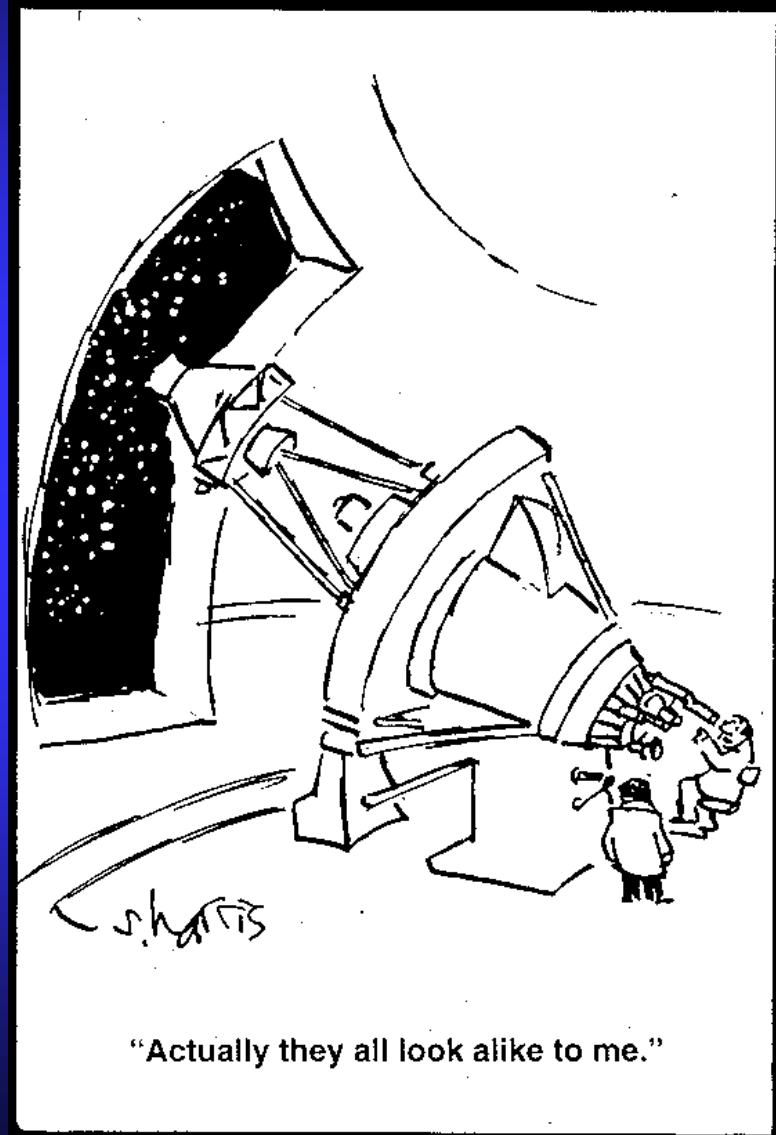


Stars



Overview

A. Definitions

A. Luminosity

B. Apparent Brightness

C. Absolute Magnitude

D. Apparent Magnitude

E. A.U.

F. Parallax

G. HR-Diagram

H. Main Sequence

I. Red Giant Star

J. Horizontal Branch Star

K. Asymptotic Giant Branch Star

Overview

B. The Distance Ladder

- A. Luminosity, Apparent Brightness, and Distance.
- B. The Distance to the Sun.
- C. Distances to nearby stars.
- D. The HR-Diagram and **Spectroscopic Parallax**

