Astronomy 122

This Class (Lecture 13):

The HR Diagram

Next Class:

Star Formation

HW #6 due on Sunday

Midterm next Thursday

Music: *Blister in the Sun* – Violent Femmes

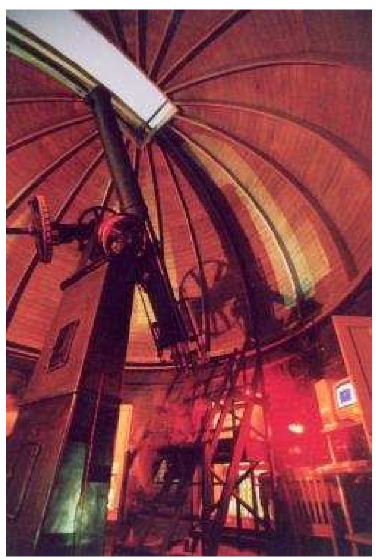
Jill Tarter

- Director of SETI
- Giving a talk on the Allen Telescope Array for SETI on Thursday at 1600 (4pm!) in 141 Loomis.

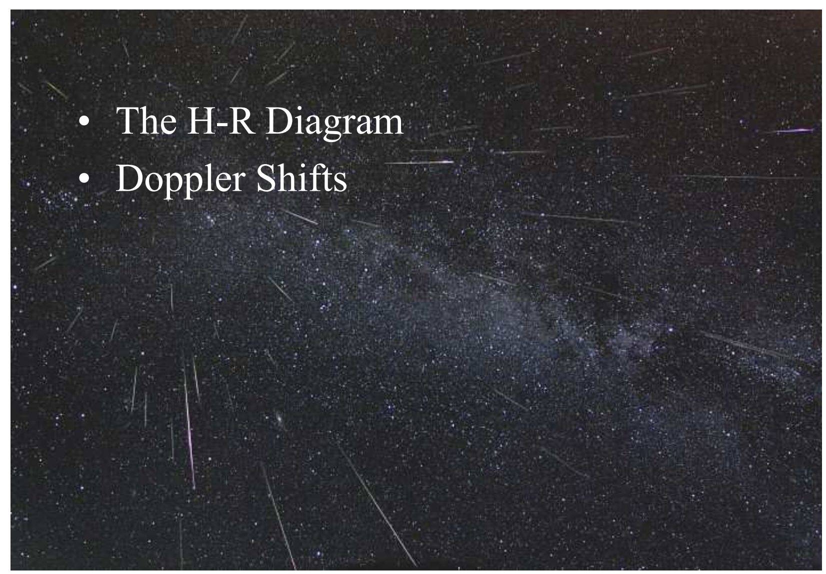
John Todd / AP

Night Observing

- Last week of formal Night Observing!
  - Feb 25-28th: Monday-Thursday
- Will be a make-up week due to weather, maybe two?
- Don't wait until last minute (never know about Illinois weather)!
- Observing sessions are from 7:30pm-9:30pm (allow 45 mins to complete)

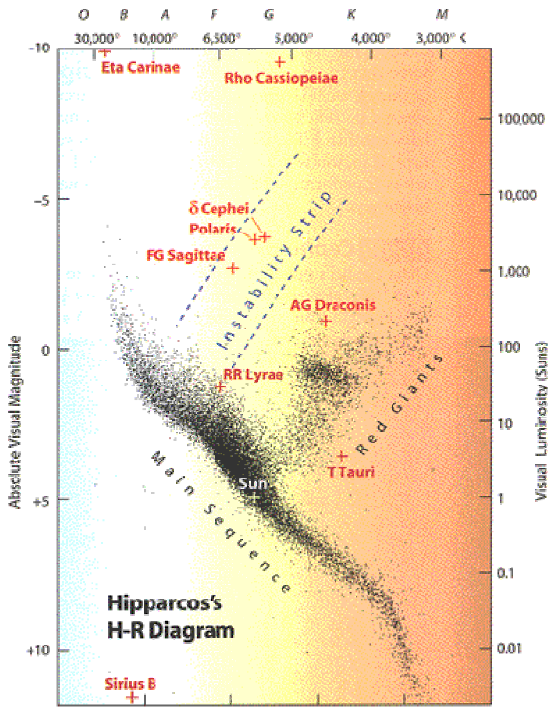


Outline



- The H-R Diagram
- Doppler Shifts

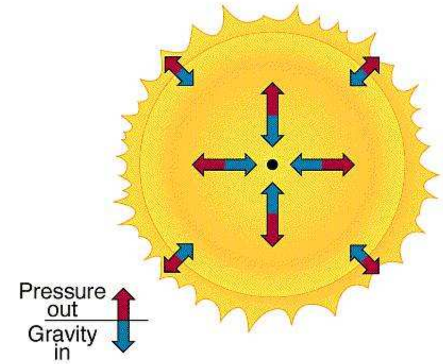
HR Diagram



- Notice the large number of stars on the main sequence.
- The Sun is very average.

