Study Guide – Midterm 3

Exam procedures

- Sit in assigned row, as for previous midterms.
- As before, a seating chart will be displayed on the screen when you enter the room.
- A person-by-person list of row assignments will be posted on the wall by the door.
- Photo-ID required.
- Closed book, closed notes. No calculators, cell-phones, etc.

What to Know

- You should know about all of the things I have discussed in class.
- This study guide just gives some of the high points.
- Study your lecture notes first, then use your textbook to help you understand your notes.

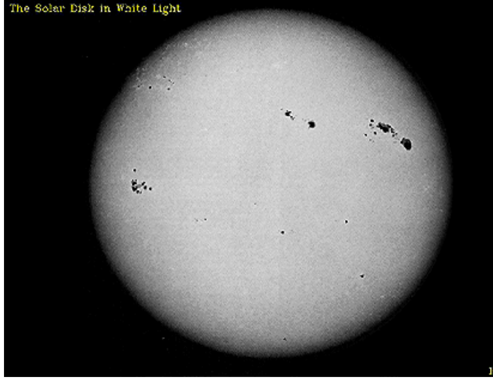
Some general ideas that you should understand:

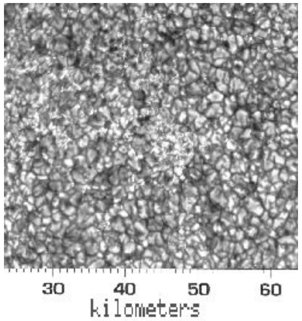
- What is the energy source of the Sun? Of other stars?
- How do we know what goes on inside of the Sun and other stars?
- In what ways do stars change during their lifetimes? What simple fact means that they *must* evolve (i.e. change their interior structure)?
- You should know what the H-R diagram shows, and why it is such an important tool in astronomy.
- How do you find the age of a star cluster? What is the basic principle?
- What are the three possible end states of a star's life? What determines which end state befalls a particular star?
- The basic ideas of General Relativity, and the tests that show that General Relativity describes gravity better than does Newton's Law of Gravity.

Some specific numbers to know:

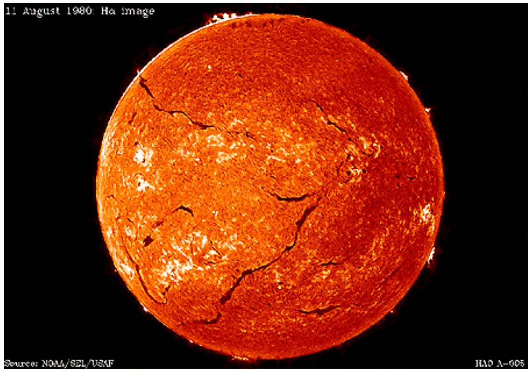
- Age of the Sun (= age of solar system) = 4.5 billion yrs.
- Predicted lifetime of Sun's core H-burning phase = 10-11 billion years (depends on exactly what you specify as the end-point).

- Photosphere
  - Deepest layer from which light directly escapes into space.
  - Low density and pressure (10^{-4}, 0.1 x Earth's surface values)
  - But *hot* (5800^{o} K)
  - Granules (in photosphere)
    - Tops of convection currents.

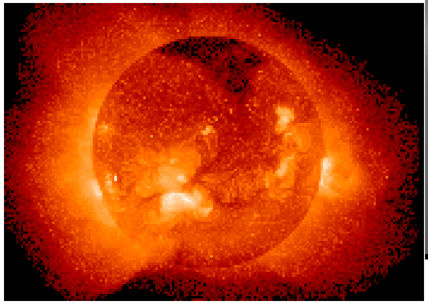


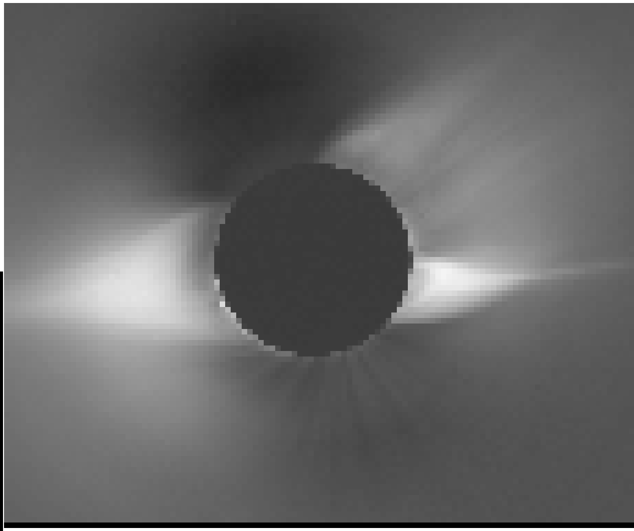


- Chromosphere
  - Transparent gas layer, reaches 2000-3000 km above photosphere.
  - T ~5,000-10,000^{o} K
  - Photosphere = point we can no longer see through chromosphere.

