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.
- There will some questions similar to those on the homework assignments.

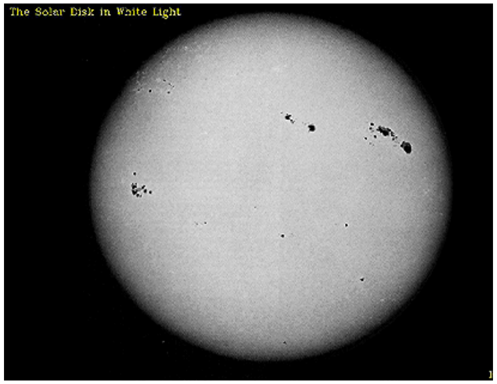
Some general ideas that you should understand:

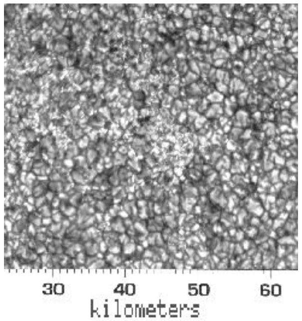
- What is the energy source of the Sun? Of other stars?
- How do we know what goes on inside of the Sun and other stars?
- In what ways do stars change during their lifetimes? What simple fact means that they *must* evolve (i.e. change their interior structure)?
- You should know what the H-R diagram 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:

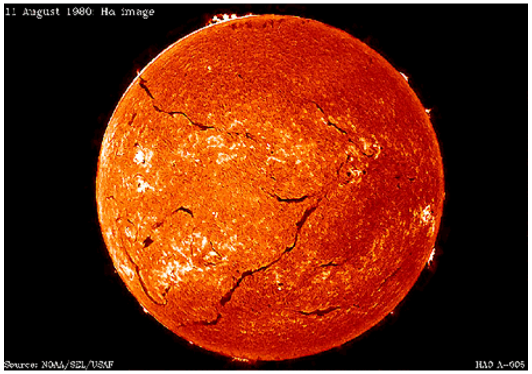
- Age of the Sun (= age of solar system) = 4.5 billion yrs.
- Predicted lifetime of Sun's core H-burning phase = 10-11 billion years (depends on exactly what you specify as the end-point).

- 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.

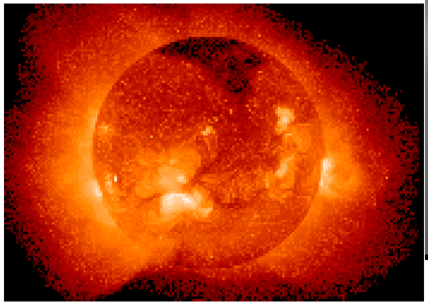


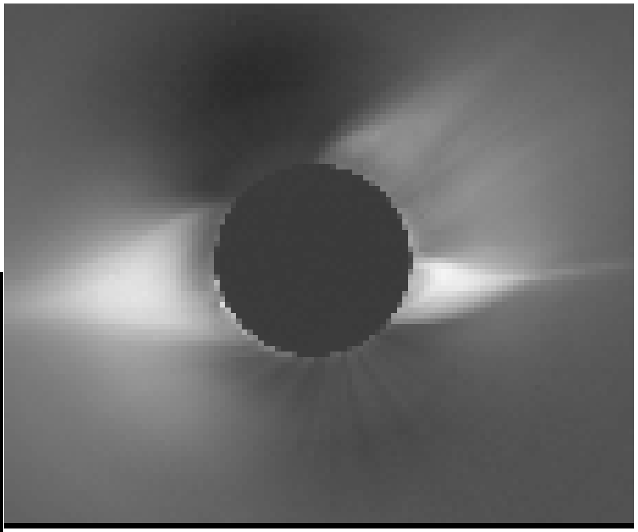


- Chromosphere
  - Transparent gas layer, reaches 2000-3000 km above photosphere.
  - T ~5,000-10,000^{o} K
  - Photosphere = point we can no longer see through chromosphere.