Hydrostatic Equilibrium

- The battle between Gravity and Pressure is a draw for these stars.
- Pressure pushes out and gravity pulls in – an equilibrium
- This is why a main sequence star isn't shrinking even though it's a big ball of gas
- A star's life is all about this battle!



Question

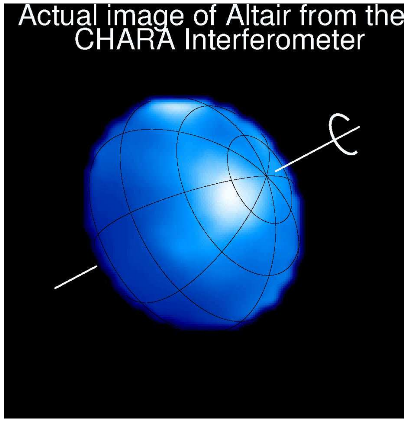
There are so many stars on the main sequence of the HR diagram (compared to else where) because

a) There are a lot of stars.
b) There are a lot of planets.
c) They spend most of their time there.
d) They are born there and live for a long time.
e) They just are..

Stellar Radii

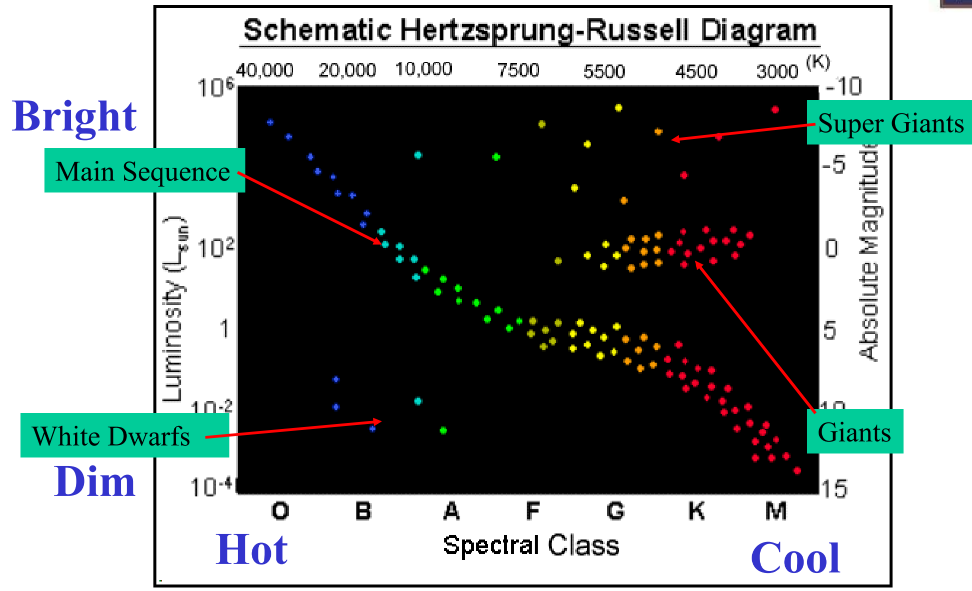
Optical interferometers (many telescopes that combine to simulate a larger telescope), can measure the radii of stars.

Are you getting too big?