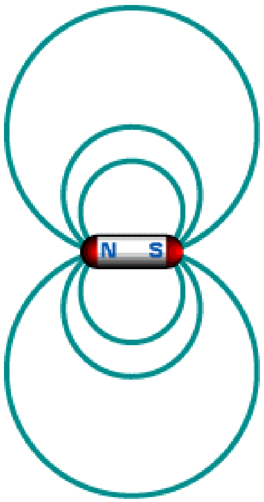


- Corona
  - T > 1,000,000^{o} K
  - Very low density: 10^{-10} atmospheres.
  - Heated by magnetic energy.
  - Several x diameter of photosphere.

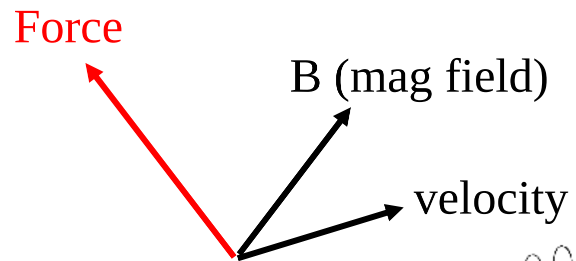




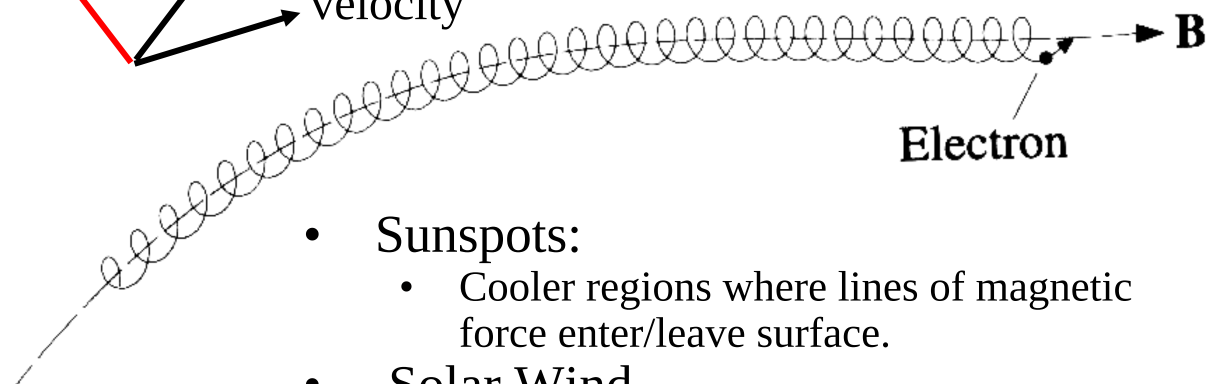
Magnetic Fields Control Much of Sun's Surface Activity