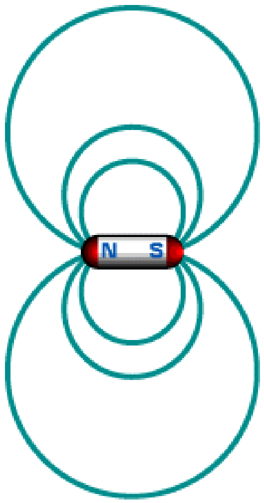


- Corona
  - T > 1,000,000^{o} K
  - Very low density: 10^{-10} atmospheres.
  - Heated by magnetic energy.
  - Several x diameter of photosphere.

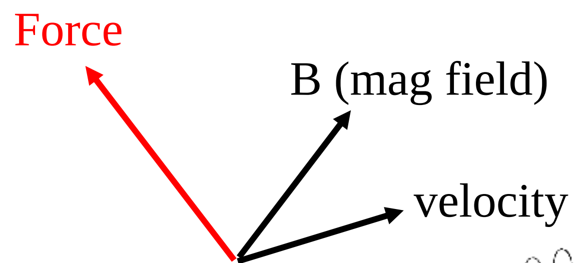




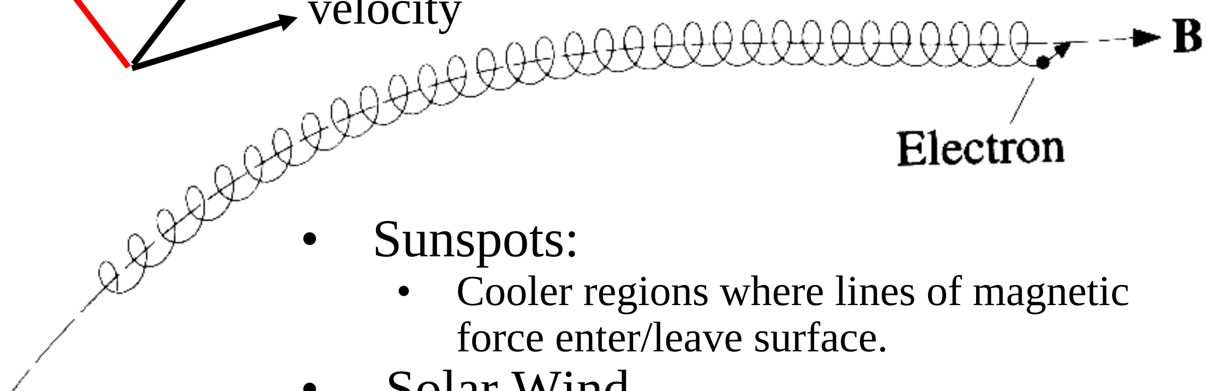
Magnetic Fields Control Much of Sun's Surface Activity

