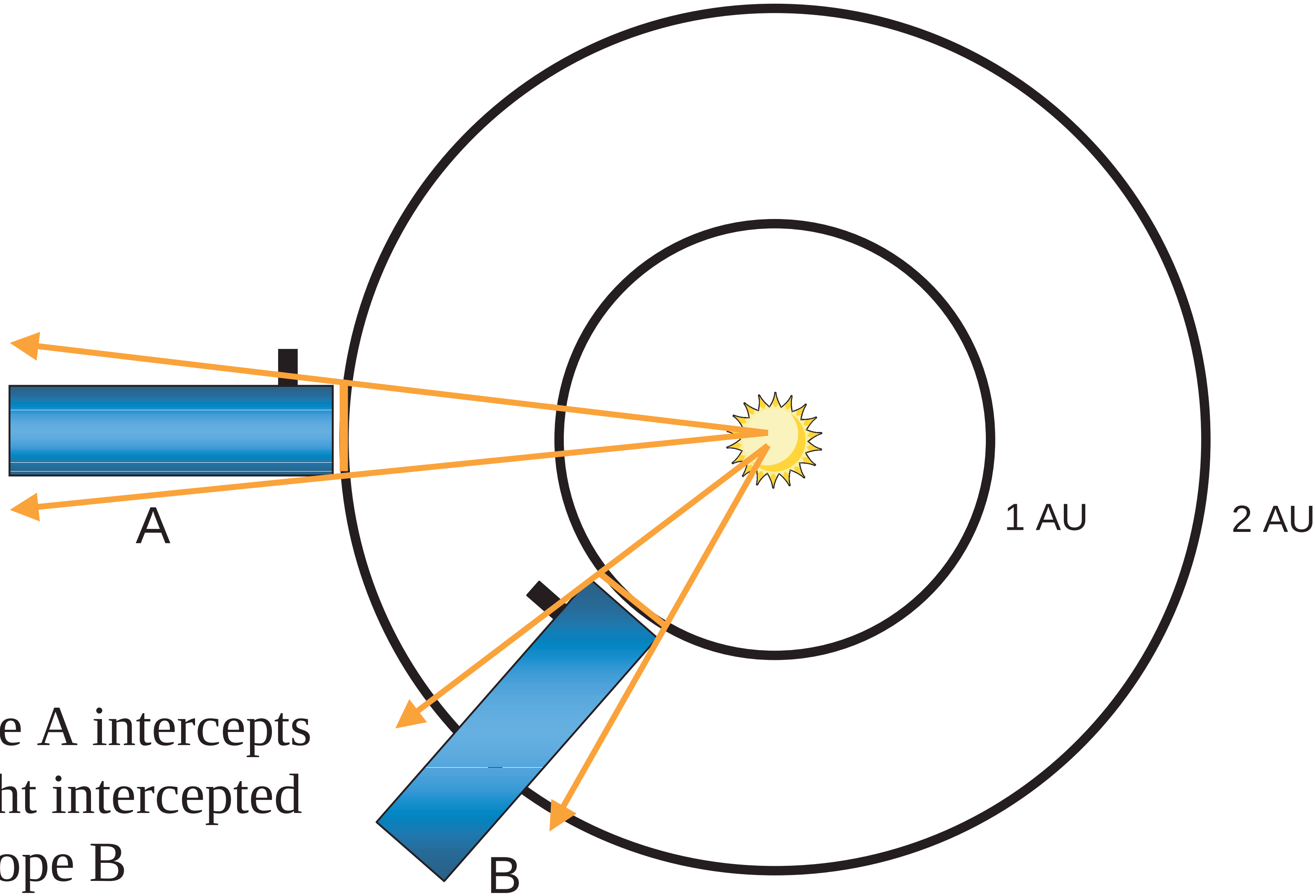
- The Moon or the streetlamp?
- Why?
- Apparent brightness and luminosity difference.



http://www.danheller.com/images/California/CalCoast/SantaCruz/Slideshow/img13.html

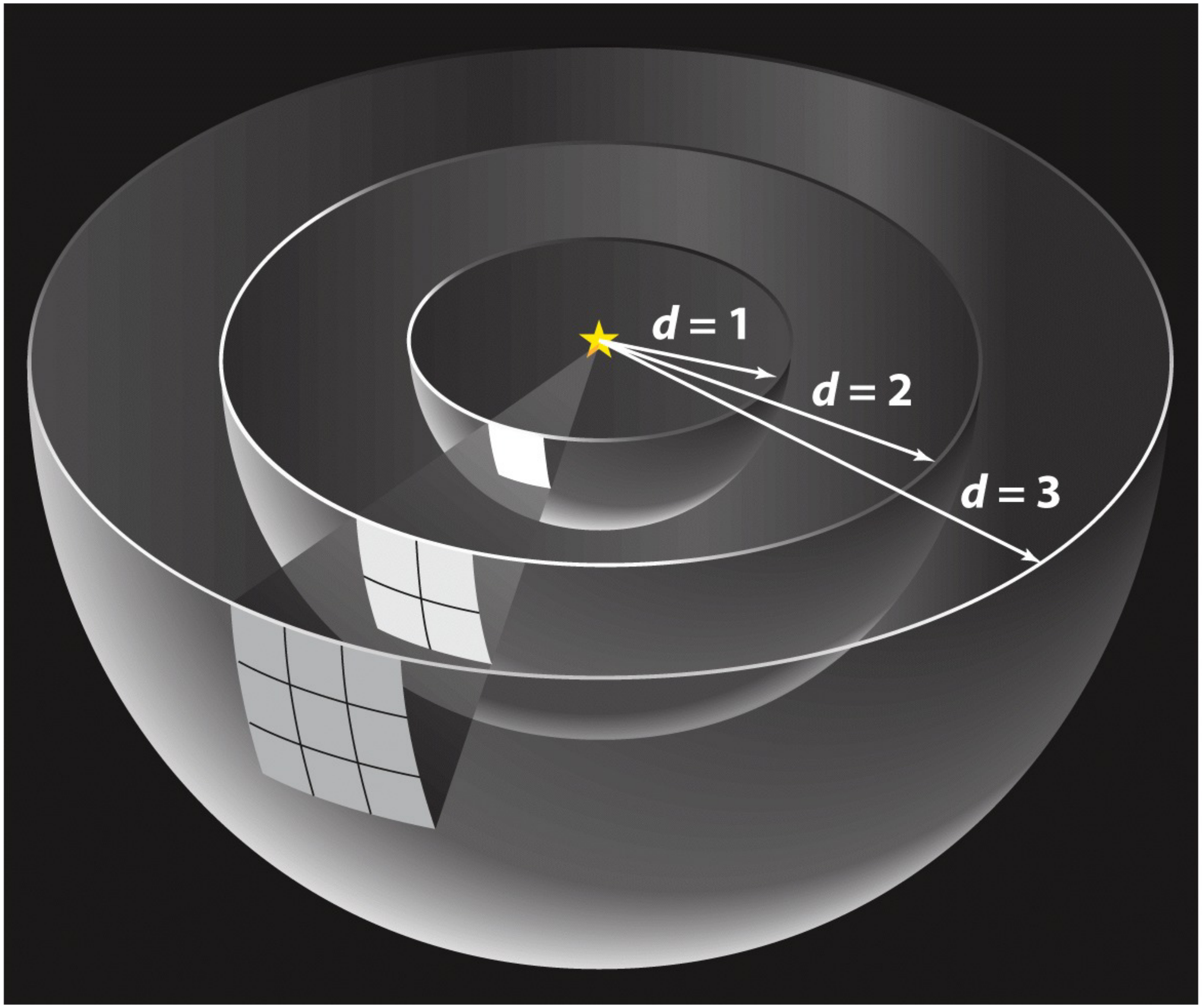
Why do more distant objects look so much fainter?

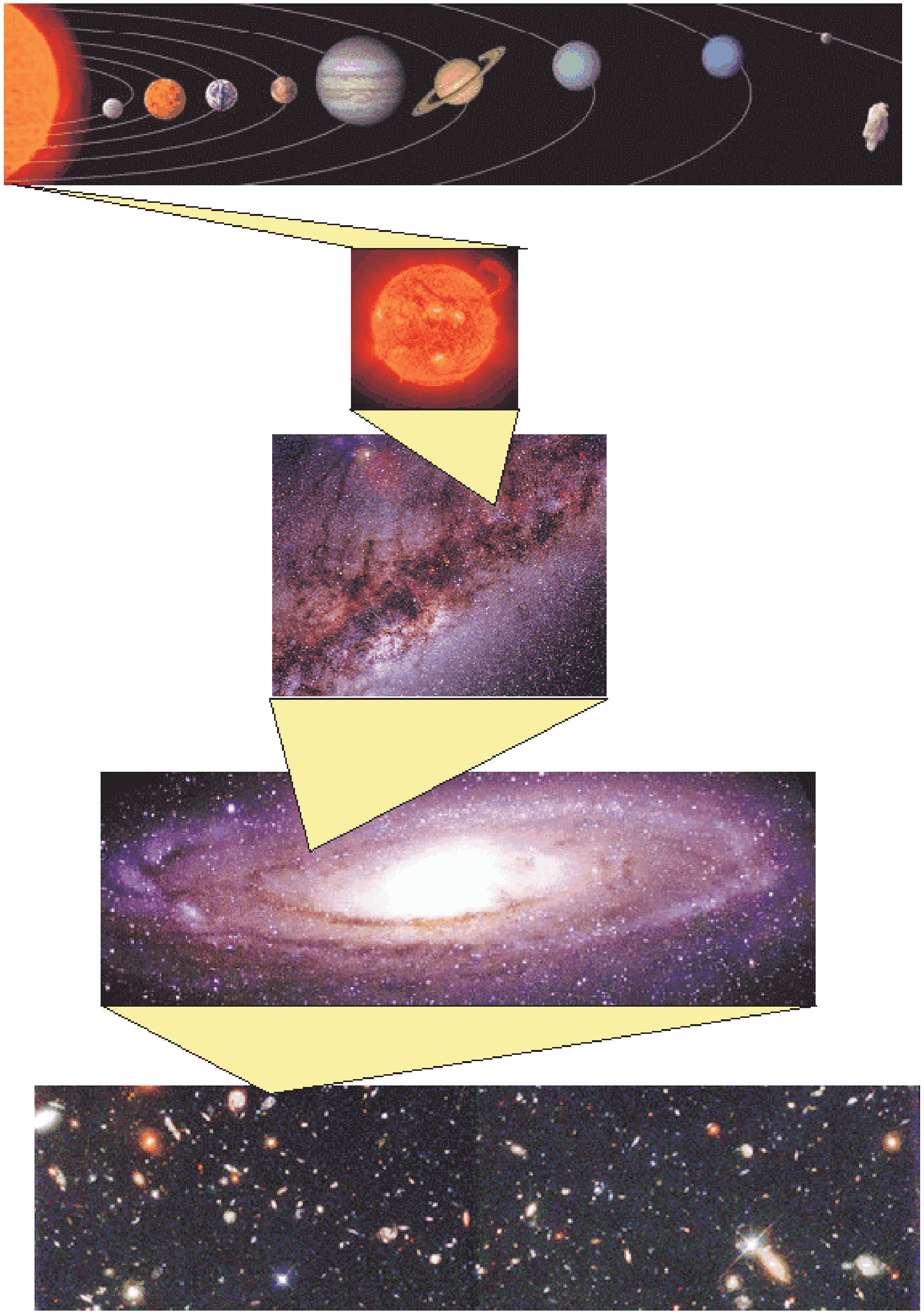
- More distant stars of a given luminosity appear dimmer
- Apparent brightness drops as square of distance



Telescope A intercepts ¼ the light intercepted by telescope B

Same number of Photons, but more area.