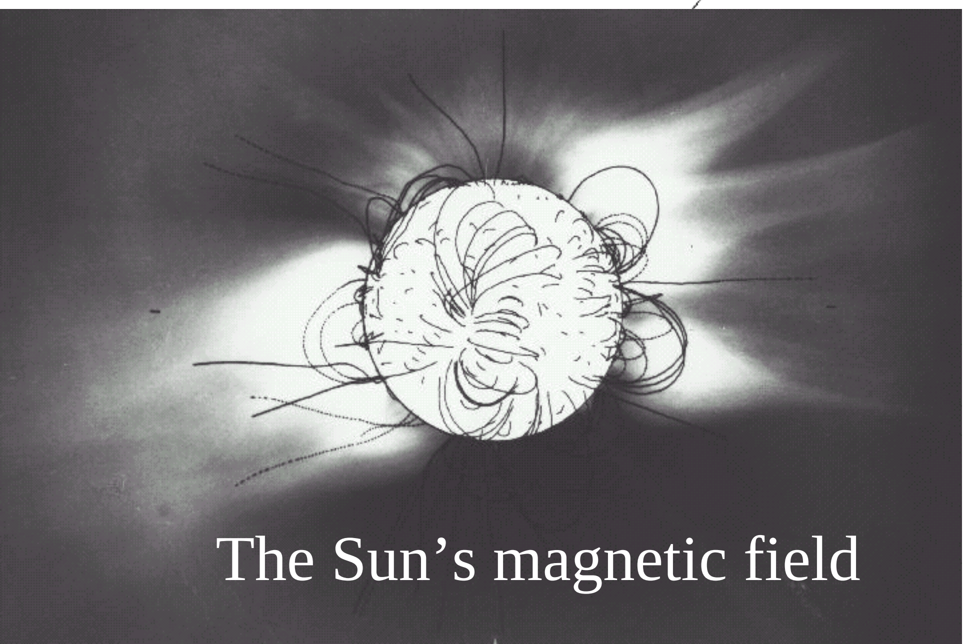


Magnetic field lines of force



Motion of a charged particle around a magnetic field line





- Sunspots:
  - Cooler regions where lines of magnetic force enter/leave surface.
- Solar Wind
  - Charged particles with greater than escape velocity, escaping through holes in magnetic field.
- Prominences
  - Charged particles following magnetic lines of force.
- Flares
  - Magnetic field lines short out ➔ Huge burst of charged particles
- 11/22 yr. Solar cycle
  - Due to "winding up" of Sun's magnetic field.

What Powers the Sun?

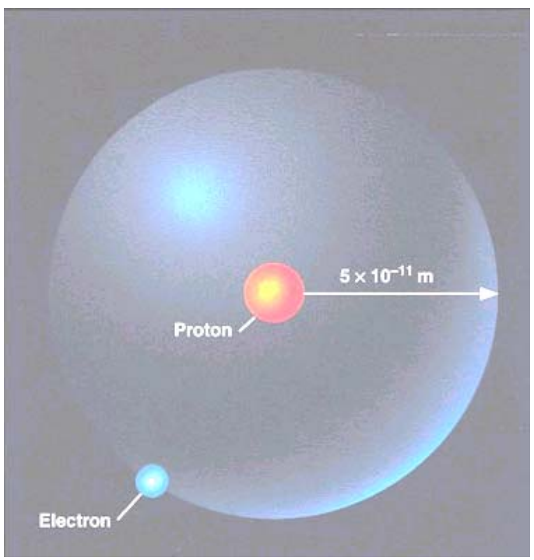
- Need to provide
  - 4×10^{26} watts
  - $< 2 \times 10^{33}$ grams (mass of Sun)
  - > 4.5 billion years (age of Sun)
- Nuclear fusion reactions:
  - $4 \times {}^{1}H \rightarrow {}^{4}He$ + neutrinos + energy

$E = mc^2$

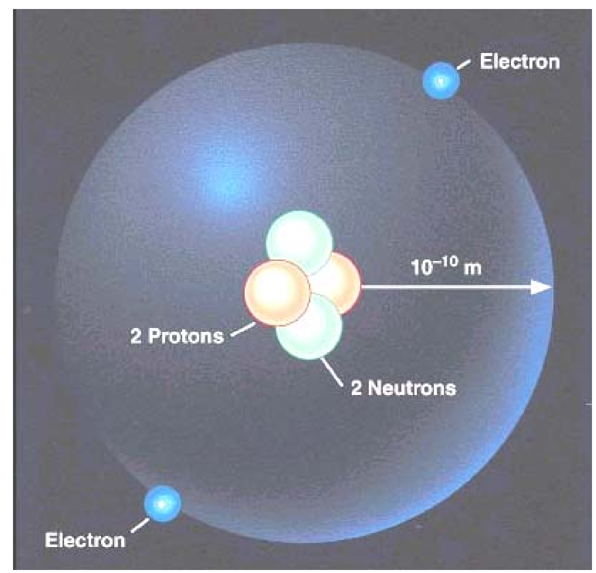
What does this mean???