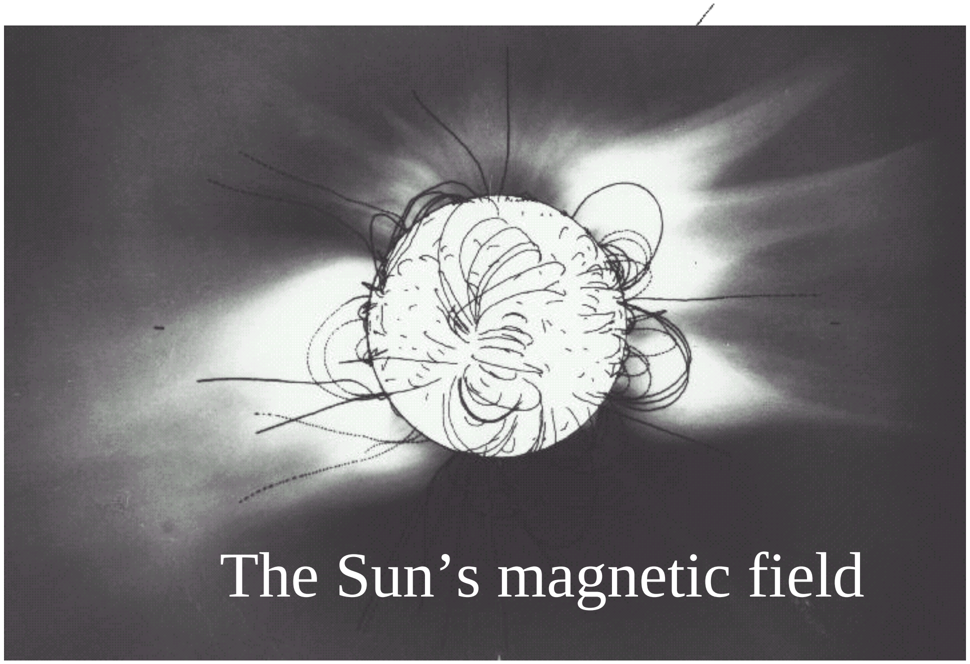


Magnetic field lines of force



Motion of a charged particle around a magnetic field line





The Sun's magnetic field

- 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?

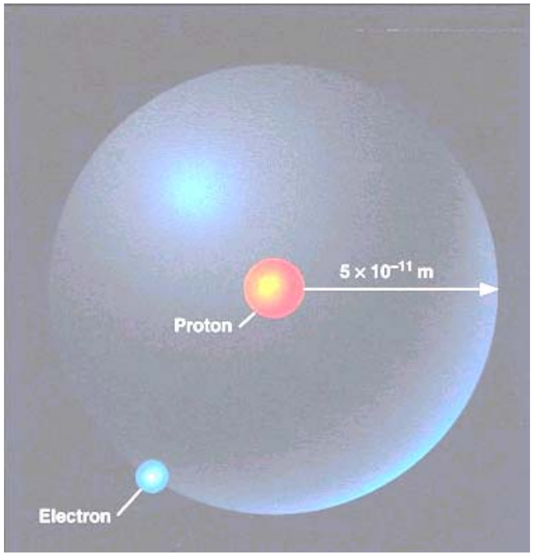
- Need to provide
  - 4×10^{26} watts
  - $< 2 \times 10^{33}$ grams (mass of Sun)
  - > 4.5 billion years (age of Earth)
- Nuclear fusion reactions:
  - $4 \times {}^{1}H \rightarrow {}^{4}He$ + neutrinos + energy

$E = mc^2$

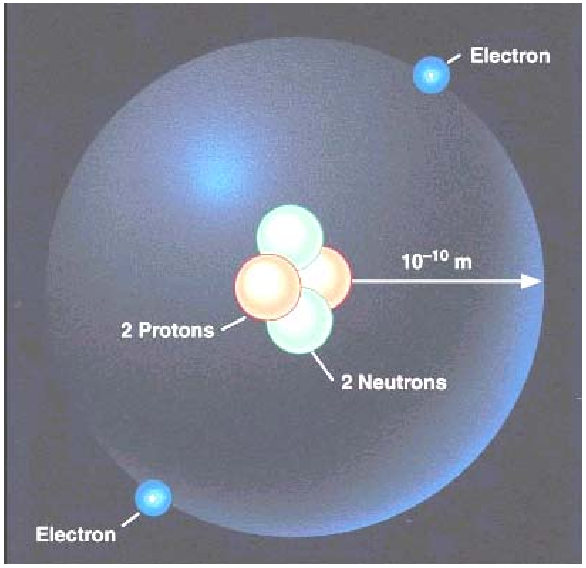
What does this mean???

Hydrogen: ^{1}H

4 x



Helium: ^{4}He



Computer simulations of stars

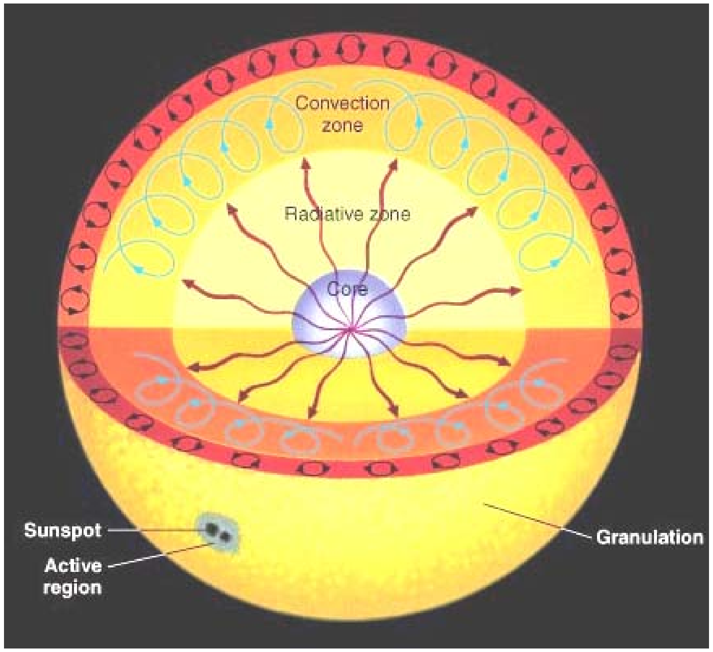
We can measure:

- 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.

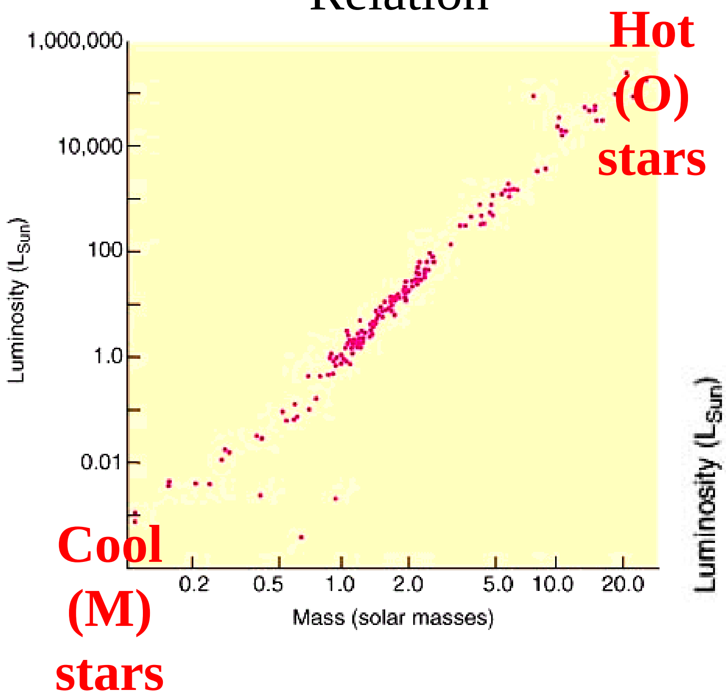
- Internal structure.
- Which nuclear reactions generate energy at what points.
- Lifetimes.