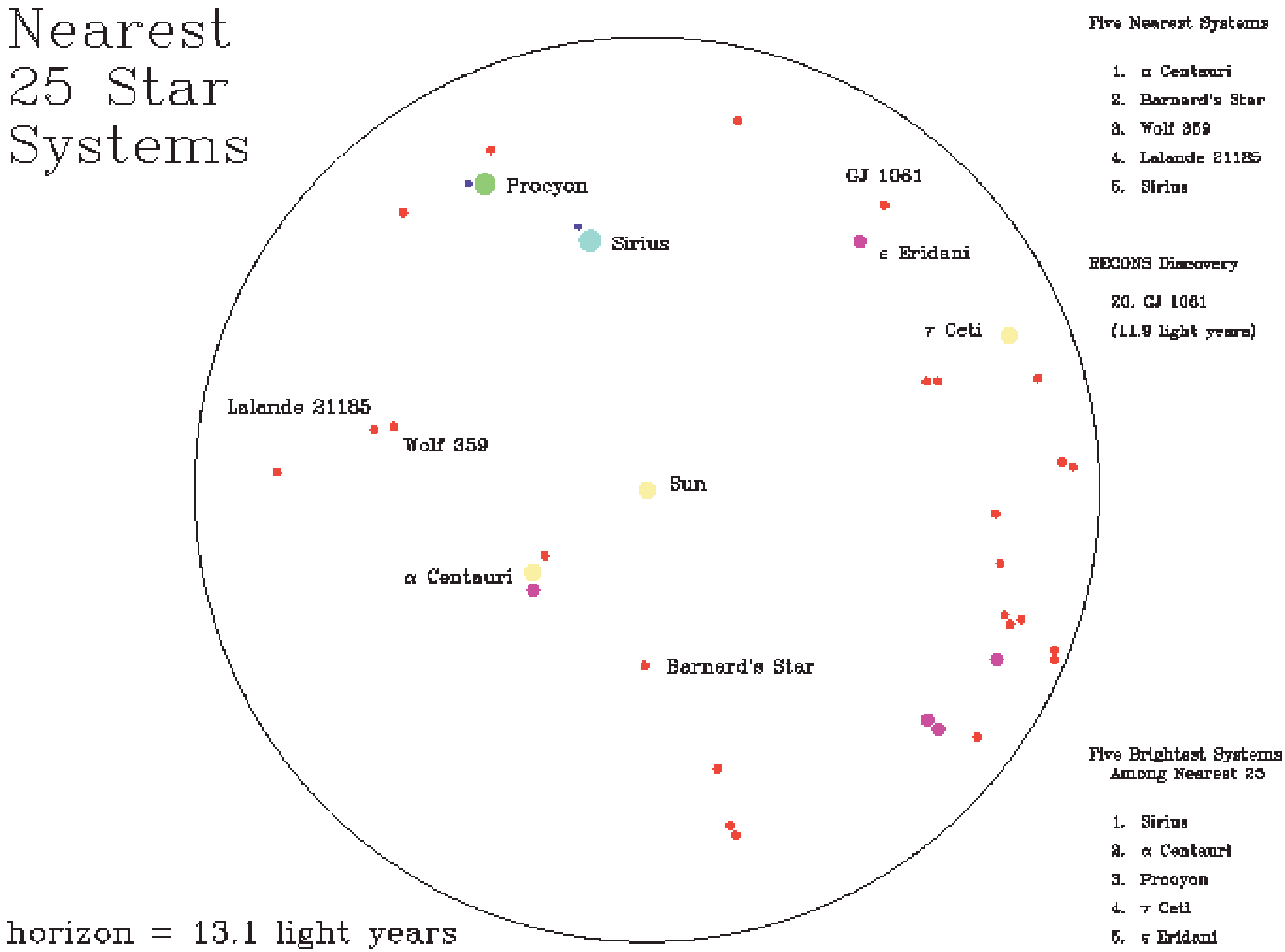




Astronomy: The Big Picture

Now, on to other stars!

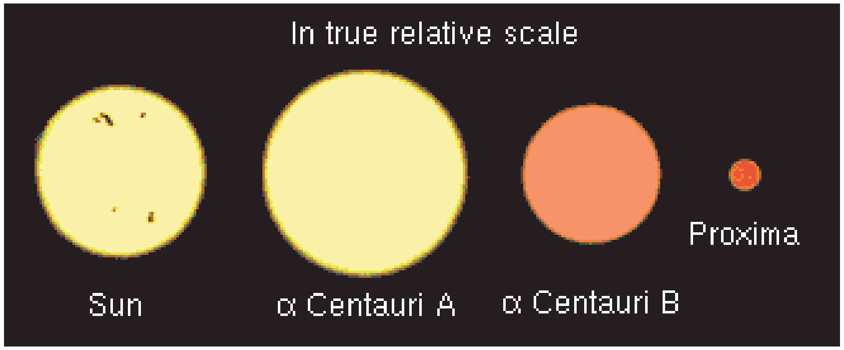
Our Nearest Neighbors

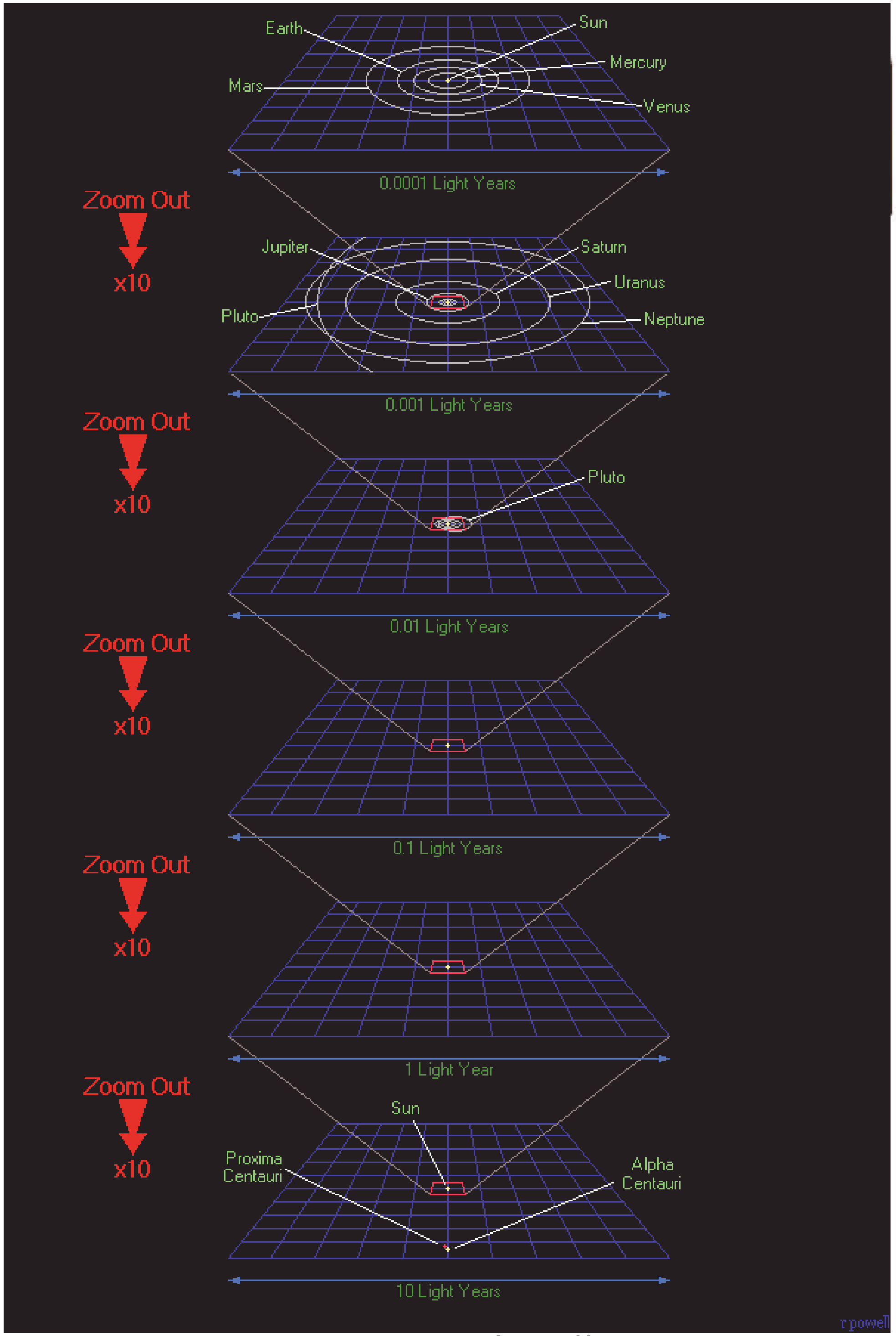


http://antwrp.gsfc.nasa.gov/apod/ap010318.html

Leaving Home

- Nearest star is 4 x 10^{13} km away (more than 5000x distance to Pluto) or around 4 light years. The Alpha Centauri triple system– the closest being Proxima.
- Walking time: 1 billion years
- Fastest space probes (Voyagers 1 & 2, Pioneers 10 & 11) – 60,000 years at about 3.6 AU/year.

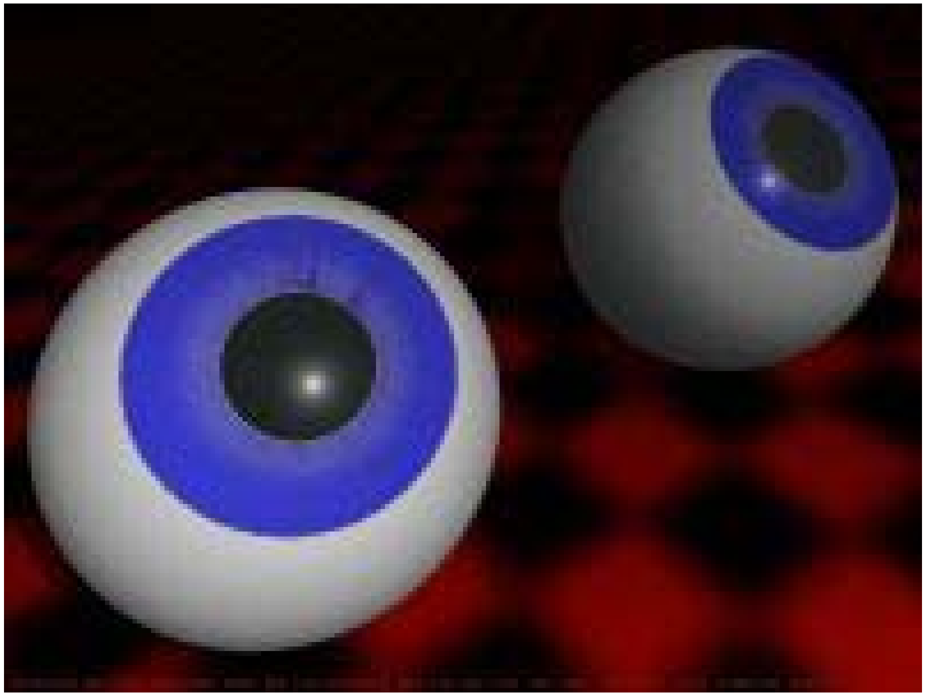




http://www.anzwers.org

Parallax– Is Triangulation

If one loses the use of an eye, then it becomes very difficult to judge distances. Usually, each of your eyes observe objects with slight shifts in position. When objects are closer, the effect is larger. Stereo-vision!