Hydrogen: ^{1}H

4 x



Helium: ^{4}He



Computer simulations of stars

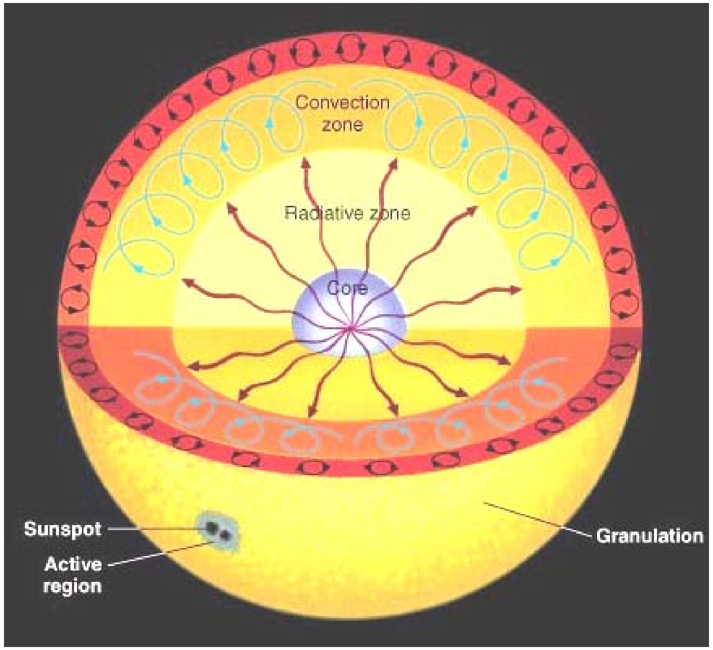
We can measure:

- Luminosity
- Mass
- Size
- Chemical composition

Computer “models” assuming:

- Made of gas.
- Neither contracting nor expanding.
- Neither heating up nor cooling down.
- Specify method of energy transfer.

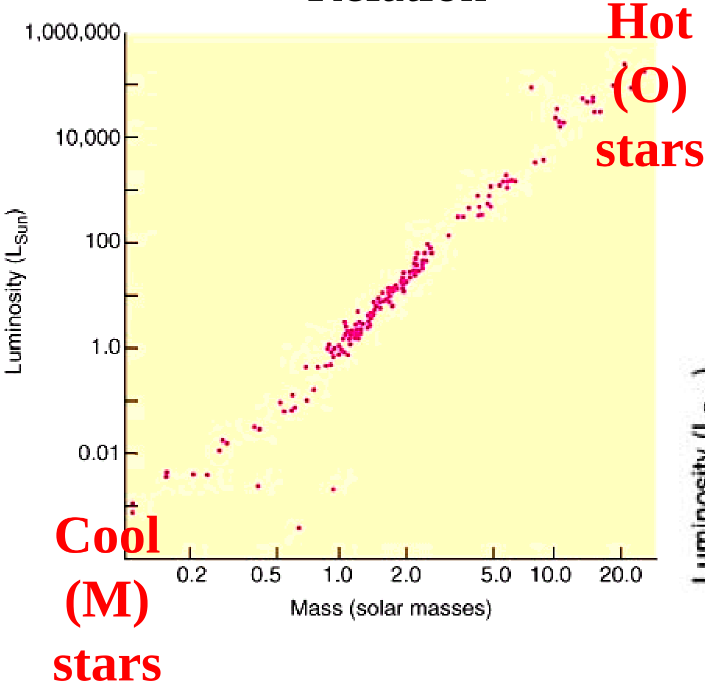
- Internal structure.
- Which nuclear reactions generate energy at what points.
- Lifetimes.