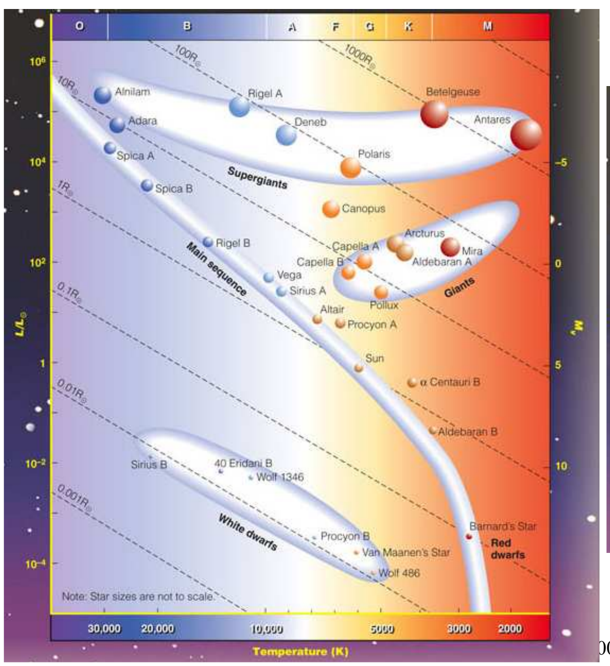


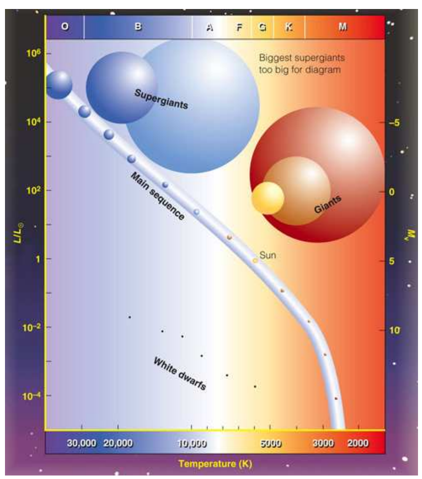
http://www.astro.lsa.umich.edu/~monnier/Altair2007/altair2007.html