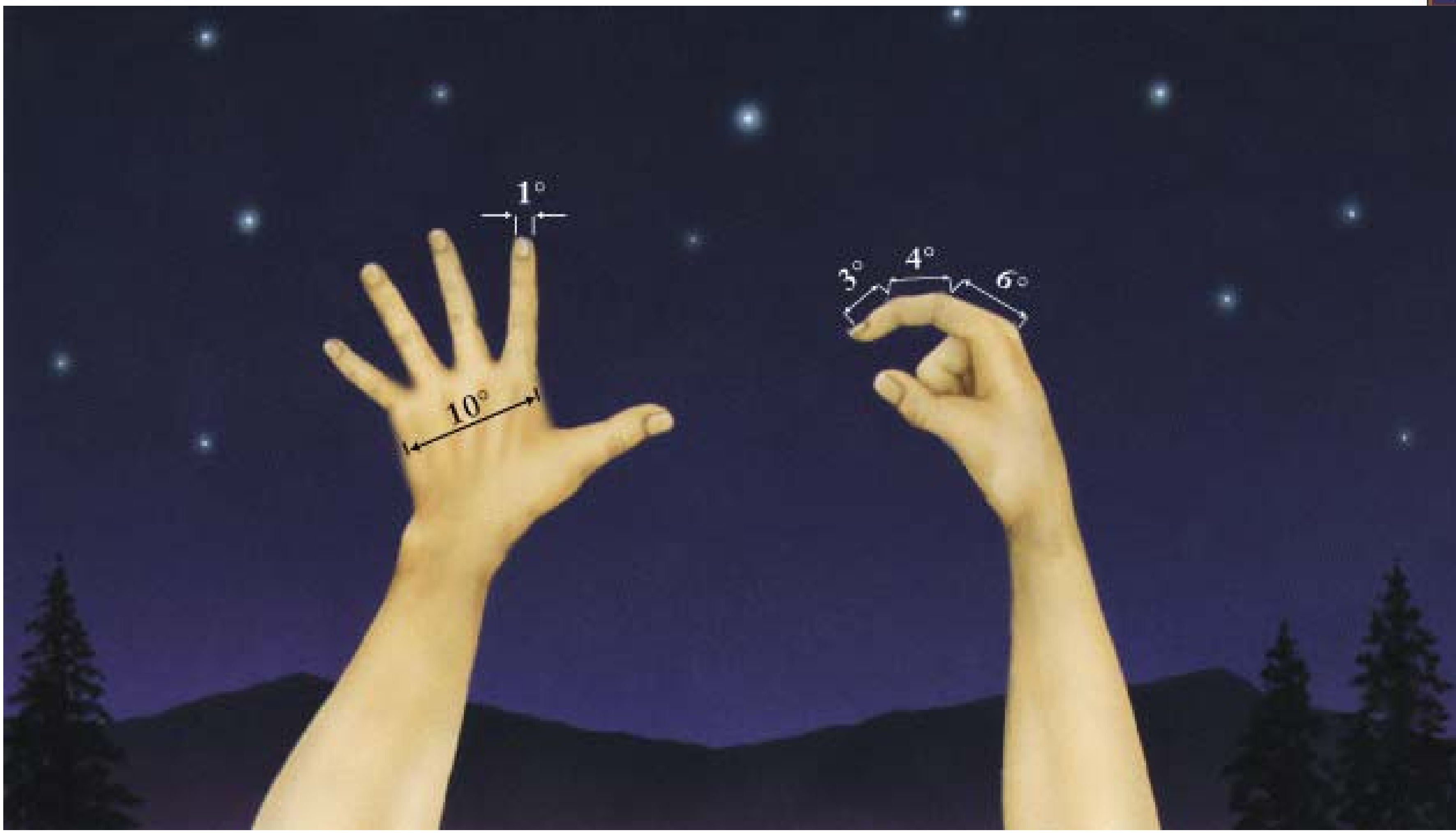


http://www.kidsdomain.com/holiday/halloween/clipart/eyes.jpg

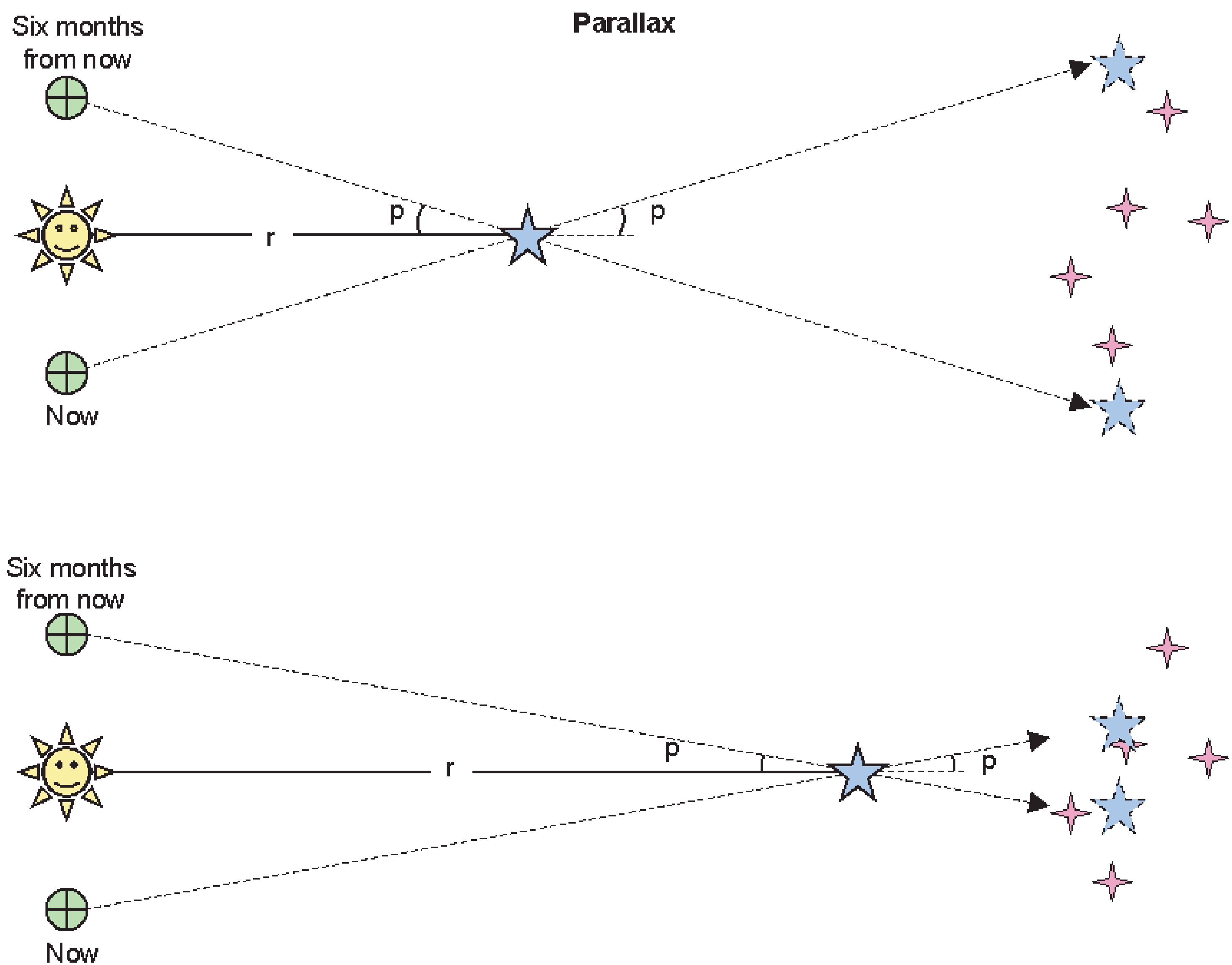
How Astronomers Measure Parallax.

- Look at a star compared to background stars– and wait 6 months.
- How much, if any, have the stars moved?

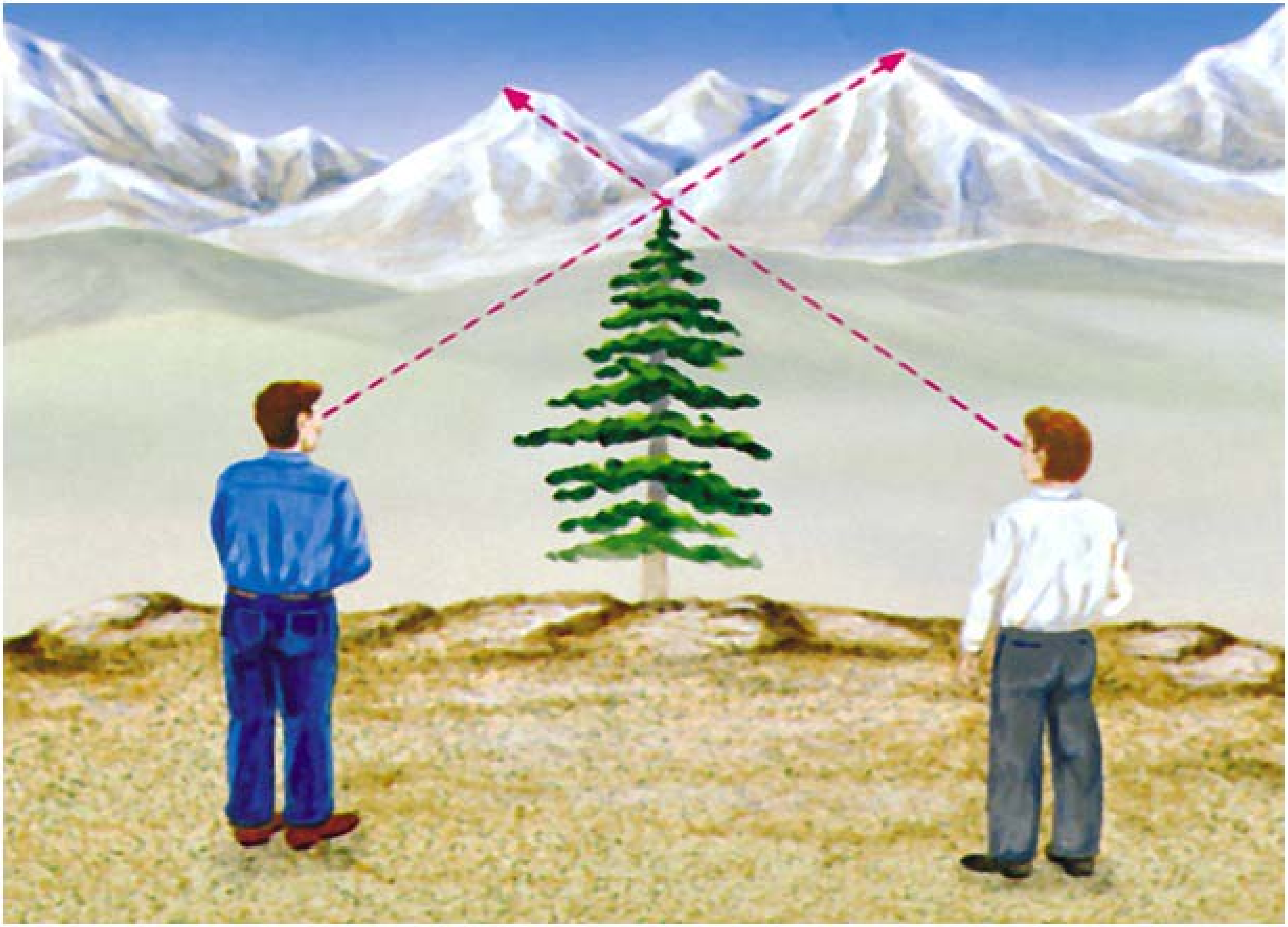
Angular Sizes



How far away am I– with parallax?