The interior of the Sun

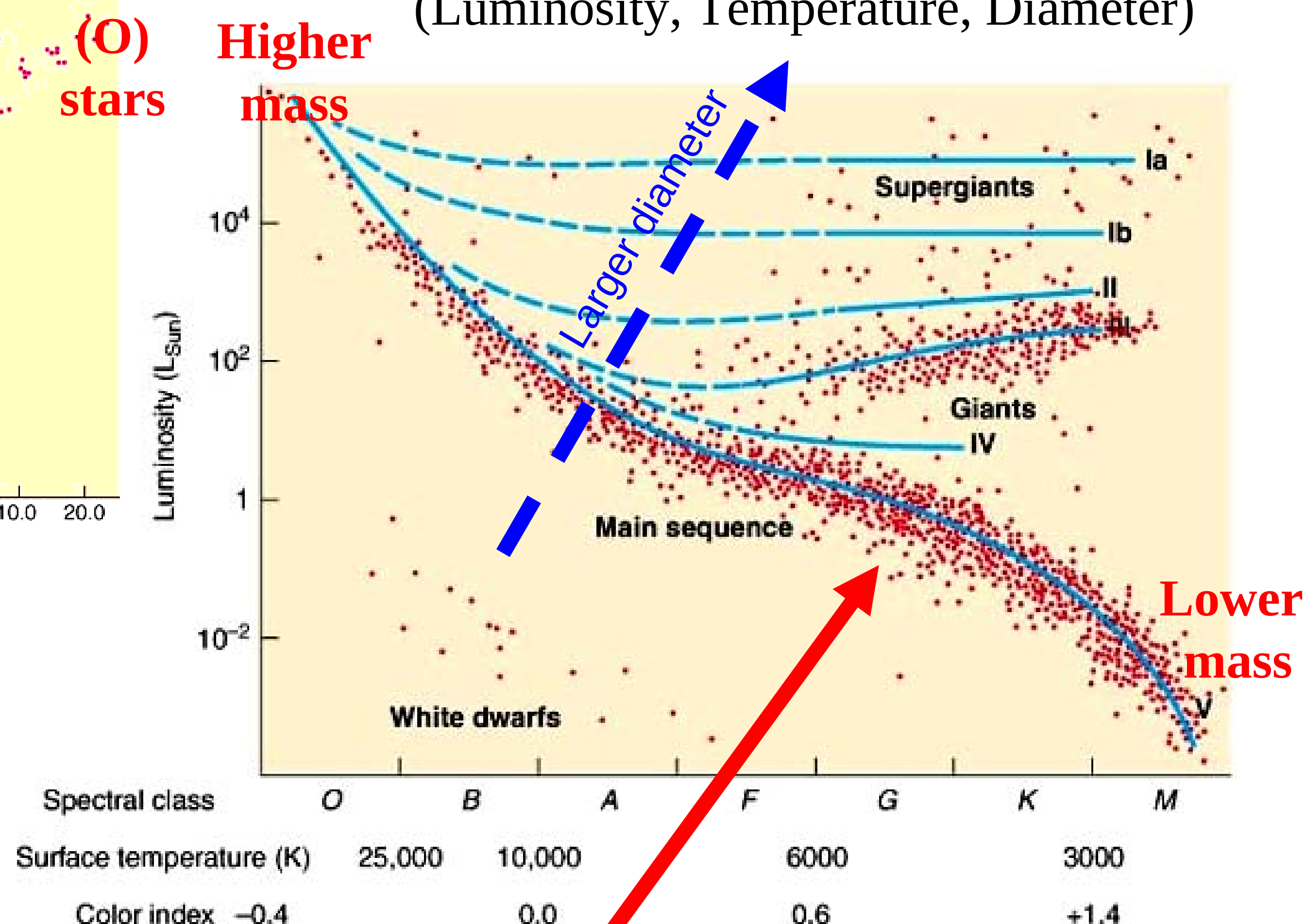
Here's what we observe about stars.

The Mass-Luminosity Relation



Main sequence is a mass sequence

The H-R Diagram (Luminosity, Temperature, Diameter)