Overview

C. Stellar Evolution

A. What is the size (mass) distribution of stars?

B. What is the evolutionary sequence of a low mass star?

C. What is the evolutionary sequence of a high mass star?

D. How can we determine the AGE of a star cluster?

Apparent Brightness

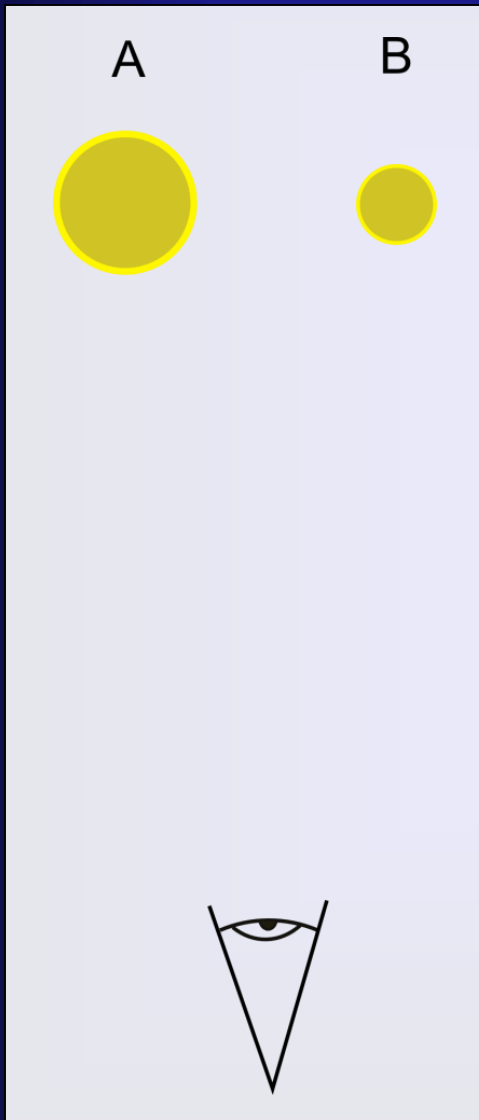
Luminosity:

The total amount of light emitted by an object in space.

Apparent Brightness:

The light that reaches the Earth from an object in space.

Apparent Brightness



Star A and B are at the same distance from the Observer

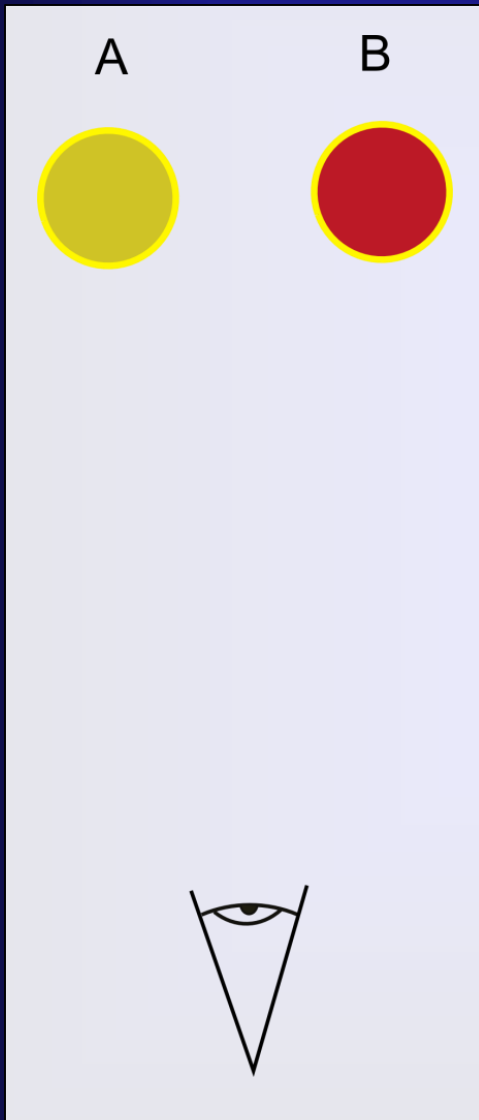
Star A and B are at the same Temperature