Hertzsprung-Russell Diagram



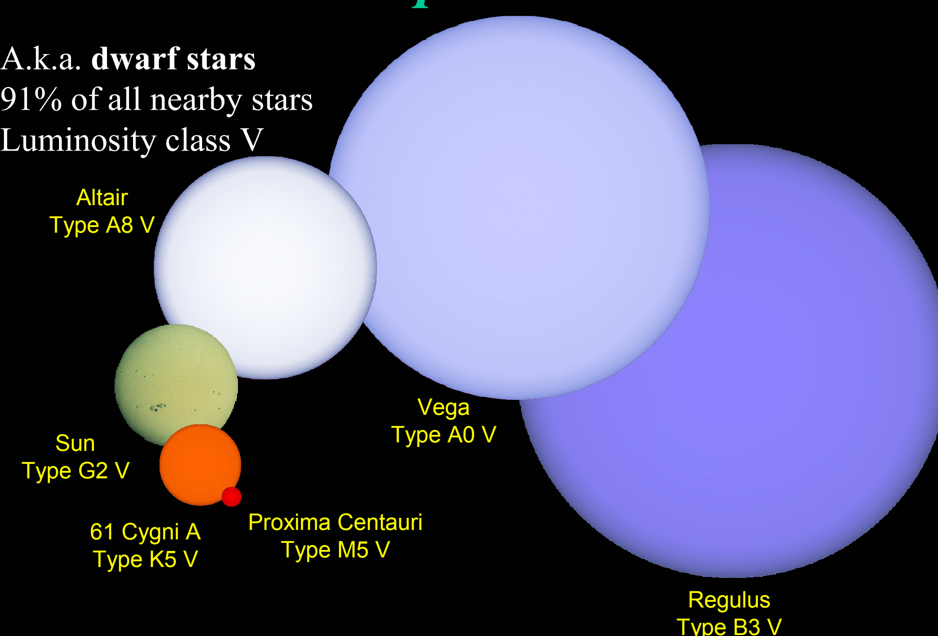
HR Diagram





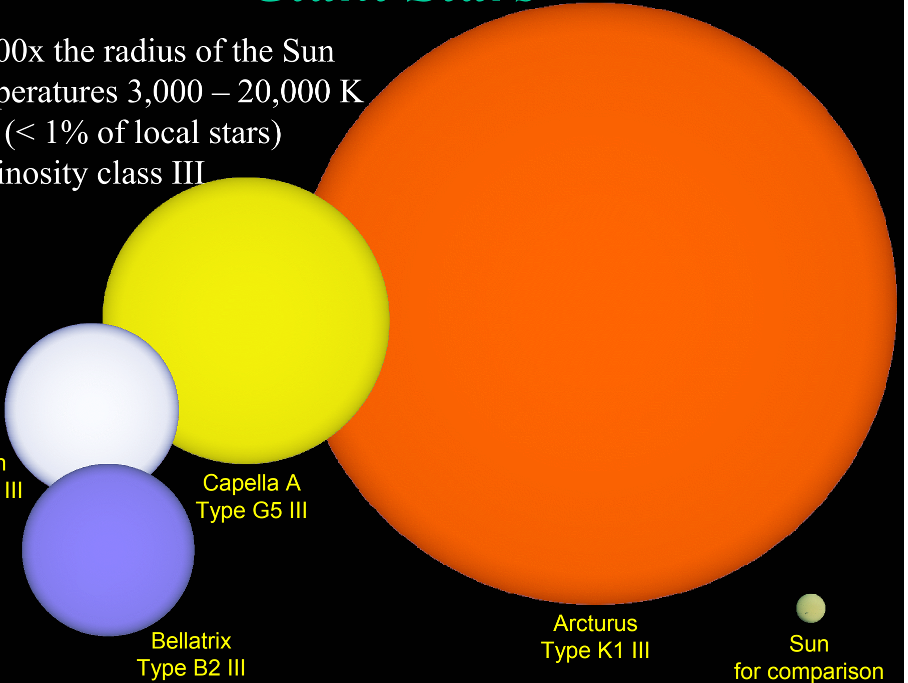
Main Sequence Stars

- A.k.a. **dwarf stars**
- 91% of all nearby stars
- Luminosity class V



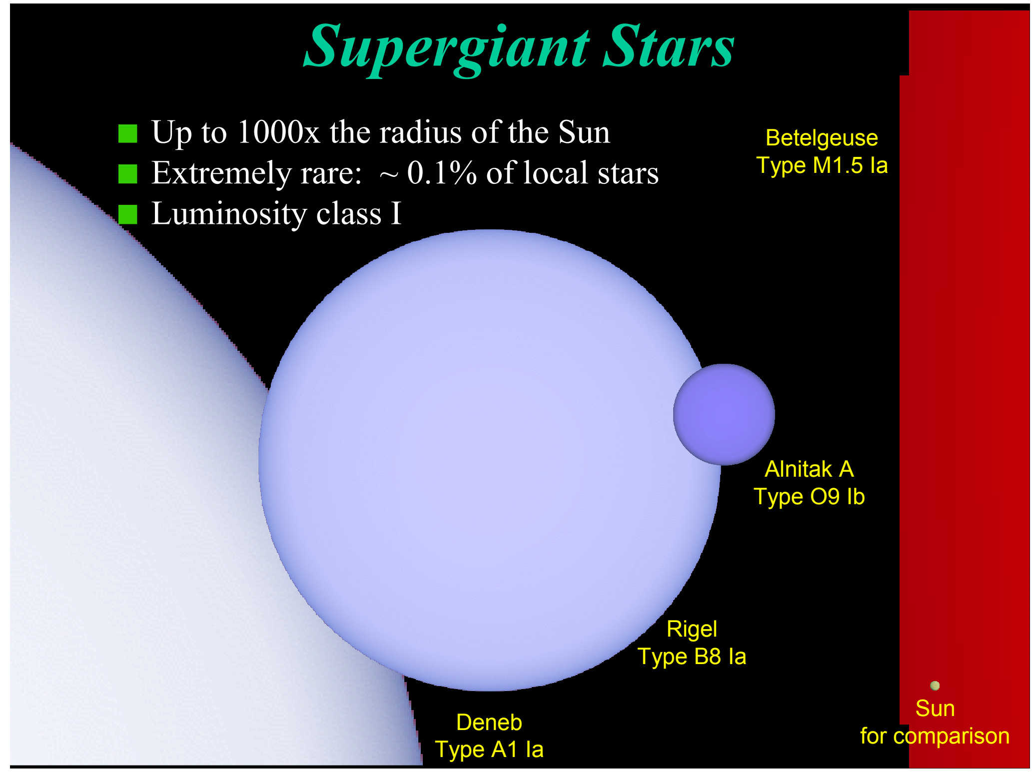
Giant Stars

- 10-100x the radius of the Sun
- Temperatures 3,000 – 20,000 K
- Rare (< 1% of local stars)
- Luminosity class III



Supergiant Stars

- Up to 1000x the radius of the Sun
- Extremely rare: ~ 0.1% of local stars
- Luminosity class I

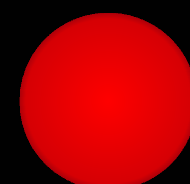


White Dwarf Stars

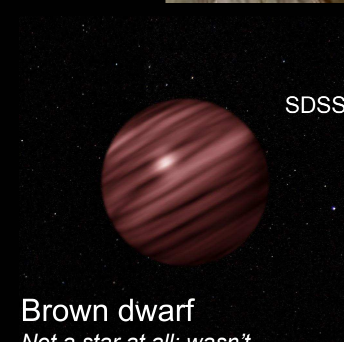
- About the size of the Earth
- Very hot: 5,000 – 20,000 K
- About 8% of local stars
- Luminosity class D