Parallax
Six months from now
p
p
r
Now
Six months from now
p
p
r
Now

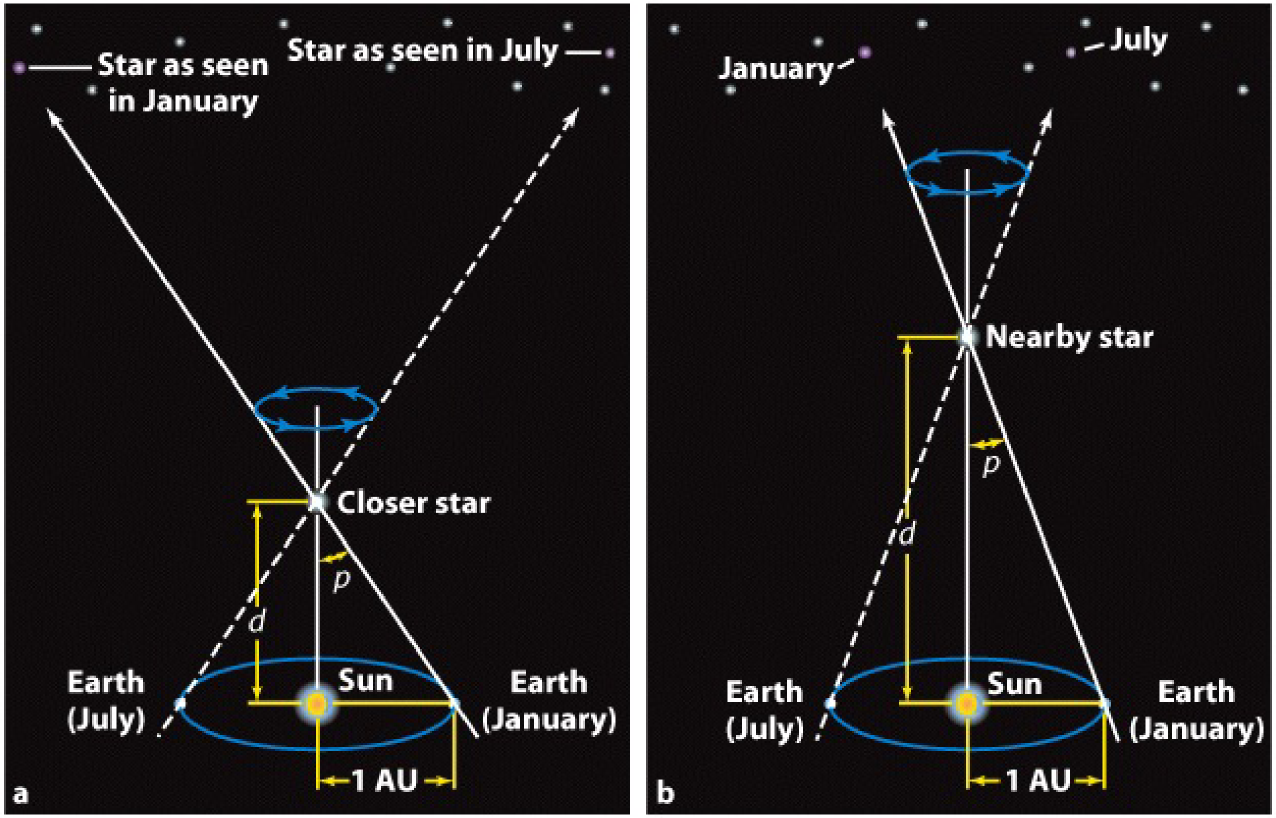
Parallax



http://www.astro.ubc.ca/~scharein/a310/Sim.html#Parallax

The Relationship Between Parallax and Parsec

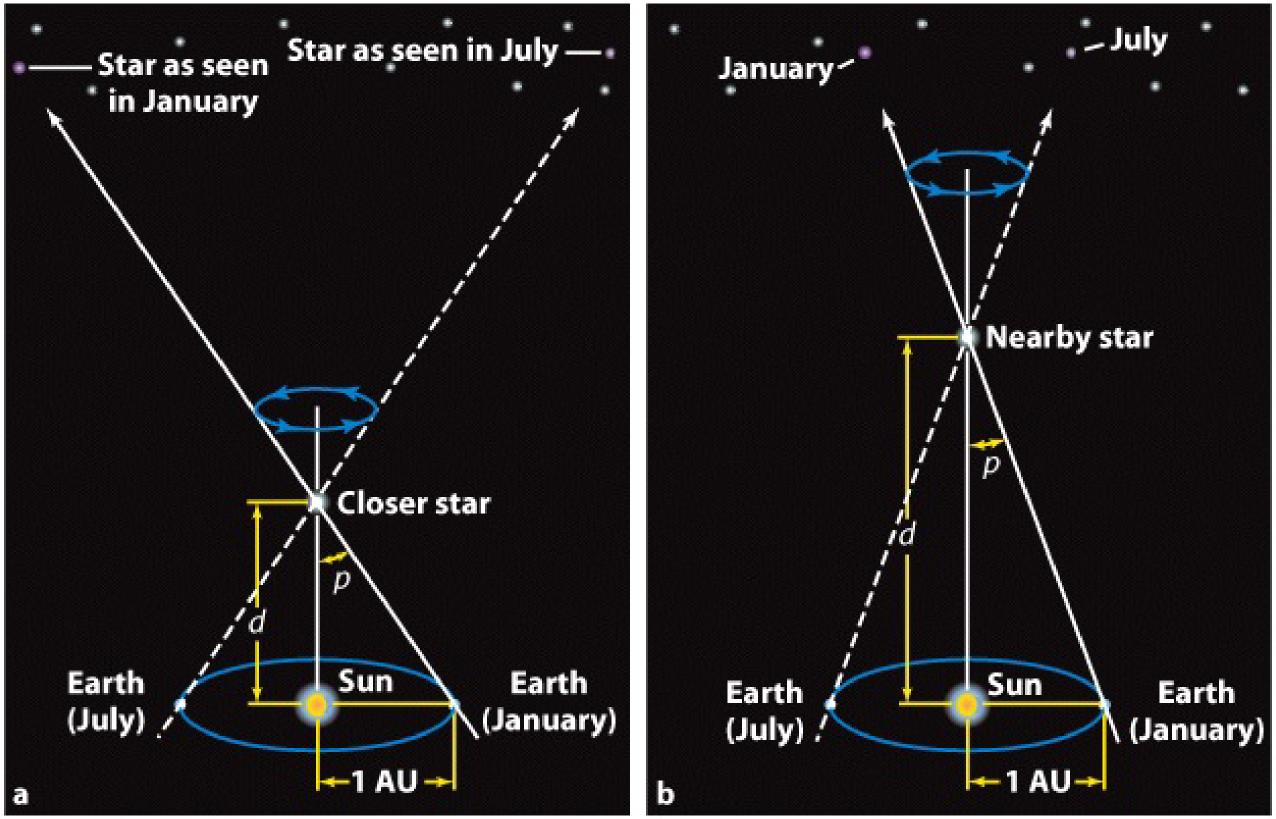
1 parsec (1 pc) = distance at which the radius of the Earth's orbit would subtend an angle of 1 arcsecond (1/3600 degree)



The Relationship Between Parallax and Parsec

1 parsec (1 pc) = 3.09×10^{13} km = 3.26 light years

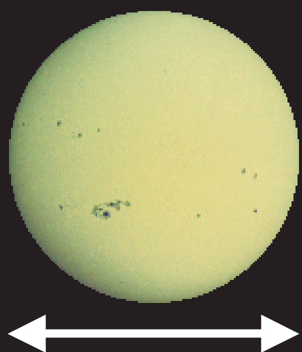
The further away the star, the smaller the parallax angle. Works out to about 50 pc.



$$\text{Distance to a star in parsecs} = \frac{1}{\text{Star's parallax in arcseconds}}$$

