

Thursday, 20 November, 2008 -corrected

# PHYS-1060 (1)

Fall 2008

3:30-4:45pm Tu Th 1104 Rood

Dr. Philip Edward Kaldon  
Western Michigan University

Unit 3

## Exam 2 Scores

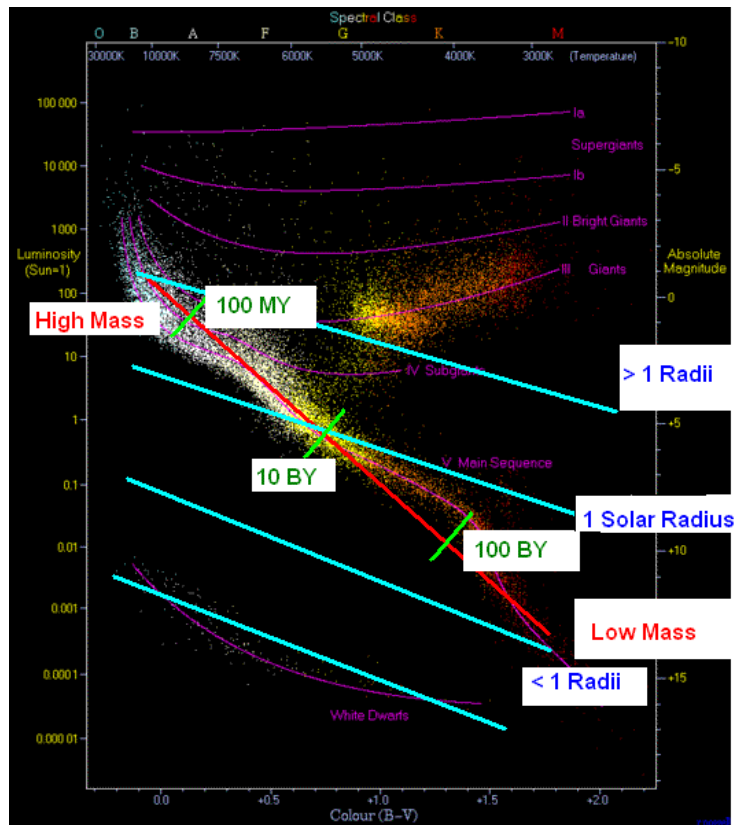
X2rraw (30), X2raw (150), X2curved (150)

	X2rraw	X2 raw	X2curved		15	75	92
					14	70	87
					13	65	82
	27	135	150		12	60	77
	26	130	147		11	55	72
	25	125	142		10	50	67
	24	120	137		8	40	60
	23	115	132				
	22	110	127				
	21	105	122	n	110	110	110
	20	100	117	hi	27	135	150
median/ mean	19	95	112	lo	8	40	60
	18	90	107	ave	18.88	94.41	111.4
	17	85	102	s.d.	4.105	20.52	20.42
	16	80	97				

To get Percent Grade, find "X2curved"  $\div$  1.5

## Things We Can Learn From The H-R Diagram:

Main Sequence Distribution  
and  
Those bands NOT Main Sequence



Our Sun is:  
Spectral Type G2  
Luminosity Class V

(G2 V)

## Star Clusters

### Open and “Closed” Globular Clusters

Star clusters are Localized:

The stars are all about the same distance from Earth and all about the same age.

Open clusters in the flat plane of the galaxy, where the dust and gasses are.

Up to a few thousand stars,  
loosely held together by gravity.

Globular clusters are in the “halo” or sphere around the galaxy – and are very old.

Up to a hundred thousand stars,  
tightly bound by gravity.  
No dust or gas. Low metal stars.

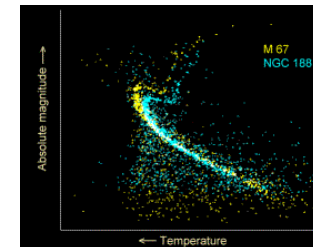
### Stellar nurseries

The H-R Diagram for an Open Cluster is cut off at the high mass end (O B A), and though it has a strong Main Sequence line, there is some spread outward.

### Age of Star Clusters

The Main Sequence Turn-Off... occurs because the stars in a cluster are roughly of the same age and the high mass stars have shorter lifetimes. So as the star cluster ages, any high mass stars will end their hydrogen burning life and leave the Main Sequence.