Kinds of Dwarfs

Red dwarf
Just a very cool main-sequence star



White dwarf
White-hot burned-out core of a star



Black dwarf
A very old cooled white dwarf

Brown dwarf
Not a star at all; wasn't massive enough

UKIRT/JAC

Question

A white dwarf is extremely hot, but have very low absolute magnitudes because

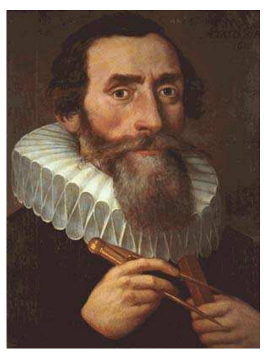
a) They are always very far away.
b) They are obscured by dust.
c) They are very big.
d) They are very small.
e) They are made out of diamonds.

What do the regions of the H-R Diagram mean?

- One big question - What are the differences between stars in the regions of the H-R diagram?
- The regions of the H-R diagram reflect different states of stellar evolution (aging)
  - Main sequence stars are "adult stars"
  - Giants and supergiants are "aged stars" (nearing the end of their lives)
  - White dwarfs are "dead stars"
- Mass is crucial for evolution, but what are the masses?

Mass

- How can we measure the mass of stars?
- We use Kepler's 3rd Law (modified by Newton).



Kepler's Third Law

A planet's orbital period (P) in years, squared, equals the semimajor axis of its orbit (a) in AUs, cubed

$$P^2 = a^3$$

years (P) — **AUs (astronomical units)** (a)

Question

$P^2 = a^3$ is Kepler's third law. If the Earth's orbital radius was decreased by a factor of two, the time it takes to orbit the Sun would be

a) 0.35 years [which is $(½)^{3/2}$]
b) 2.83 years [which is $2^{3/2}$]
c) 0.63 years [which is $(½)^{2/3}$]
d) 1.58 years [which is $2^{2/3}$]
e) 1 year

Binaries

- Stars like to form in *binary* (or more) star systems
  - Stars orbit each other
  - **About half of all star systems are binaries!**
- Binary systems allow us to measure:
  - with Newton's version of Kepler's law

$$M_1 + M_2 = \frac{a^3}{P^2}$$

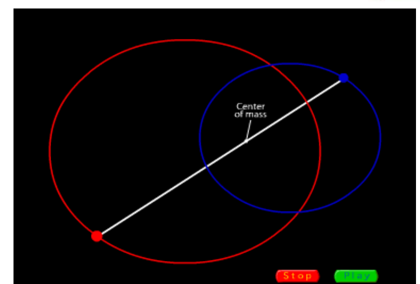
- Now, the problem is how to measure the a's and P's

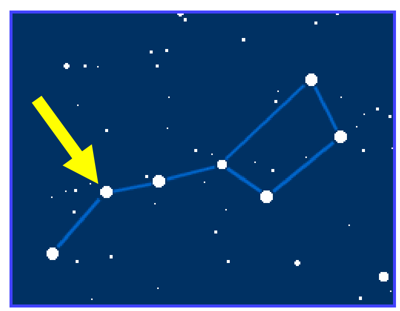
Types of Binary Stars

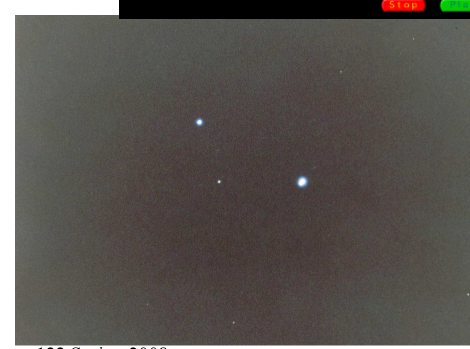
- **Visual binary** – can distinguish stars in the pair
- **Spectroscopic binary** – can only detect using Doppler shifts
- **Eclipsing binary** – each star passes in front of the other

Beautiful Binary: Visual

The handle of the big dipper is a visual binary Mizar/Alcor (12′).   Can see both stars oribt, but we would have to wait a long time to watch them orbit.







http://www.robonecela.host.sk/fotky/deepsky/velke/mizar-alcor.JPG

Doppler Effect

Those of you familiar with racing events like the Indy 500 or the sound of a police siren, are use to the Doppler effect.