Star A is Larger than Star B

Which has a greater **Luminosity?**

Which has a greater **Apparent Brightness?**

Apparent Brightness



Star A and B are at the same distance from the Observer

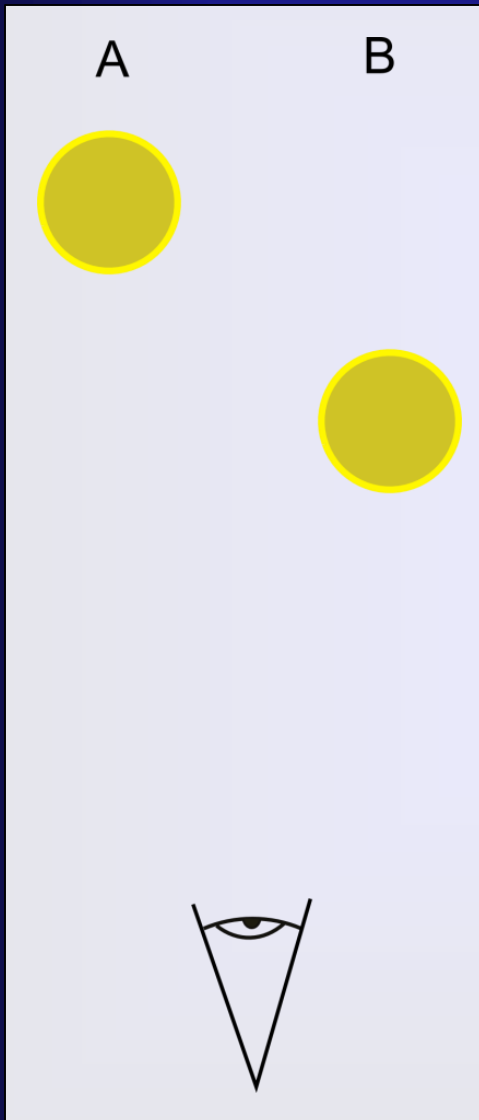
Star A is hotter than Star B

Star A and Star B are the same size

Which has a greater **Luminosity?**

Which has a greater **Apparent Brightness?**

Apparent Brightness



Star A is farther away than Star B

Star A and B are at the same
Temperature

Star A and Star B are the same
size

Which has a greater
Luminosity?

Which has a greater
Apparent Brightness?

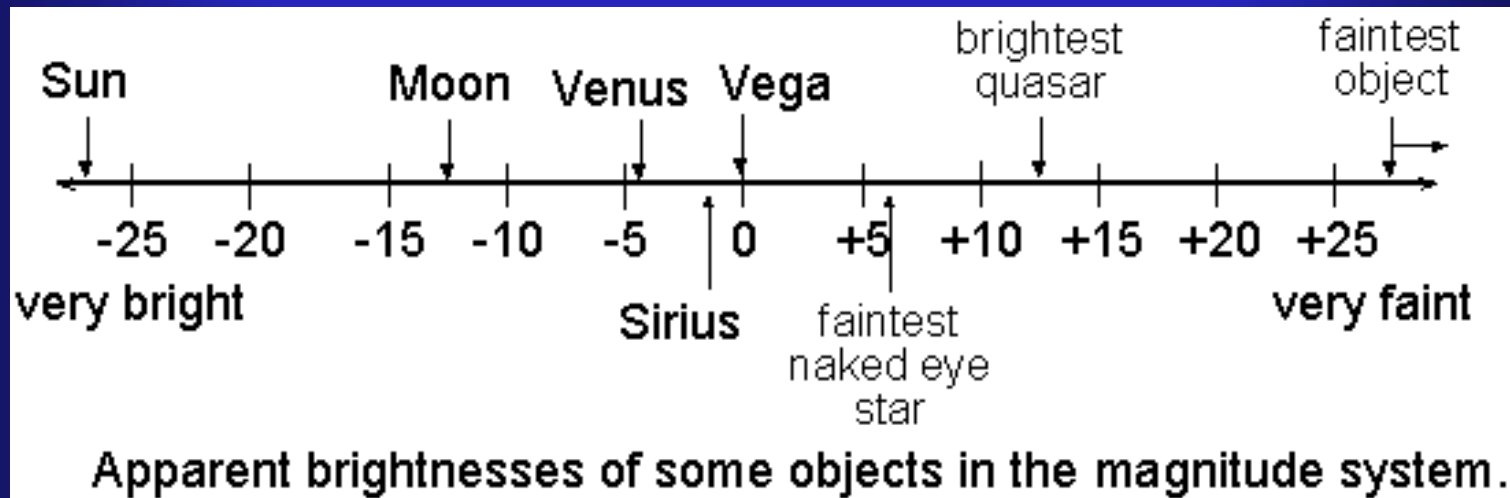
Relationships

	T	R	D
L			
B			

If I increase T, R, or D, what happens to L and B

Magnitudes

Here's something stupid that astronomers did



Absolute Magnitude:

The intrinsic brightness of a star on the magnitude system.