H-R Diagram for two clusters (M67 and NGC 188):



Recall that the Main Sequence stars have age estimates based on their mass...

So NGC 188 is older than M67.

## Stellar Lives

### **Cloud –**

**Protostar** – collapsed down to a spinning object, but not enough yet for thermonuclear ignition in the core.

When the core reaches 10,000,000K – hydrogen fusion gets efficient enough for the star to ignite.

Stabilization takes time:

O star, maybe 1,000,000 years  
G2 star, maybe 30,000,000 years

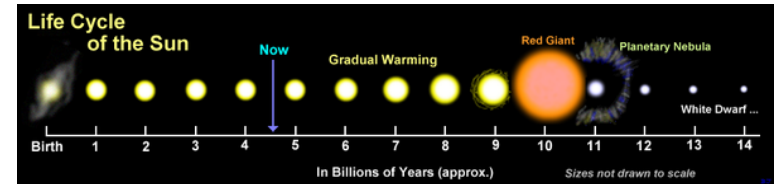
Perhaps not so strange when you consider that for our G2 star, it takes several million years for light to get out to the surface from the core.

### **Main Sequence**

**high end**, about 150 solar masses (but this number is under debate)

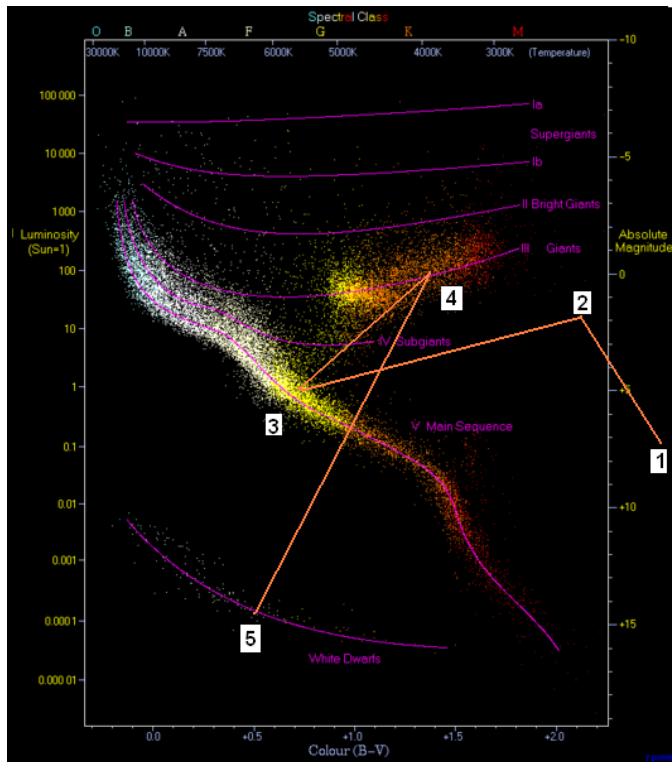
**low end** for mass, 0.08 solar masses or about 80 Jupiters

## The Sun's Life



Hydrogen ignition – 10,000,000 K

Helium ignition – 100,000,000 K  
requires 0.5 solar masses and up  
(requires mass, pressure, gravity to reach that temp!)



1 – condensing phase, 2 – protostar,  
 3 – Main Sequence, 4 – Red Giant,  
 5 – White Dwarf

What is so surprising about stars  
 is the link between these large objects  
 and  
 quantum mechanics – the study of the very  
 smallest of things inside the atom.

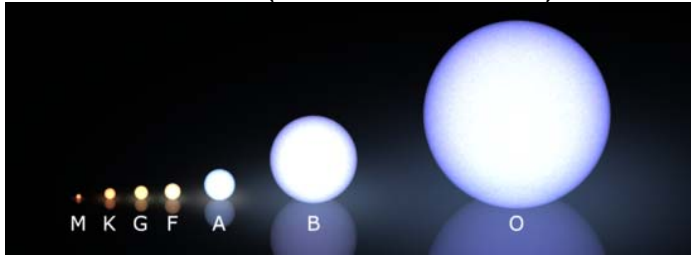
**AN IMPORTANT NOTE:**

The current Quiz 7 (mismarked as Quiz 6 in some handouts) is about drawing an H-R diagram. The scale of absolute magnitudes **SHOULD** go from +20 at the bottom to -5 at the top, because we want the most luminous stars at the top. (The scale says +5 to -20, which makes no sense. I really wish someone who had noticed this *had sent me an e-mail alerting me to the error!*)

A corrected handout can be downloaded at the website if you wish.