Doppler Shift

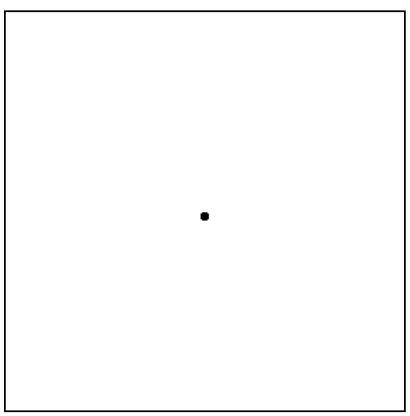
- The amount of shift in wavelength depends on the *relative* velocity of the source and the observer

$$\lambda_{obs} - \lambda_{source} = \lambda_{source} \times \left(\frac{v_{source}}{c} \right)$$

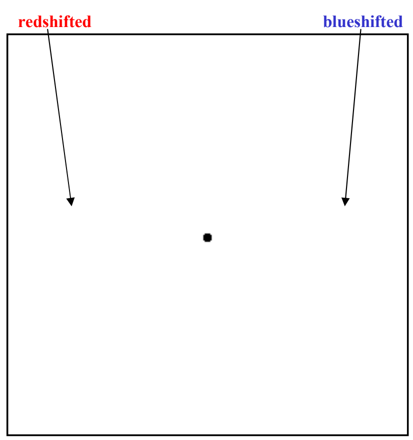
- By measuring the Doppler shift of the light we observe, we can study the motions of the planets and stars
- The Doppler effect is also used by modern storm-tracking radar

The Doppler Effect

The effect arises from the relative motion of the observer and the source of light, sound, etc. The waves get squashed in the direction of motion and stretched in the opposite direction.



Source standing still



Source moving to right

Question

A star is moving toward you, its spectrum is

a) Redshifted
b) Blueshifted
c) Purpleshifted
d) There is no change in the spectra.

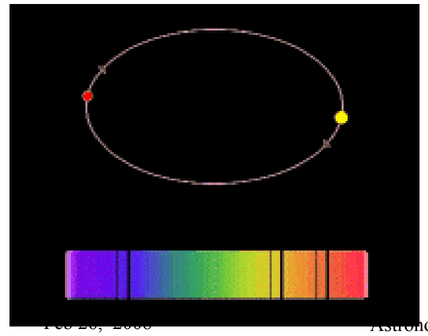
Question

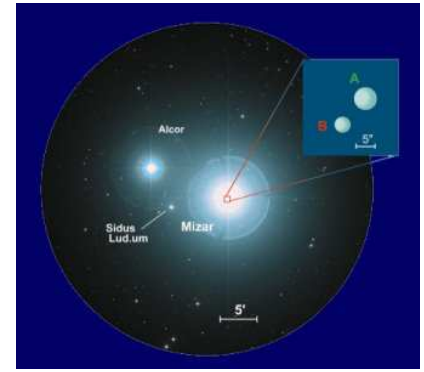
A star is moving at a 90 degree angle from you, its spectrum is

a) Redshifted
b) Blueshifted
c) Purpleshifted
d) There is no change in the spectra.

Beautiful Binary: Spectroscopic

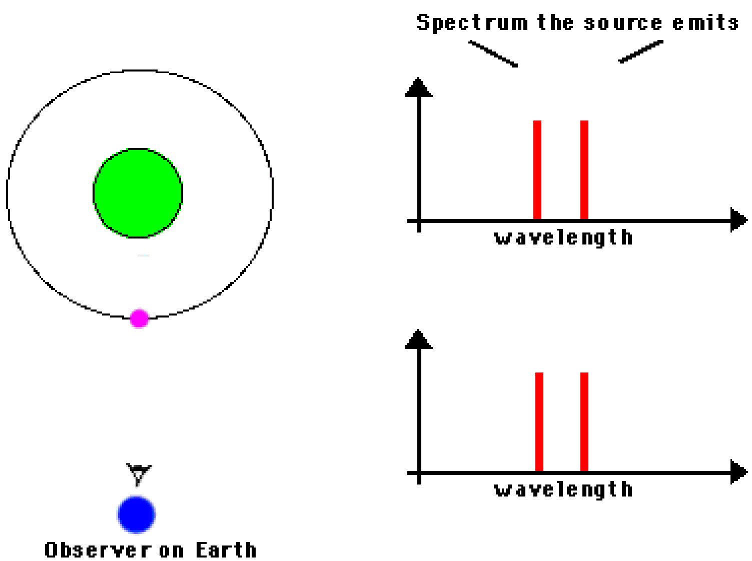
Mizar is the first known double star (14″). Each of those stars is also a binary system, but very close together. Can see spectroscopic binary system from Doppler shift.