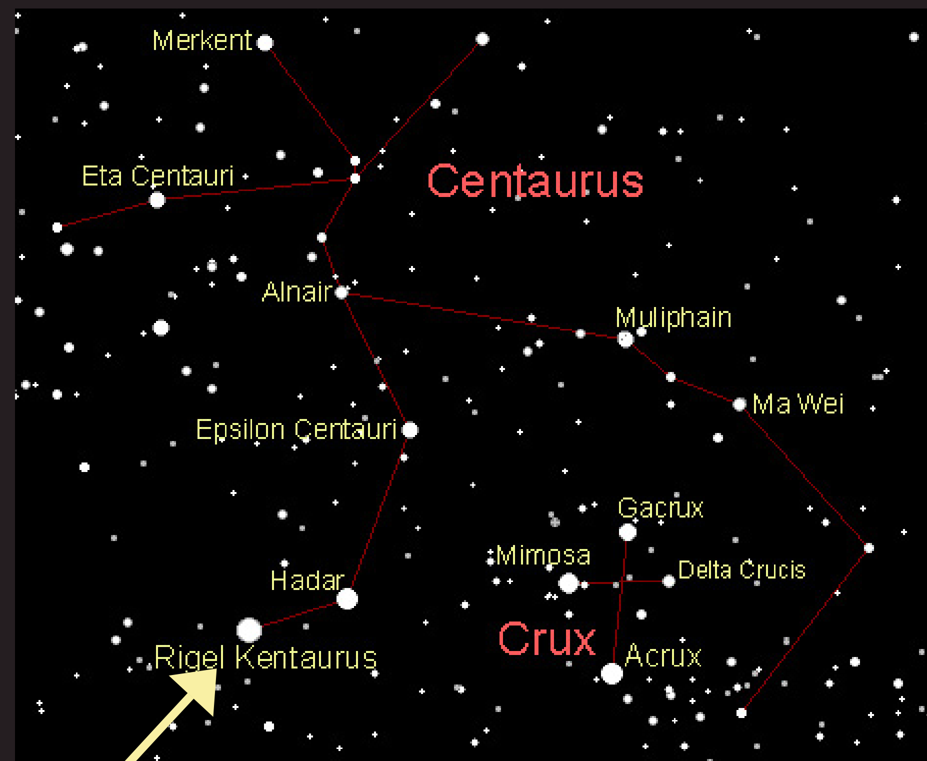
The Distances to the Stars

Sun's disk seen from Earth



½ degree = 1800 arcsec

Dime at arm's length

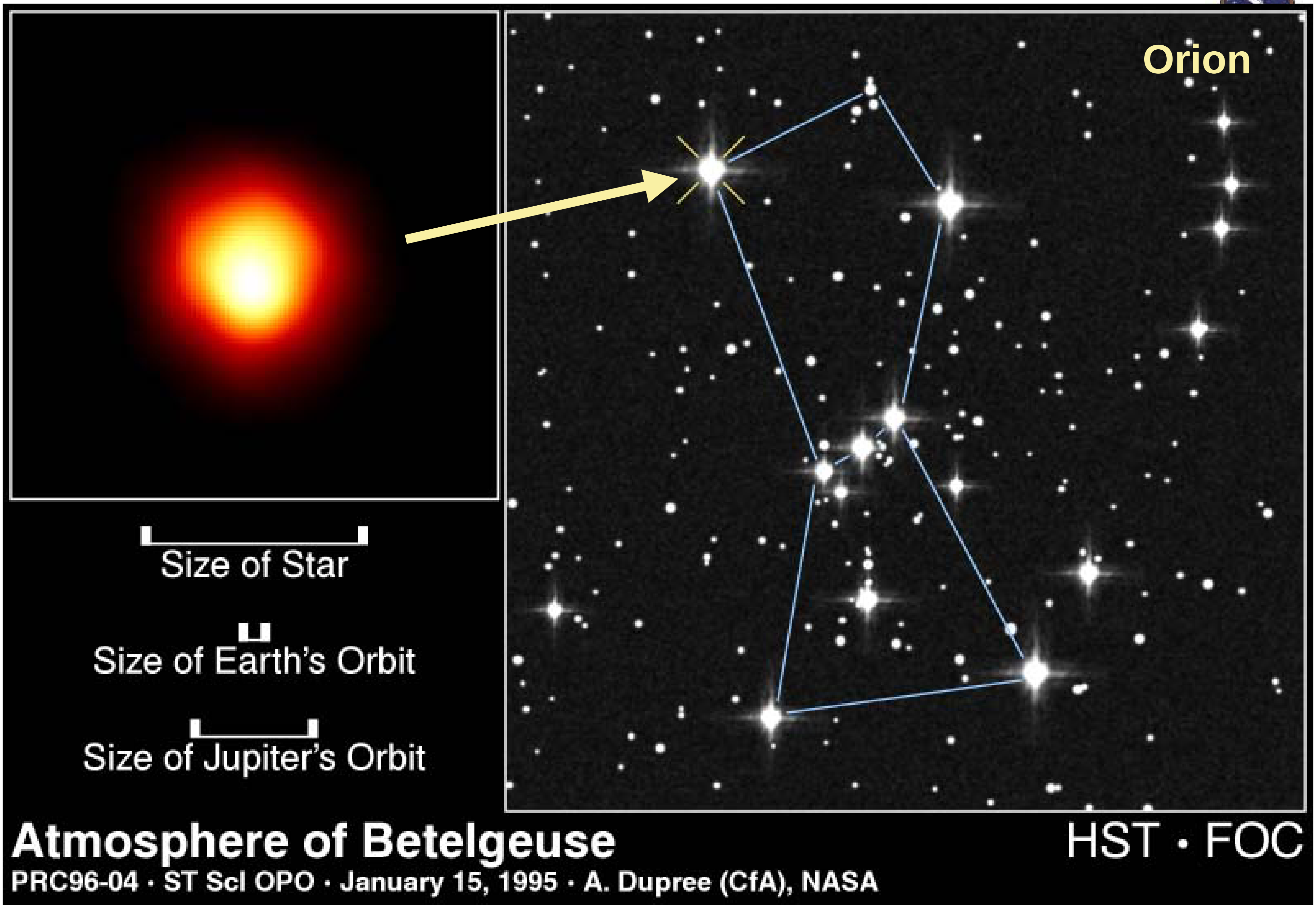


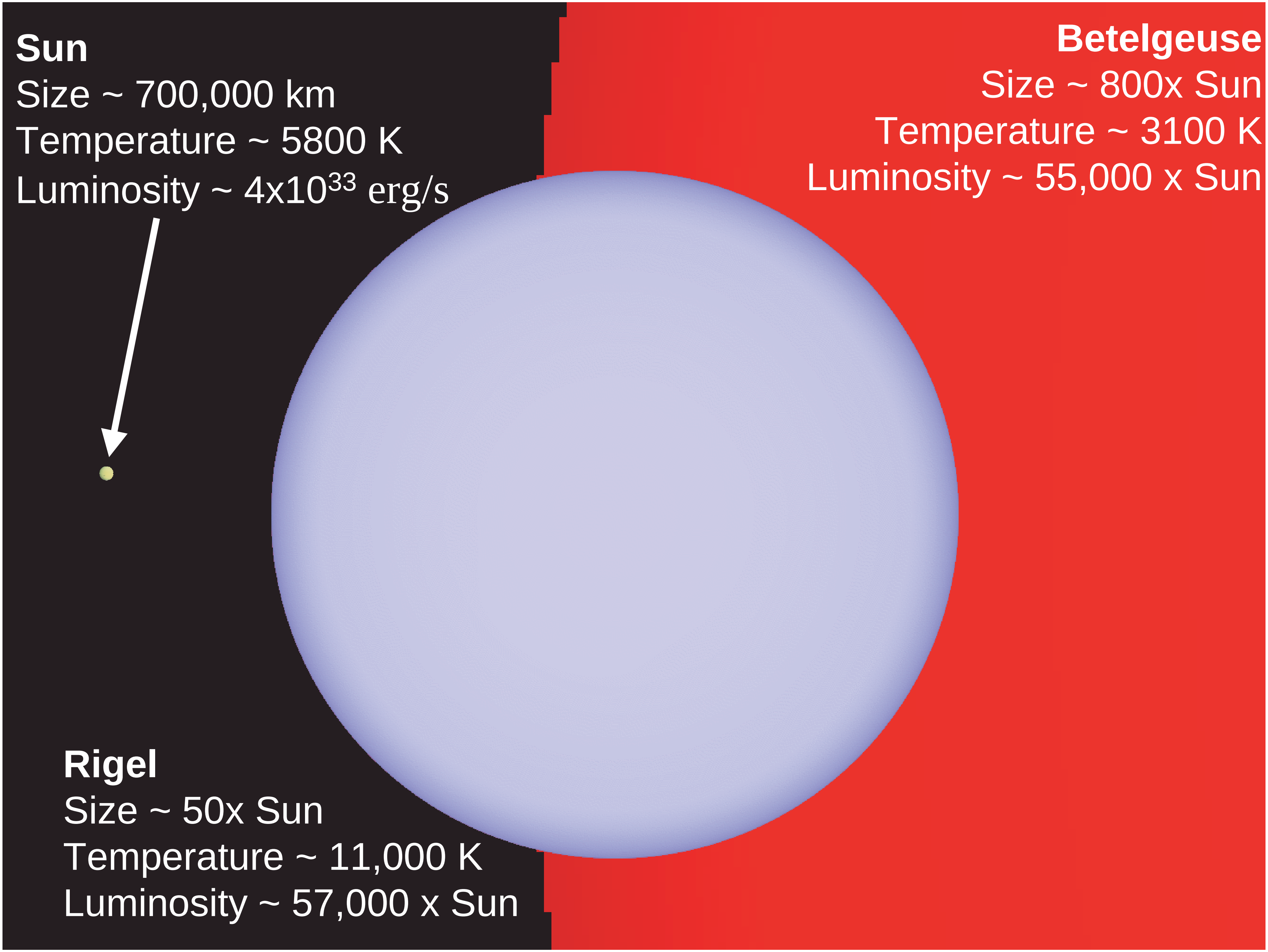
Closest star to Earth:
Proxima Centauri
(part of α Centauri system)
1.3 pc = 4.2 ly
Parallax: like a dime 2 km away

Stellar Consensus

- Are all stars the same? Are they all just like our Sun?
- Do they have different masses?
- Do they have different sizes?
- Do they have different temperatures? Colors?
- What happens to them? Just grow old and get retirement?

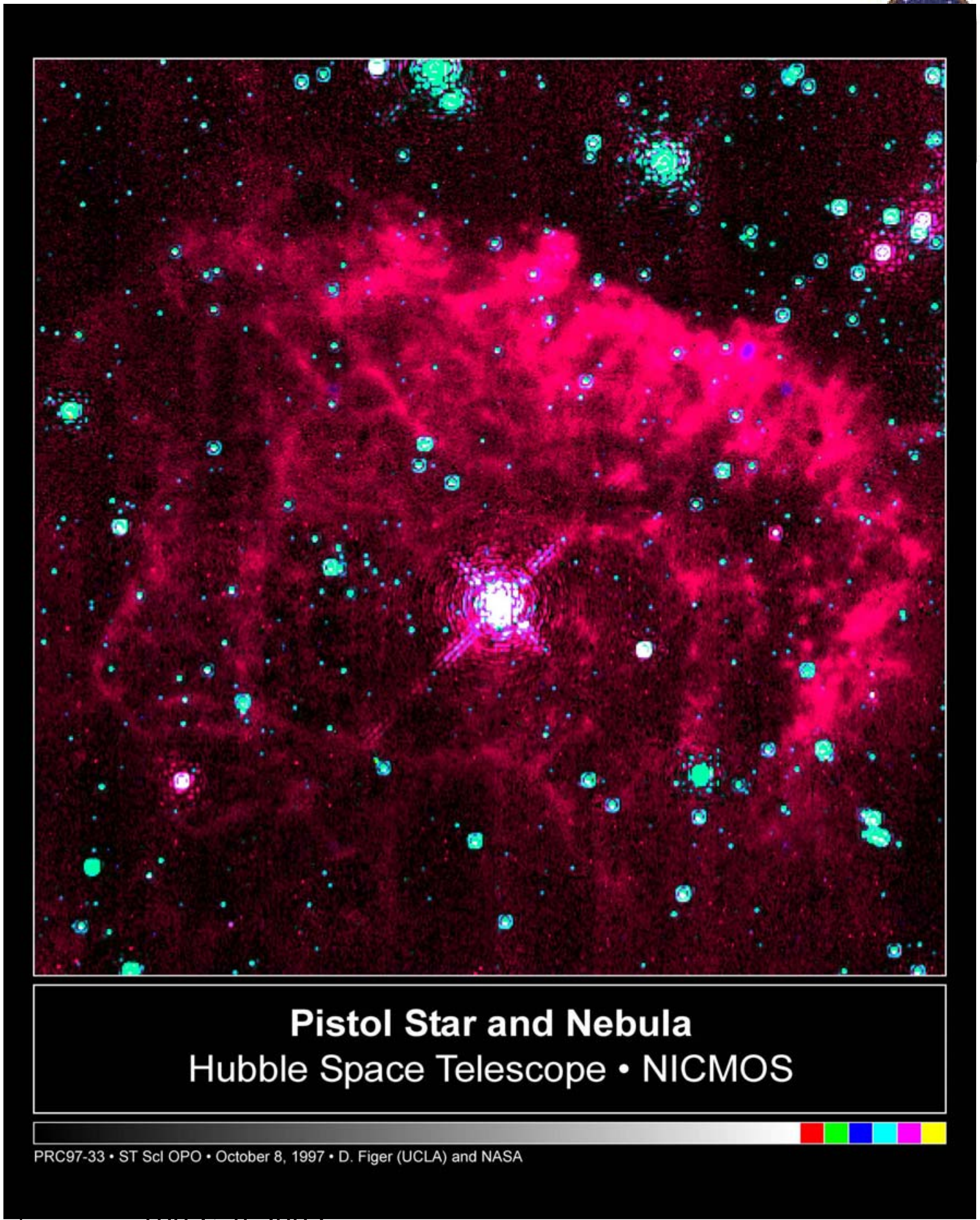

Earth’s orbit about the Sun
Betelgeuse
(Red supergiant)