Apparent Magnitude:

The magnitude of the star as measured from Earth

Distances

**Distance Gives us
Luminosity and Size**

**So to study Anything
we need to know:**

**How Far Away
Is It?**

Kepler's 3rd Law

$$P^2 = a^3$$

A.U. (Astronomical Unit):

The distance between the Earth and Sun

a = Semi-major axis

P = Orbital Period

We can measure P and
calculate a (in AU)

From Kepler's 3rd Law

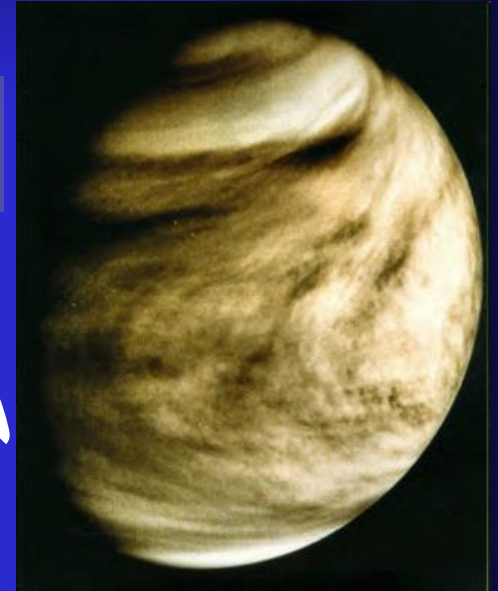
Planet	Period (Years)	Orbital Radius(A.U.)
Mercury	0.2	0.4
Venus	0.6	0.7
Earth	1	1
Mars	1.9	1.5
Jupiter	11.9	5.2
Saturn	29.5	9.5
Uruanus	84.3	19.2
Neptune	165	30

But how many Kilometers in an AU?

Distances in the Solar System

Earth to Venus = 0.3 A.U

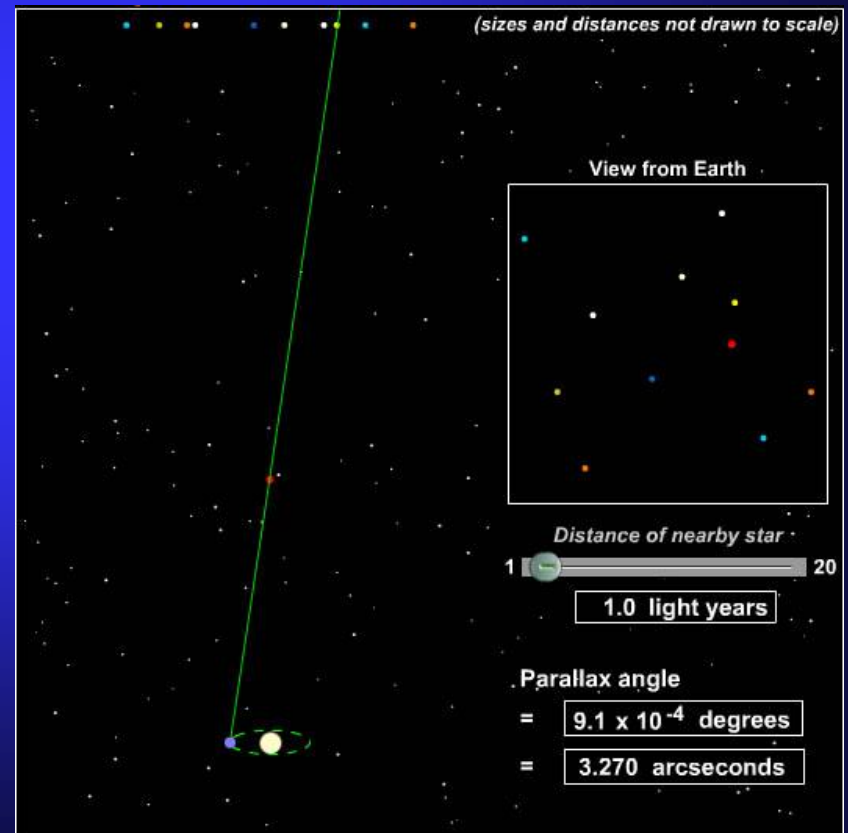
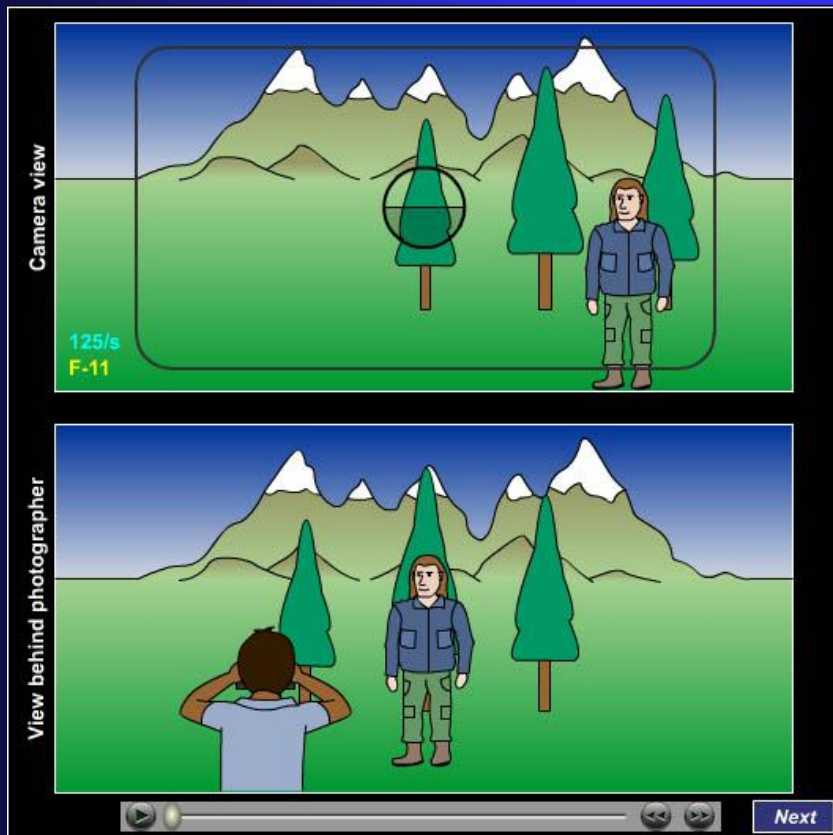
Earth to Venus = 4.47×10^7 km