http://home-3.worldonline.nl/~ppsmeets/Sterren.html

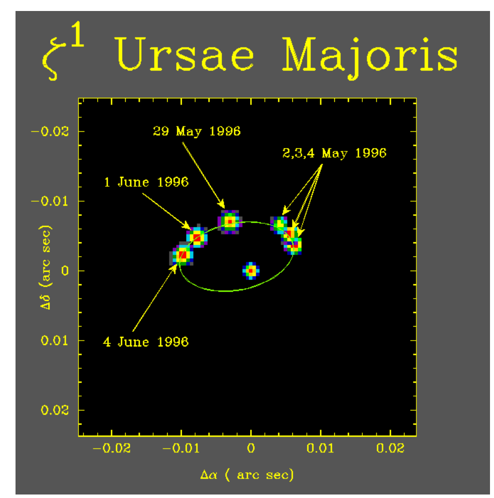
Beautiful Binary: Spectroscopic



NASA

Beautiful Binary: Spectroscopic

One of the close Mizar binaries has been observed with an optical interferometer. Separation is like a penny at 300 miles away!

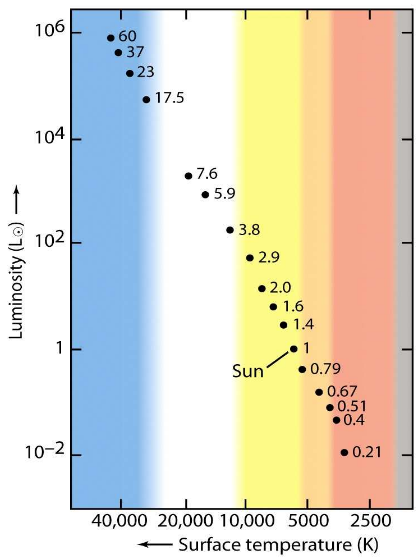


http://instruct1.cit.cornell.edu/courses/astro101/java/binary/binary.htm

http://antwrp.gsfc.nasa.gov/apod/image/9702/mizarA_npoi_big.gif

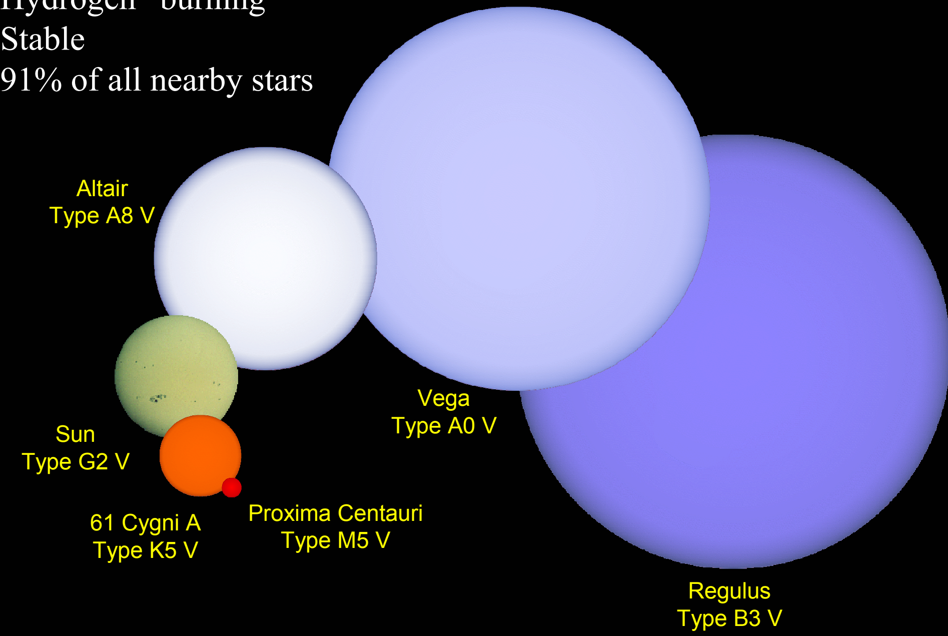
The Mass-Luminosity Relationship

- Luminosity is proportional to Mass
- Much larger range in luminosity than in mass
- Higher mass = higher luminosity, higher temp, and large radius
- Lower mass = lower luminosity, lower temp, and smaller radius
- Non-main sequence stars deviate from this relationship



Main-Sequence Stars

- Hydrogen "burning"
- Stable
- 91% of all nearby stars



What is the Age of the Solar System?