Orion
Size of Star
Size of Earth's Orbit
Size of Jupiter's Orbit
Atmosphere of Betelgeuse
HST • FOC
PRC96-04 • ST ScI OPO • January 15, 1995 • A. Dupree (CfA), NASA


Sun
Size ~ 700,000 km
Temperature ~ 5800 K
Luminosity ~ 4x10^{33} erg/s
Betelgeuse
Size ~ 800x Sun
Temperature ~ 3100 K
Luminosity ~ 55,000 x Sun
Rigel
Size ~ 50x Sun
Temperature ~ 11,000 K
Luminosity ~ 57,000 x Sun

"Pistol" Star

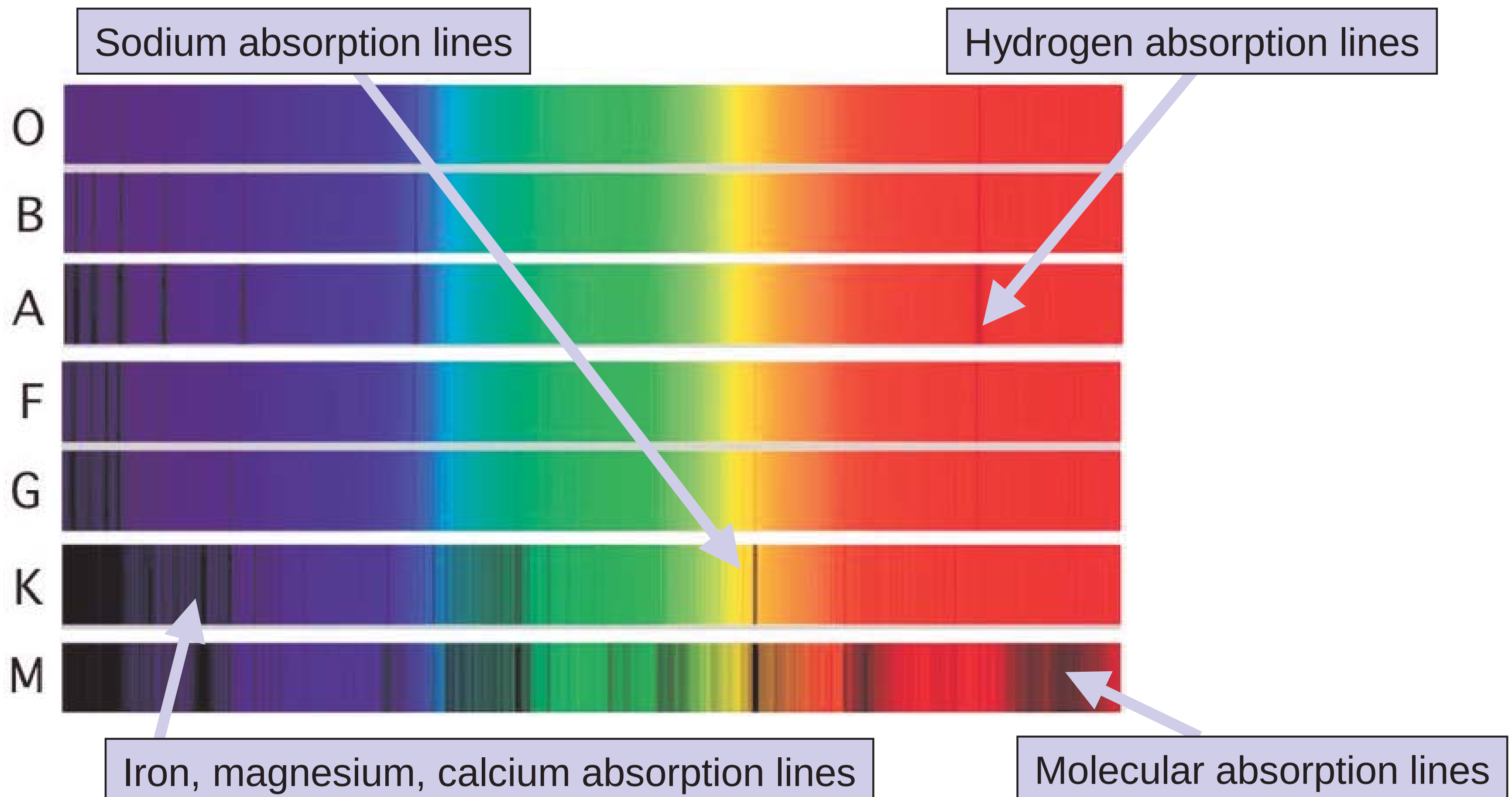
- 10 million times more luminous than Sun
- 100 times more massive than the Sun
- 25,000 ly away – near center of Milky Way
- Shrouded by dust – observed only in infrared



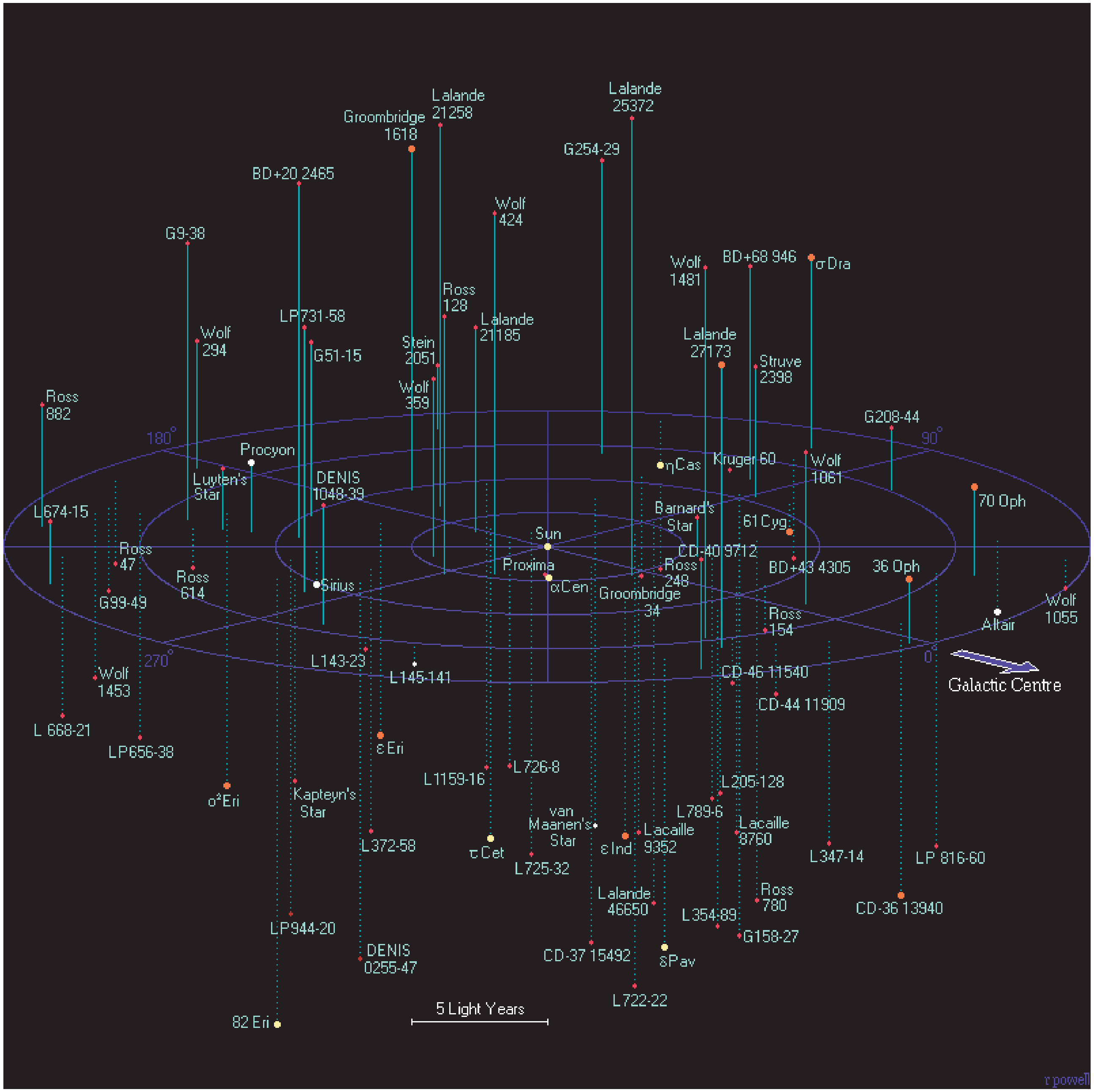
What does our consensus tell us?

Some stars are very, very hot and the hotter they are, the brighter they are. We can look at their spectra to figure out their temperature. These **spectral classes** are used to categorize stellar spectra. Our Sun is a “G dwarf” star.

“**Oh**, **Be** **A** **F**ine **G**irl (Guy), **K**iss **M**e”



Hot Stars Are Relatively Rare



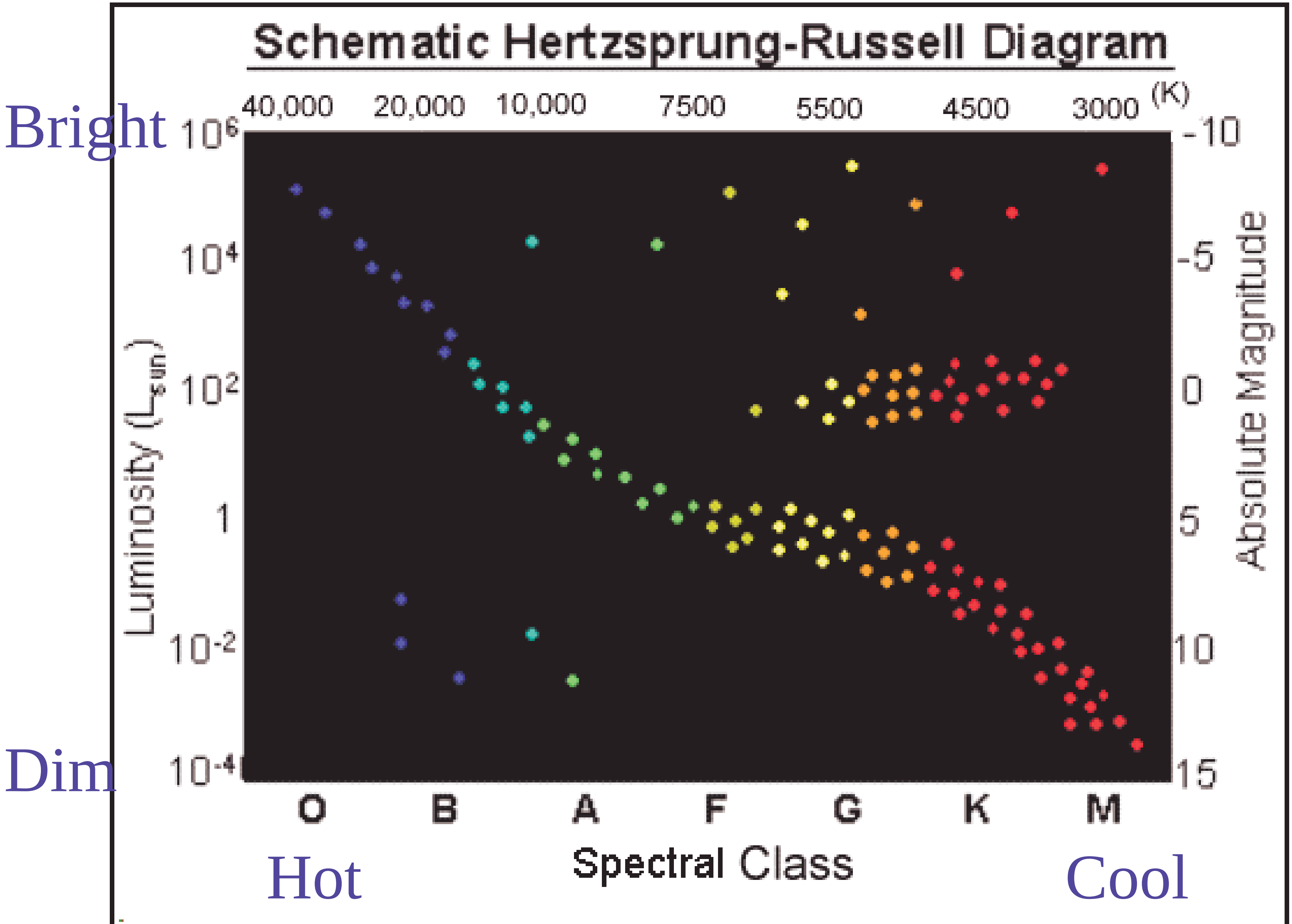
A Census of stars within 20 lys	
2	Type A stars
1	Type F star
6	Type G stars
16	Type K Stars
75	Type M Stars
1	Type M Brown Dwarf
1	Type L Brown Dwarf
4	Type T Brown Dwarfs
6	White Dwarfs