Because of this confusion, we will extend the Q7 deadline to Tuesday 18 November 2008.

## A Comparison of Main Sequence Stars (color and size)



Note the puny little yellow G star towards the left.

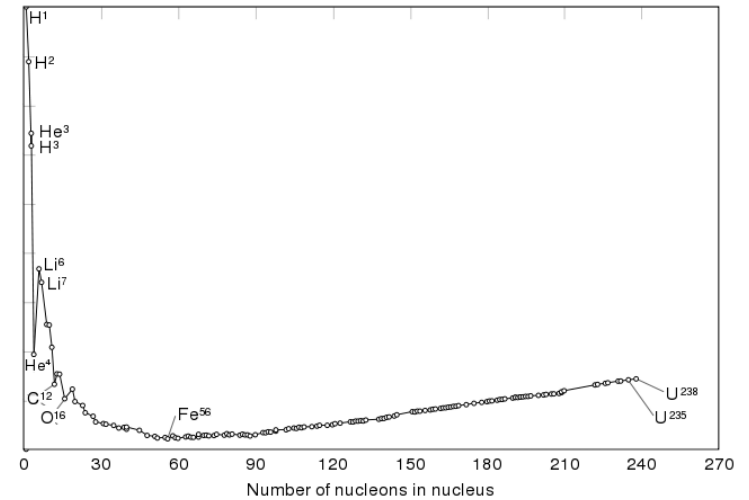
There is tremendous variety in star classifications, because each star has its own composition and age.

A young G star is different than an older G star.  
Some stars are Variable stars.  
Giant stars build up carbon and other elements.

Wolf-Rayet stars (W or WR) – Helium rich...  
or are they late stage supergiants which have blown away their hydrogen shell, exposing their helium cores?

Brown dwarfs  
(L 1300-2000 K, T 700-1300K, Y < 700K ?)

Fig 12-17

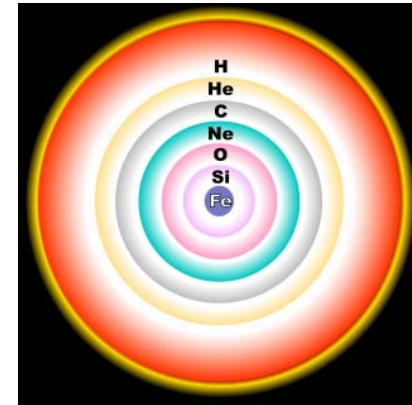
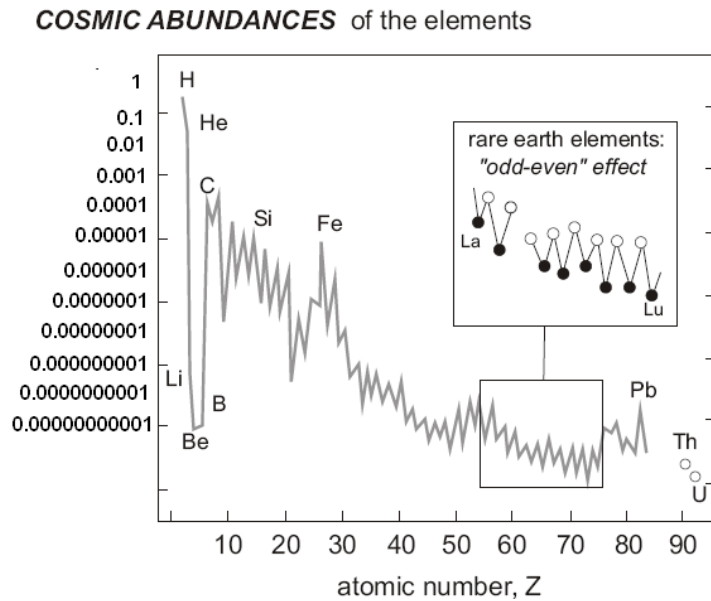


### Mass per nucleon. The Iron Minimum.

Isotopes on the left can use fusion to reach Iron-56 and release energy.  
Isotopes on the right can use fission to reach Iron-56 and release energy.

During the death of a massive star, the energy of the collapse can drive the fusion reactions past Iron-56, but cannot sustain the energy.