The interior of the Sun

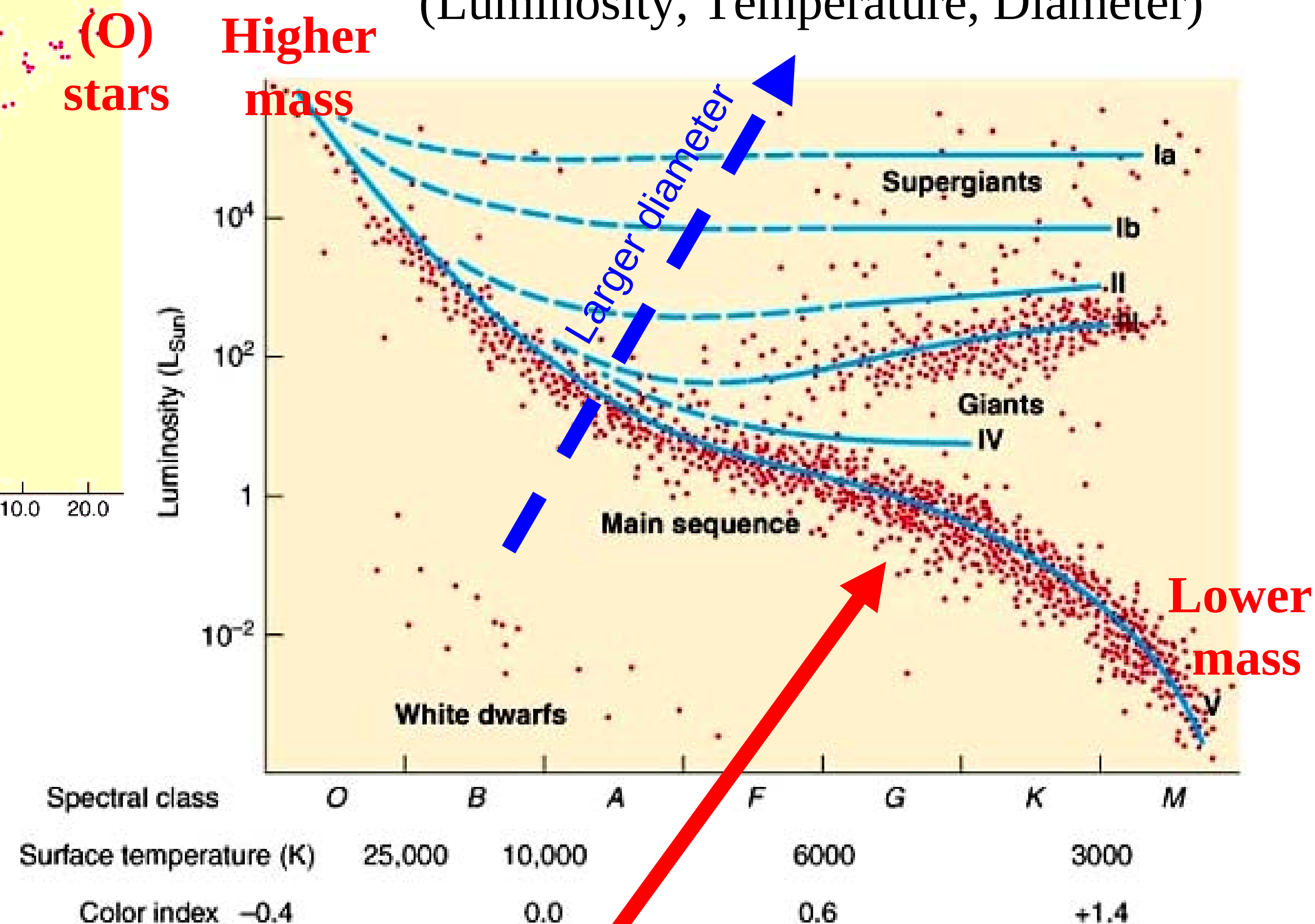
Here's what we observe about stars.