http://www.anzwers.org

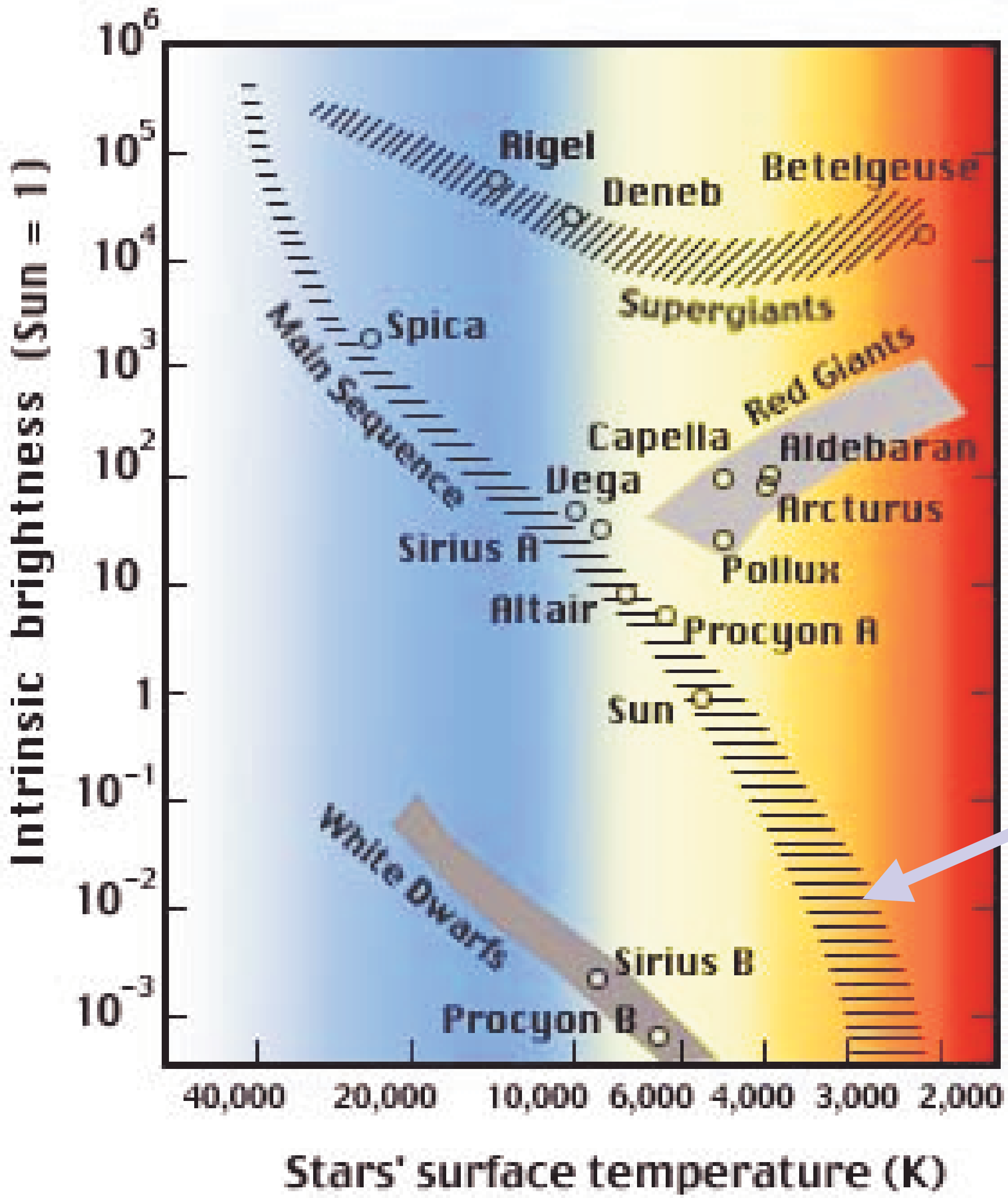
What else does our consensus tell us?

- Well, we can guess that there might be some relationship between temperature and luminosity.
- Also, as a star evolves from birth to death, the star will change its temperature (hotter or cooler) and its size (expands or contracts).
- The first astronomers to discover this (independently) was Ejnar Hertzsprung and Henry Russell– now this relationship is called the HR Diagram.

The Herzsprung-Russell Diagram



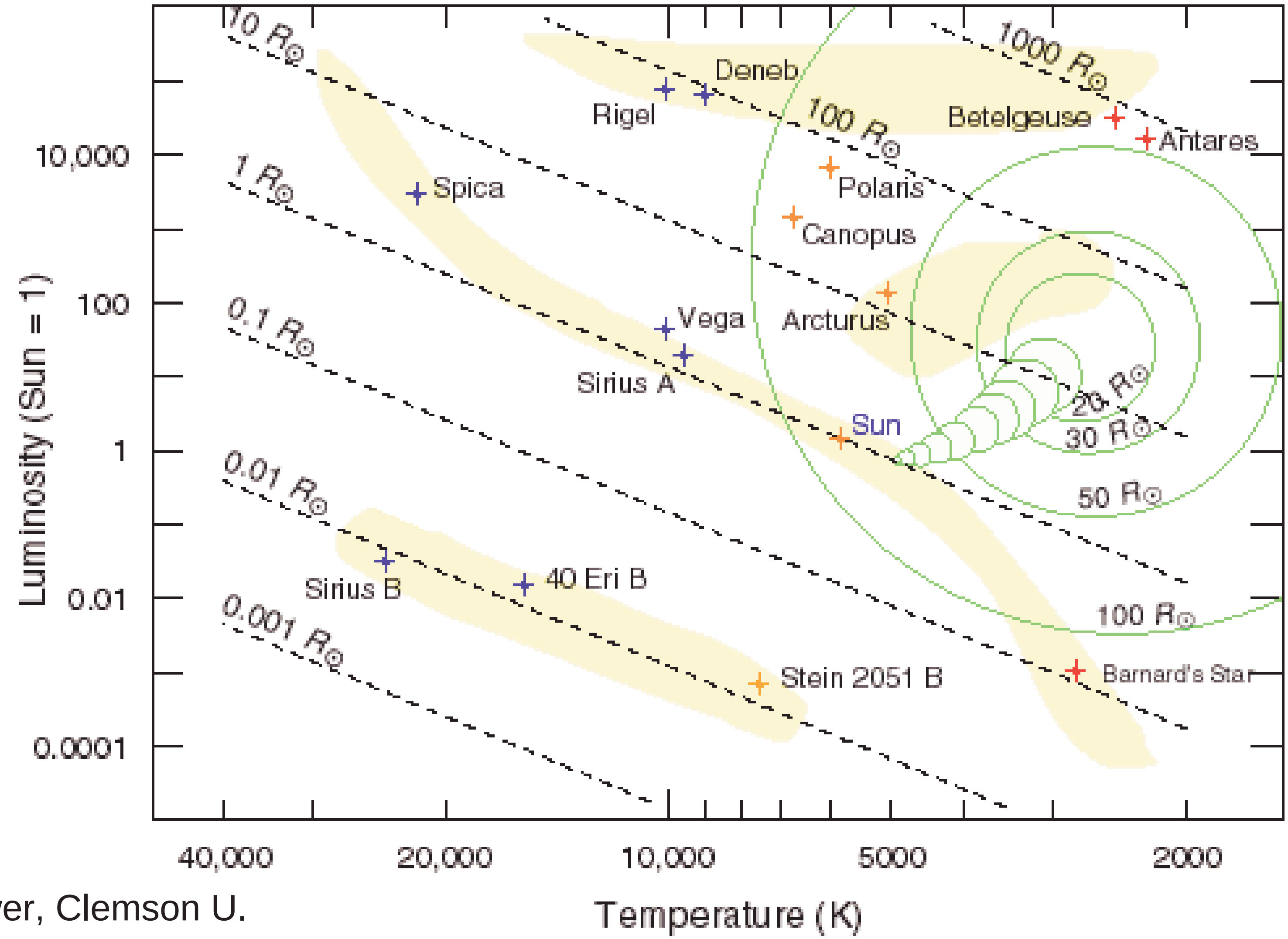
The Herzsprung-Russell Diagram



This is important, as it means that stars do not have random temperatures and brightness.