1 A.U = 1.49×10^8 km

Parallax

We use parallax to get distances to stars within 100 Light Years



Spectroscopic Sequence

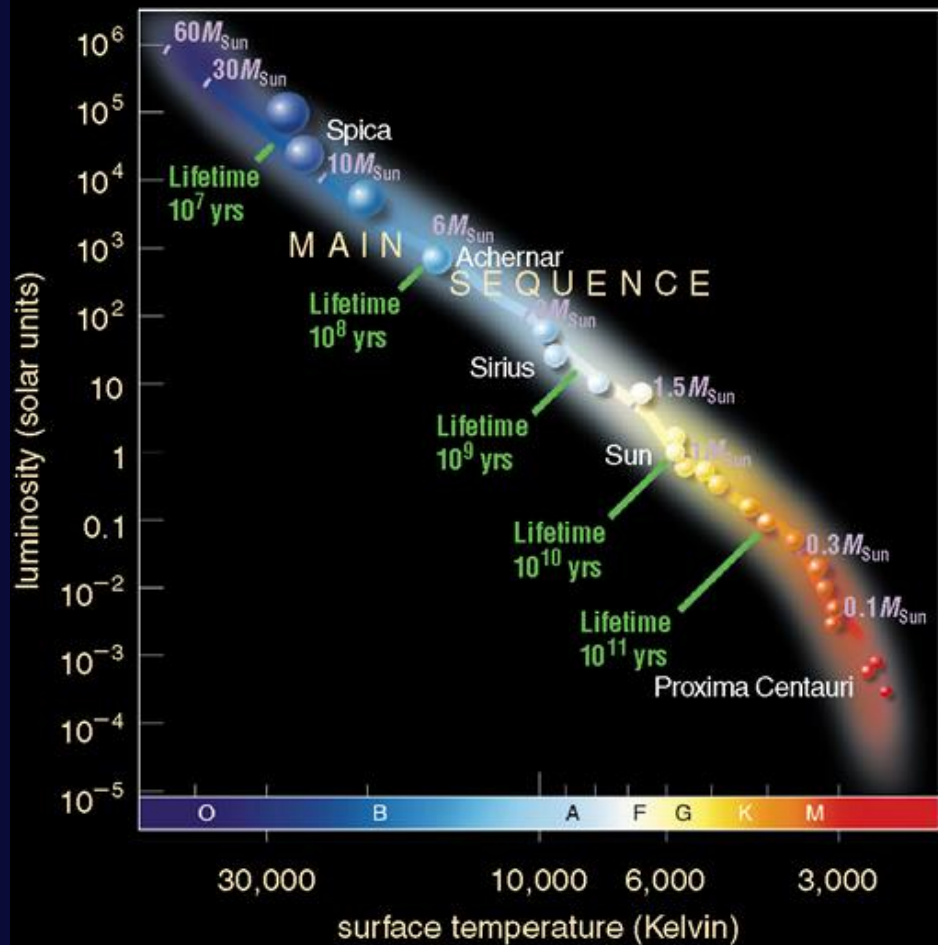
Studying stellar spectra...