Fig. 12-18

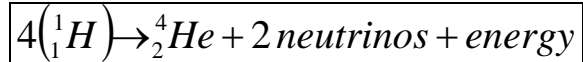


Shells of Fusion Layers Prior to  
Stellar Collapse of Large Stars  
 $M > 8 M_{\text{Sun}}$

Why Iron (Fe) at the center?

## Mass to Energy Conversion

$$E = mc^2$$



If core T exceeds 10,000,000 K ( $10^7$  K):

4 Hydrogen nuclei fuse into

1 Helium nucleus + energy (gamma-rays)

+ 2 neutrinos

at a rate sufficient to balance off the loss of energy in the form of light at the star's surface (i.e., it's luminosity).

In our Sun, the central temperature is at present about 15.7 million K, and 613.8 million metric tons of H are fused into 609.5 million metric tons of He each second.

By the way, what happens to the other 4.3 million tons of matter processed per second?

## The Pressure-Gravity Balance in Larger Stars

Higher Core Temperatures  
Larger Size and More Mass

But... Lower Density (mass-to-volume ratio)

If all Main Sequence stars had the *same* density,  
then  $R \sim M^{1/3}$

$$\left( \rho = \frac{M}{V} = \frac{M}{\frac{4}{3}\pi R^3} \right)$$

But it is more like  $R \sim M^{0.6}$   
And the Luminosity goes as  
 $L_* \sim R^2 T_{\text{surface}}^4$

So the larger, hotter stars are also more luminous.

To be more luminous, requires more fusion at the core, burning through the hydrogen fuel at a much faster rate...

## Figure 12.22

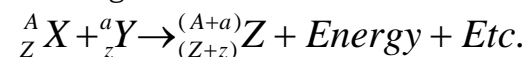
Protostar ( $25 M_{\text{sun}}$ )  
Blue Main-Sequence star  
CNO cycle  
Red Supergiant  
Helium-burning Supergiant  
core expands  
hydrogen-burning shell shrinks  
Multiple-Burning Supergiant  
Supernova  
Neutron Star or Black Hole

Protostar ( $1 M_{\text{sun}}$ )  
Yellow Main-Sequence star  
proton-proton chain  
Red Giant  
hydrogen burning around  
inert helium core  
Helium-burning star  
Double-shell burning  
inert carbon core  
Planetary Nebula  
White Dwarf

## Fun with Fusion

$Z$  = # of protons  
 $N$  = # of neutrons  
 $A = Z+N$  = # of nucleons  
(neutrons & protons)

If we fuse two nuclei together, our nuclear reaction looks something like:



Carbon-12 ( ${}^{12}_6\text{C}$ ) has 6 protons and 6 neutrons, and a mass of 12.000 amu.

But each proton by itself has a mass of 1.007825 amu and each neutron has a mass of 1.008665 amu. So, is the whole greater than the sum of its parts? Well, as you can see, 6 p's and 6 n's have more mass than that of the Carbon-12 nucleus. Since you can't just "hide" mass, forming the Carbon-12 nucleus must have some freed that excess mass as the *binding energy* for the nucleus, or the energy that holds it together.

$$6 \text{ protons} \times 1.007825 \text{ amu/proton} = 6.046950 \text{ amu}$$

$$6 \text{ neutrons} \times 1.008665 \text{ amu/neutron} = 6.051990 \text{ amu}$$

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$$\text{Total mass of } 6 \text{ p} + 6 \text{ n} = 12.098940 \text{ amu}$$

$$\text{Carbon-12 (made of } 6 \text{ p and } 6 \text{ n)} = 12.000000 \text{ amu}$$

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$$\text{Excess mass of pieces} = 0.098940 \text{ amu}$$

## Nova and Supernova

A Nova is a potentially recurring explosion in a star, typically caused when hydrogen from a companion star is pulled into the strong gravity of a white dwarf and ignites.

Supernovas are massive explosions as when a large mass supergiant reaches the iron minimum and is unable to continue multiple shell burning in the usual way

or when hydrogen from a companion star falls into a white dwarf and sufficiently raises the temperature for the inert carbon core of the white dwarf to suddenly begin fusion.

## Neutron Star

Degenerate matter remnant from a supernova explosion of a supergiant star. The gravitational force is sufficiently large to crush the neutrons, protons and electrons of the atoms into a large ~~planet-sized~~ block of neutrons ("neutronium").

## Black Hole

Supernova remnant with enough gravity to prevent light from escaping. Hence, it "looks black", like a "hole in space."