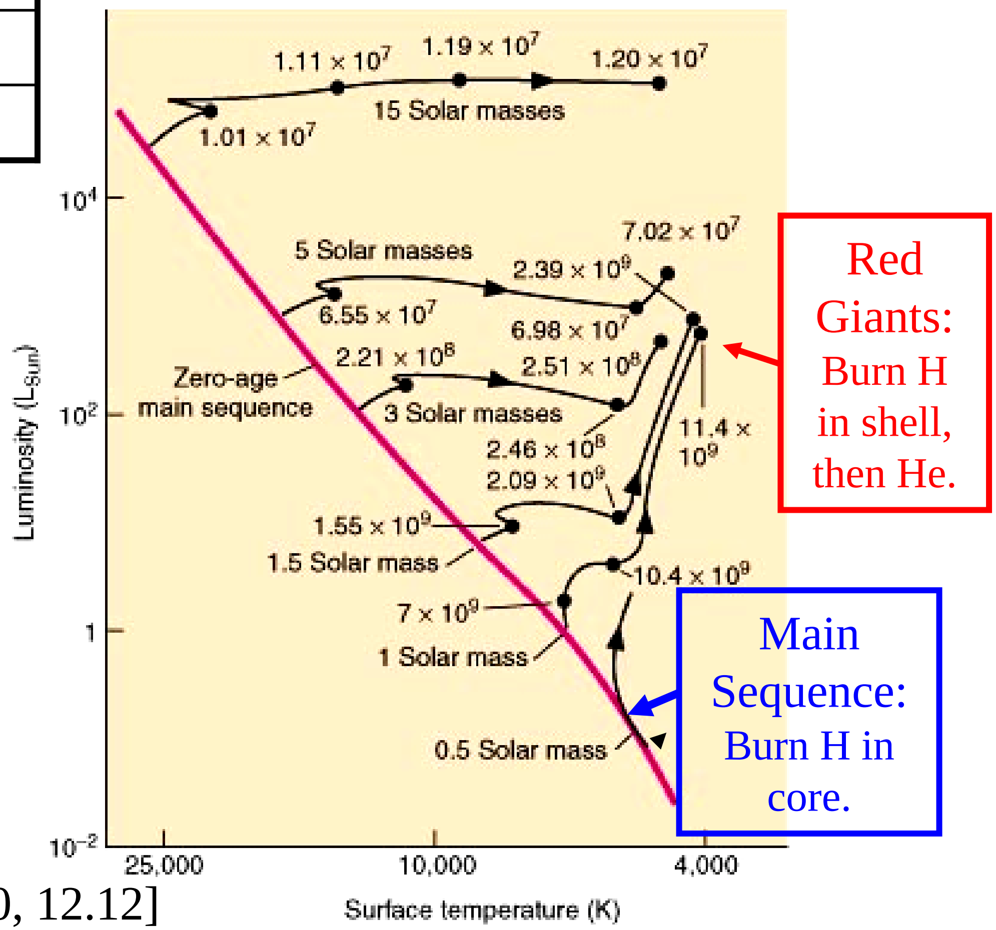


MAIN SEQUENCE:
Stars convert H into He in their cores.

Stars go through series of nuclear reactions:

Reaction	Min. Temp.
$4\ {}^{1}H \rightarrow {}^{4}He$	$10^{7}\ {}^{o}K$
$3\ {}^{4}He \rightarrow {}^{12}C$	$2x10^{8}$
${}^{12}C + {}^{4}He \rightarrow {}^{16}O$, Ne, Na, Mg	$8x10^{8}$
Ne $\rightarrow$ O, Mg	$1.5x10^{9}$
O $\rightarrow$ Mg, S	$2x10^{9}$
Si $\rightarrow$ Fe peak	$3x10^{9}$