91% of all stars on the Main Sequence

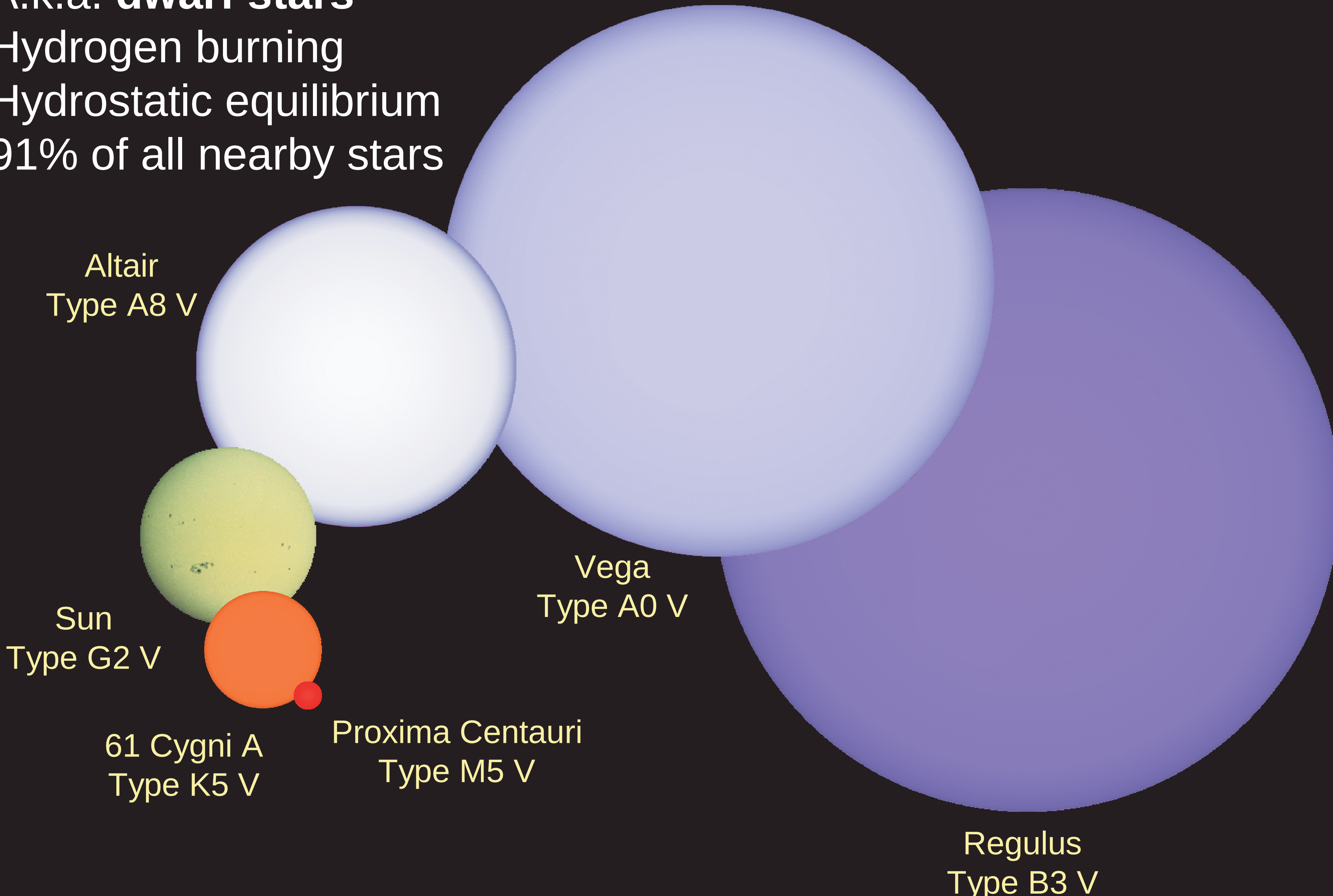
How does Stellar Radii Change Across the HR Diagram

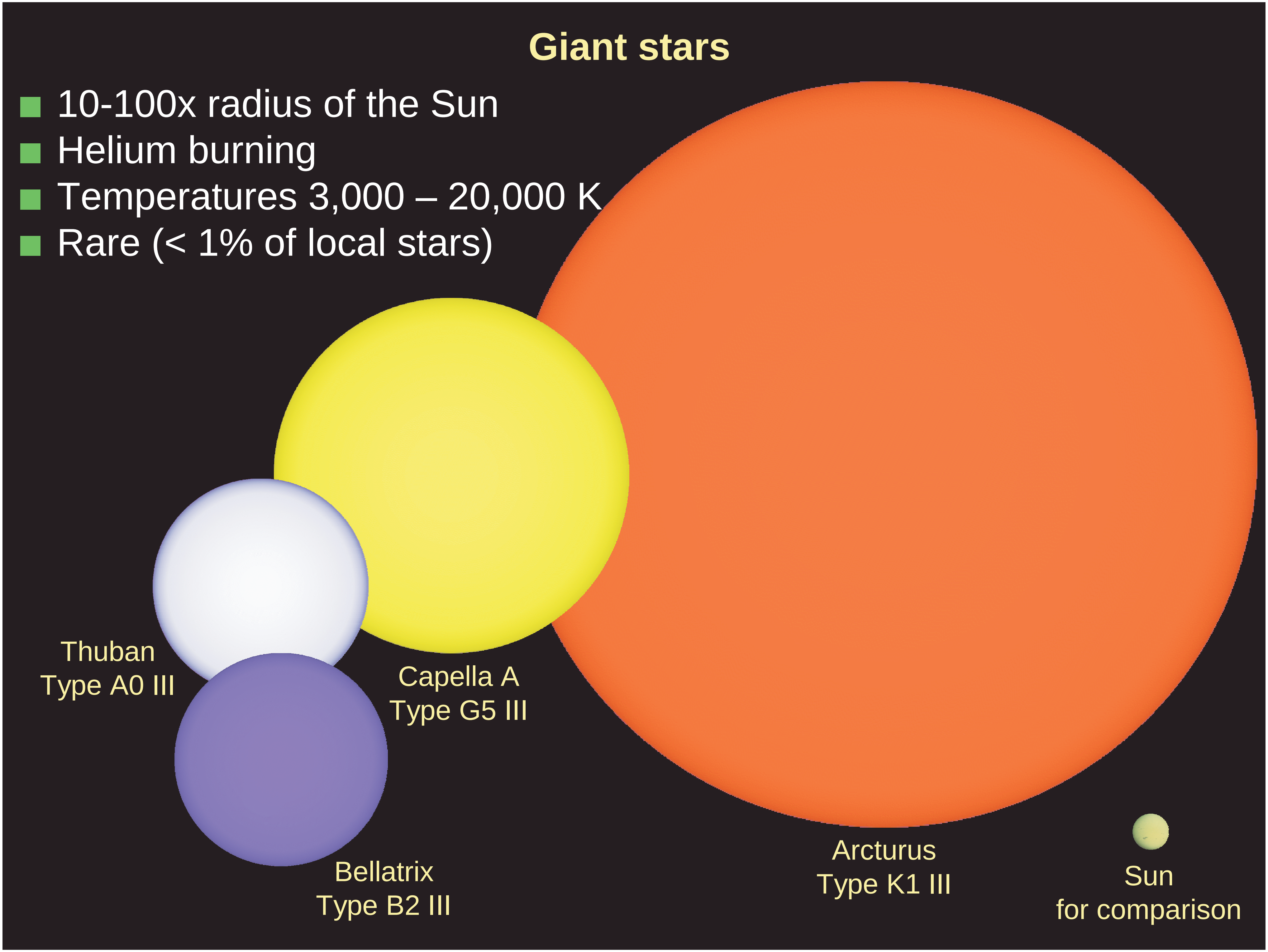


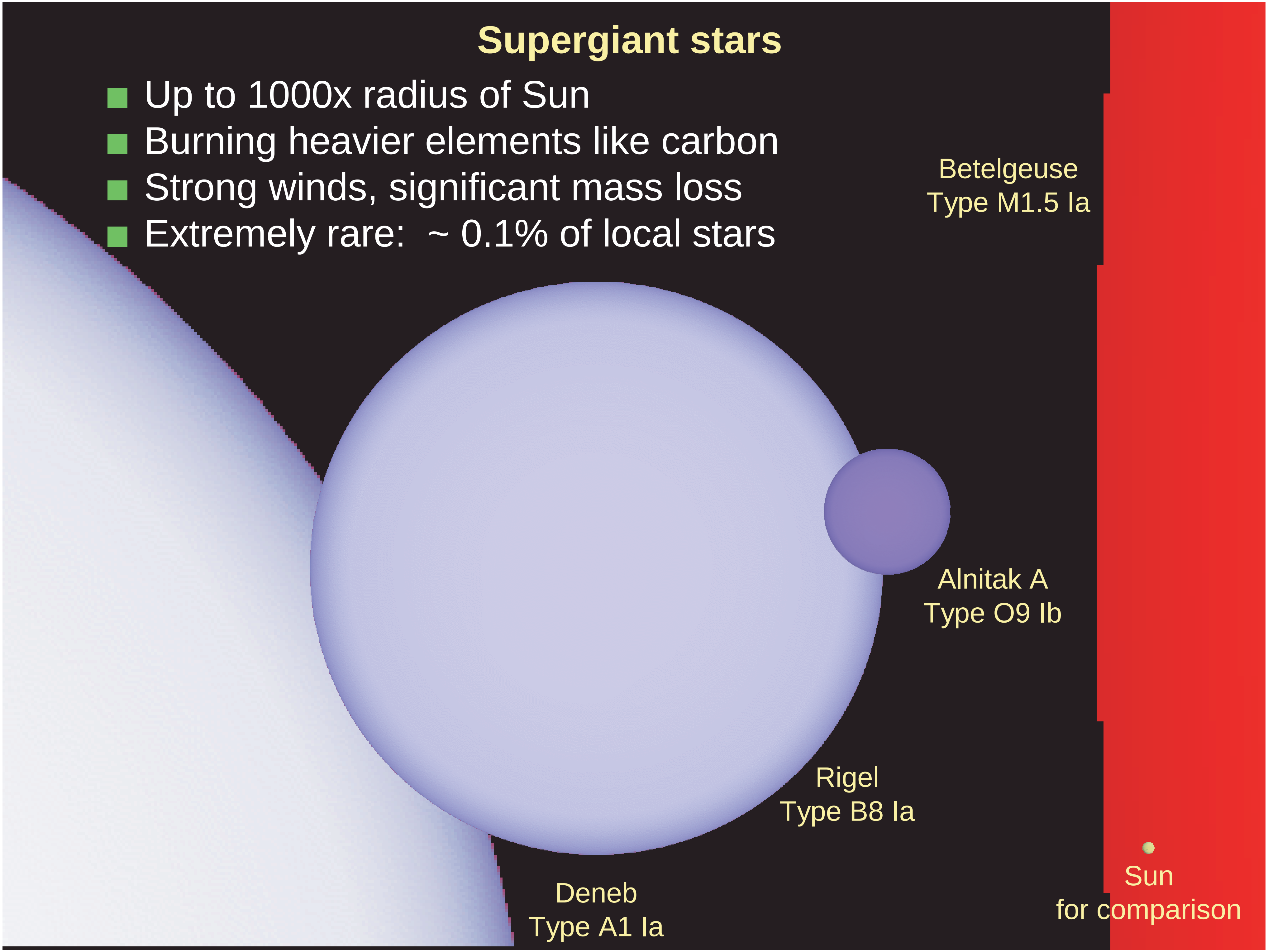
P. Flower, Clemson U.

Main-Sequence Stars

- A.k.a. **dwarf stars**
- Hydrogen burning
- Hydrostatic equilibrium
- 91% of all nearby stars




Giant stars
10-100x radius of the Sun
Helium burning
Temperatures 3,000 – 20,000 K
Rare (< 1% of local stars)
Thuban
Type A0 III
Capella A
Type G5 III
Bellatrix
Type B2 III
Arcturus
Type K1 III
Sun
for comparison


Supergiant stars
Up to 1000x radius of Sun
Burning heavier elements like carbon
Strong winds, significant mass loss
Extremely rare: ~ 0.1% of local stars
Betelgeuse
Type M1.5 Ia
Alnitak A
Type O9 Ib
Rigel
Type B8 Ia
Deneb
Type A1 Ia
Sun
for comparison

White Dwarf Stars

- About the size of the Earth
- Very hot: 5,000 – 20,000 K
- No longer burning *anything*
- About 8% of local stars

Sunspot

Sirius B

Earth for comparison

Sun for comparison

Kinds of Dwarves

Red dwarf

Just a very cool main-sequence star

Gliese 229A

White dwarf

White-hot burned-out core of a star

Sirius B

Black dwarf

A very old cooled white dwarf

SDSS J1254-0122

Brown dwarf

Not a star at all; wasn't massive enough

UKIRT/JAC