The Mass-Luminosity Relation



Main sequence is a mass sequence

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

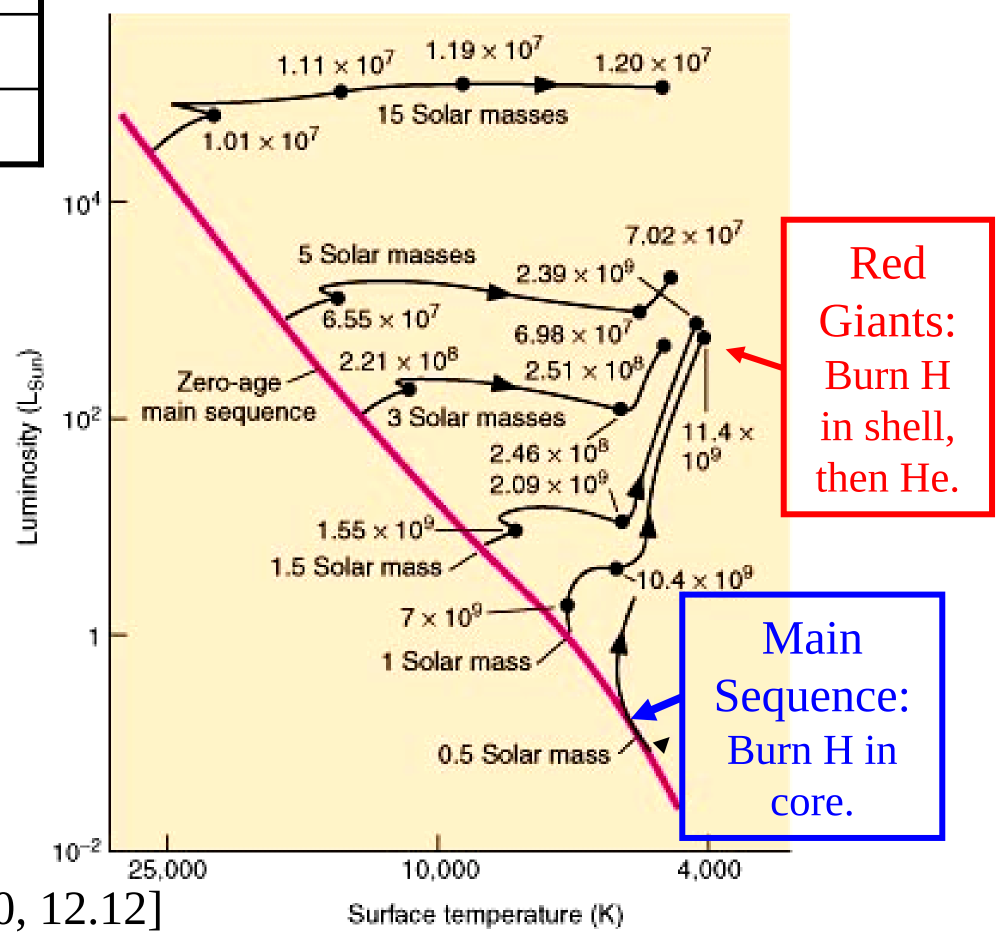


MAIN SEQUENCE:
Stars convert H into He in their cores.

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



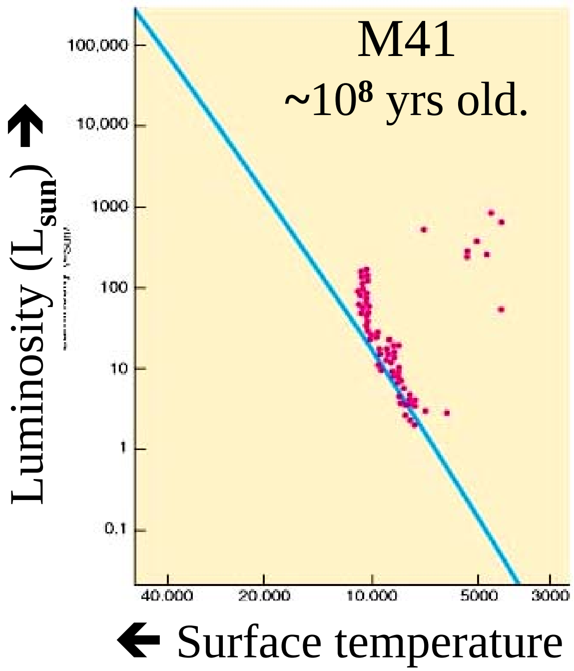
[see figs. 12.10, 12.12]

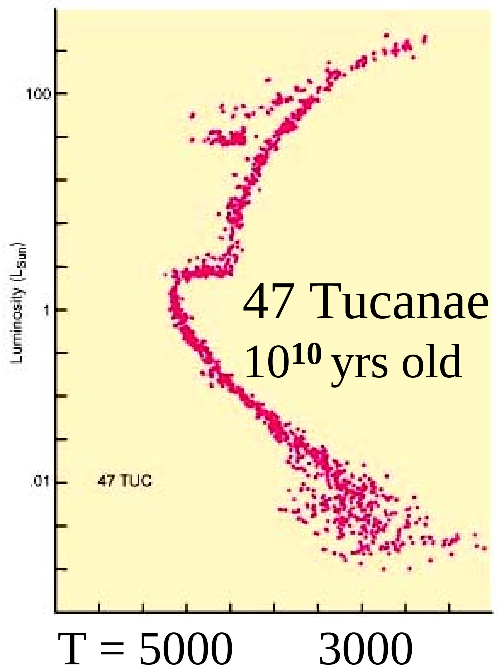
Lifetime

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

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

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.**

Planets around other stars

- Star formation → disks around stars
  - Planets form in these disks.
  - Over 250 known
  - Usually detected through their effect on motion of the parent star.
- Earth mass planet in "habitable zone" would be the real prize. *Why?*
- Most Earth-like planet so far = 3 Earth masses, found by "gravitational lensing". *What is grav. lensing?*

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 (3rd) 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.