Predicted paths of stars on HR diagram



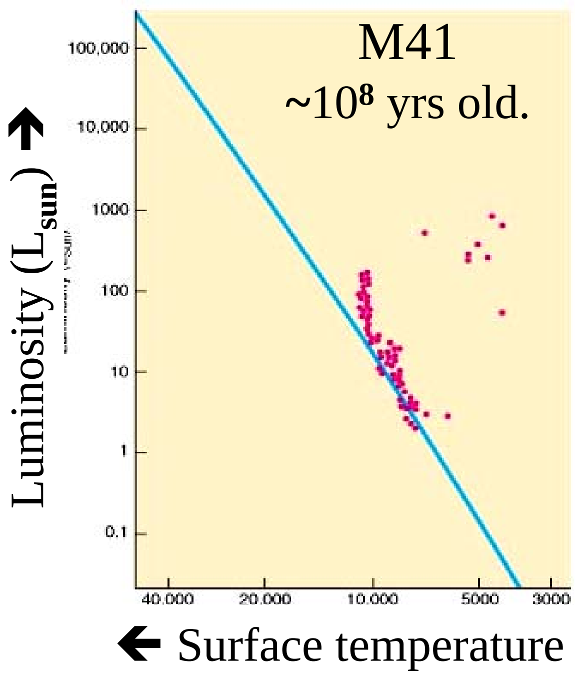
Lifetime

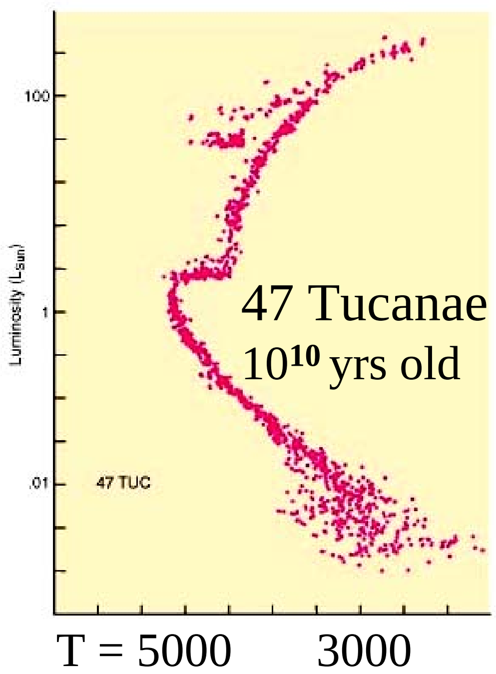
= (amount of fuel)/(rate of consumption)

- Massive stars have very short lifetimes.
- Old stars last a very long time.

[see figs. 12.10, 12.12]

Star clusters are snapshots of stellar evolution





- All stars in a given cluster formed at ~ same time.
- But with a wide range in masses.
- ***Main sequence turnoff***

  = stars just finishing main sequence evolution.

To see how it all works, look at:

http://www.mhhe.com/physsci/astronomy/applets/Hr/frame.html applet

http://www.pa.msu.edu/courses/isp205/sec-1/hr.mpg movie

Stellar Evolution

Here: Evolution through nuclear burning.	
$M_{initial} > 8M_{\odot}$	**Nuclear burning all the way to iron.**
$M_{initial} < 8M_{\odot}$	**Nuclear burning shuts off after He burning.**

Mass loss:

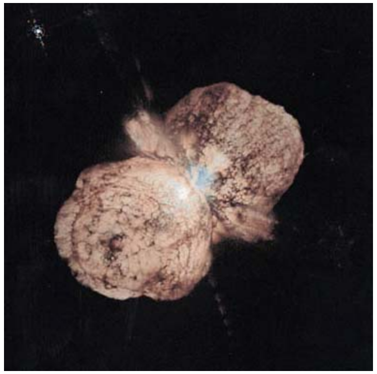
- Planetary nebulae
- Supernovae

There: Final state.	
$M_{final} > 3M_{\odot}$	**Black hole.**
$1.4 < M_{final} < 3M_{\odot}$	**Neutron star.**
$M_{final} < 1.4M_{\odot}$	**White dwarf.**

Which are supported by electron degeneracy? Which by neutron degeneracy?

- Stars make heavy chemical elements.
- Can then blow them out into space.

Planetary nebula, with white dwarf forming at center.



Unstable 150 solar mass star, expelling mass.

Expanding supernova remnant, with neutron star at center.

What we have learned about stars

We can measure:

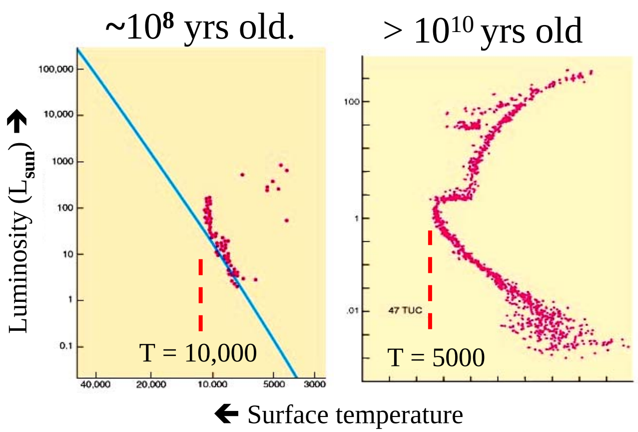
- Luminosity
- Mass
- Size
- Chemical composition

Computer "models" assuming:

- Made of gas.
- Neither contracting nor expanding.
- Neither heating up nor cooling down.
- Specify method of energy transfer.

Lifetimes of stars:

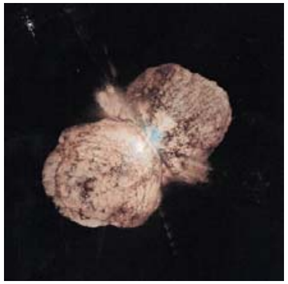
- We see both young and old clusters.
- Sun's structure consistent with 4.5 billion yr age.