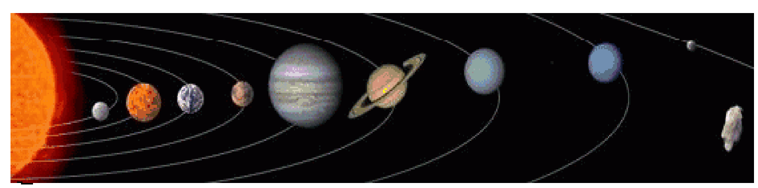
- Earth: oldest rocks are 4.4 billion yrs
- Moon: oldest rocks are 4.5 billion yrs
- Mars: oldest rocks are 4.5 billion yrs
- Meteorites: oldest are 4.6 billion yrs
- Sun: models estimate an age of 4.5 billion yrs

- **Age of Solar System is probably around 4.6 billion years old**

- **Sun could not always have been, nor will it always be… star birth and star death!**

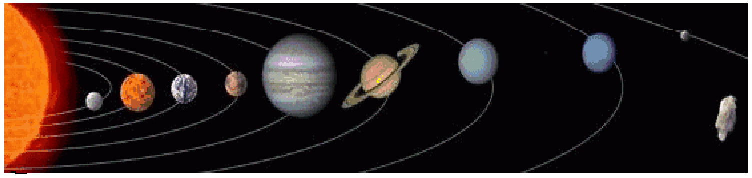
Explain Star Formation!

- We have our solar system.
- We understand some aspects of it, such as
  - Different planets properties
  - Orbital patterns
- What are the aspects (globally) that we have to explain?



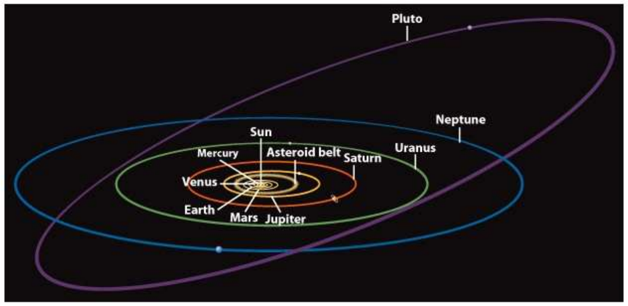
Explain It!

- Could take a whole class, but the main aspects are:
  - Orbits, spins
  - Terrestrial/Jovian differences:
    - Composition
    - Location
    - Size
    - Spacing
  - Debris: comets, asteriods



Planetary Orbits

- Most of the motions in the Solar System are counter clockwise in a flat system (pancake-like)



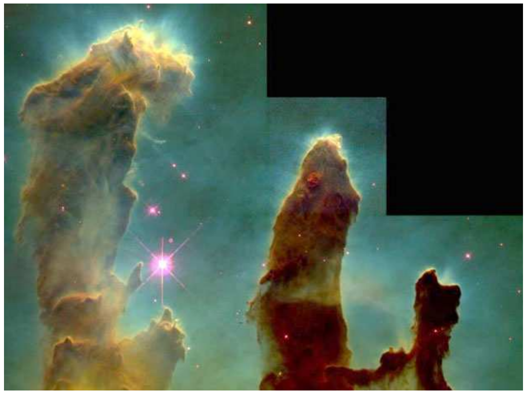
  - There are some exceptions
  - Venus, Uranus, and Pluto rotate clockwise
  - Some moons orbit backwards

http://janus.astro.umd.edu/javadir/orbits/ssv.html

Solar Nebula Theory

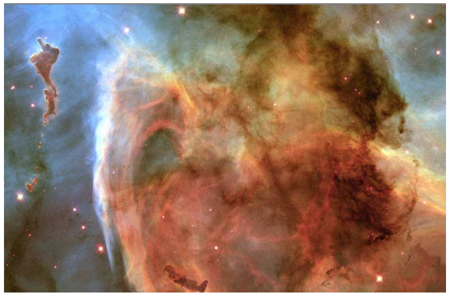
"*nebula*" = space cloud

- Proposed by Immanuel Kant (the philosopher)
- The solar system formed from a spinning cloud of gas, dust, and ice
  - Mostly hydrogen and helium
  - 4.6 billion years ago



The Interstellar Medium (ISM)

- Stuff between the stars in a galaxy.
- Sounds sort of boring, but
  - Actually very important
  - Features complex physical processes hidden in safe dust clouds
- Every star and planet, and maybe the molecules that led to life, were formed in the dust and gas of clouds.
- Exists as either
  - Diffuse Interstellar Clouds
  - Molecular Clouds



Keyhole Nebula

Orion Nebula

(near infrared)

Nearest massive star forming region with a large molecular cloud associated (distance of 1500 lys)