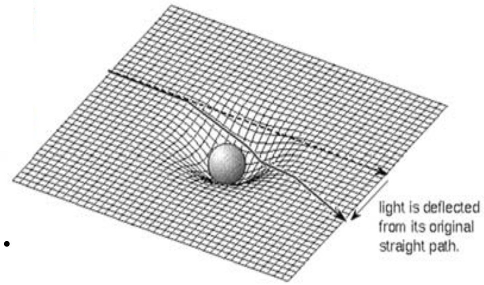
Oldest stars about 13 billion years old.

Nucleosynthesis:

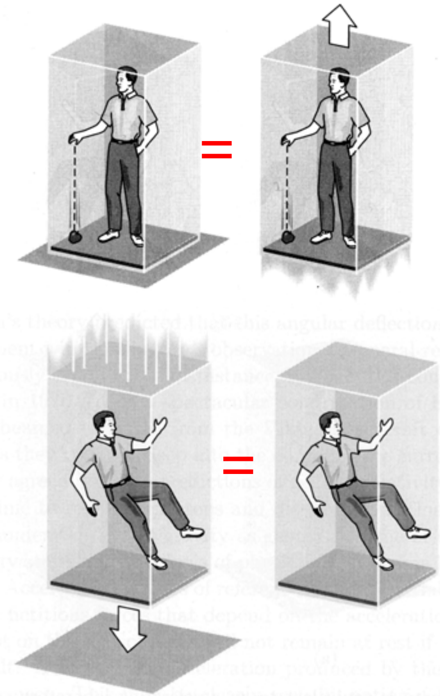
- Stars make heavy chemical elements.
- Can then blow them out into space.



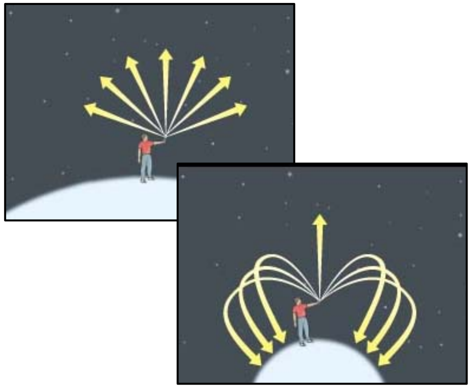
General Relativity



- Gravity = “curvature” in space.
  - Photons, planets etc follow shortest paths through curved space.
  - Analogy: 2D bug on surface that curves into an extra (3^{rd}) dimension.
- Einstein’s starting point: Equivalence Principle
  - Can’t tell difference between gravity & acceleration
  - …or between freefall & no gravity.
  - So *any* experiment should give same answer in either case.



- Many proofs that General Relativity is the better description:
  - Curved path of starlight as it passes through Sun’s gravitational field.
  - “Precession” (gradual change in direction of major axis) of orbit Mercury.
  - Time slows down in strong grav. field…. even GPS systems are affected.
- Black Holes
  - Gravity so strong that escape velocity exceeds speed of light.
    - So light falls back.
  - “Schwarzschild radius” or “event horizon” = radius around mass concentration within which light can no longer escape to outside.



Pluto

- Why did astronomers start searching for it?
- Did it turn out to be the sort of planet they thought should be there?
- How big is it compared to other objects in nearby orbits?
- Why was it reclassified as a “dwarf planet”?

Planets orbiting other stars

- So far we have found several hundred planets circling other stars. Most are similar to Jupiter.
- Why are we interested in finding other Earth-like planets?
- How many have we found so far that definitely are habitable?
- How does the “wobble technique” work? (what is the basic idea?)
  - What sort of planets is it limited to finding? Why?
- How does the gravitational lensing technique work?
  - Grav. lensing is capable of finding planets of almost any mass, at any distance from their parent stars.
- The Kepler mission
  - A telescope in orbit measures brightnesses of 100,000 stars, over and over again.
  - “Transit” method – look for effect of planet passing between us and its parent star.
    - What is that effect?
  - What sorts of planets can Kepler find?
- Future goal – measure spectrum of light reflected off distant Earthlike planets.
  - To search for signs of water, oxygen in planet’s atmosphere.
    - What would finding water tell us? What would finding oxygen tell us?
- What is the SETI project?   Has it found anything yet?