		Temperature Range	Key Absorption Line Features	Brightest Wavelength (color)	Typical Spectrum
		>30,000 K	Lines of ionized helium, weak hydrogen lines	<97 nm (ultraviolet)*	
		10,000 K–10,000 K	Lines of neutral helium, moderate hydrogen lines	97–290 nm (ultraviolet)*	
		7,500 K–7,500 K	Very strong hydrogen lines	290–390 nm (violet)*	
		6,000 K–6,000 K	Moderate hydrogen lines, moderate lines of ionized calcium	390–480 nm (blue)*	
G	Sun, Alpha Centauri A	6,000 K–5,000 K	Weak hydrogen lines, strong lines of ionized calcium	480–580 nm (yellow)	
K	Arcturus	5,000 K–3,500 K	Lines of neutral and singly ionized metals, some molecules	580–830 nm (red)	
M	Betelgeuse, Proxima Centauri	<3,500 K	Molecular lines strong	>830 nm (infrared)	

H-R Diagram

Using Distance to get Luminosity



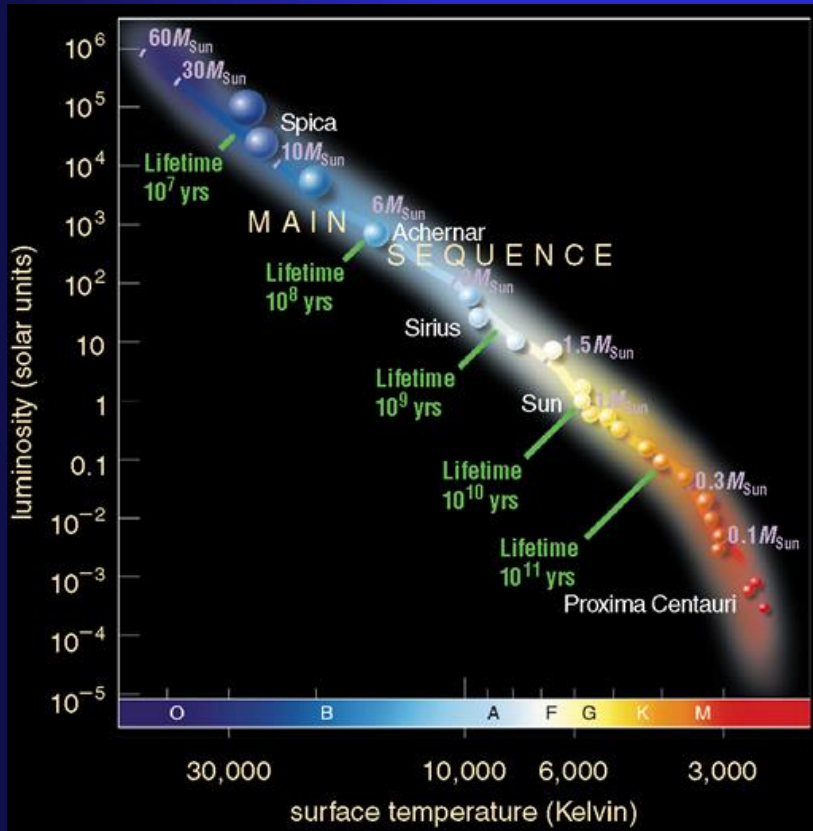
Get Luminosity from
Parallax
measurements

Get Temperature from
the spectra

There's a
correlation!

Spectroscopic Parallax

Using Luminosity to get large distances!

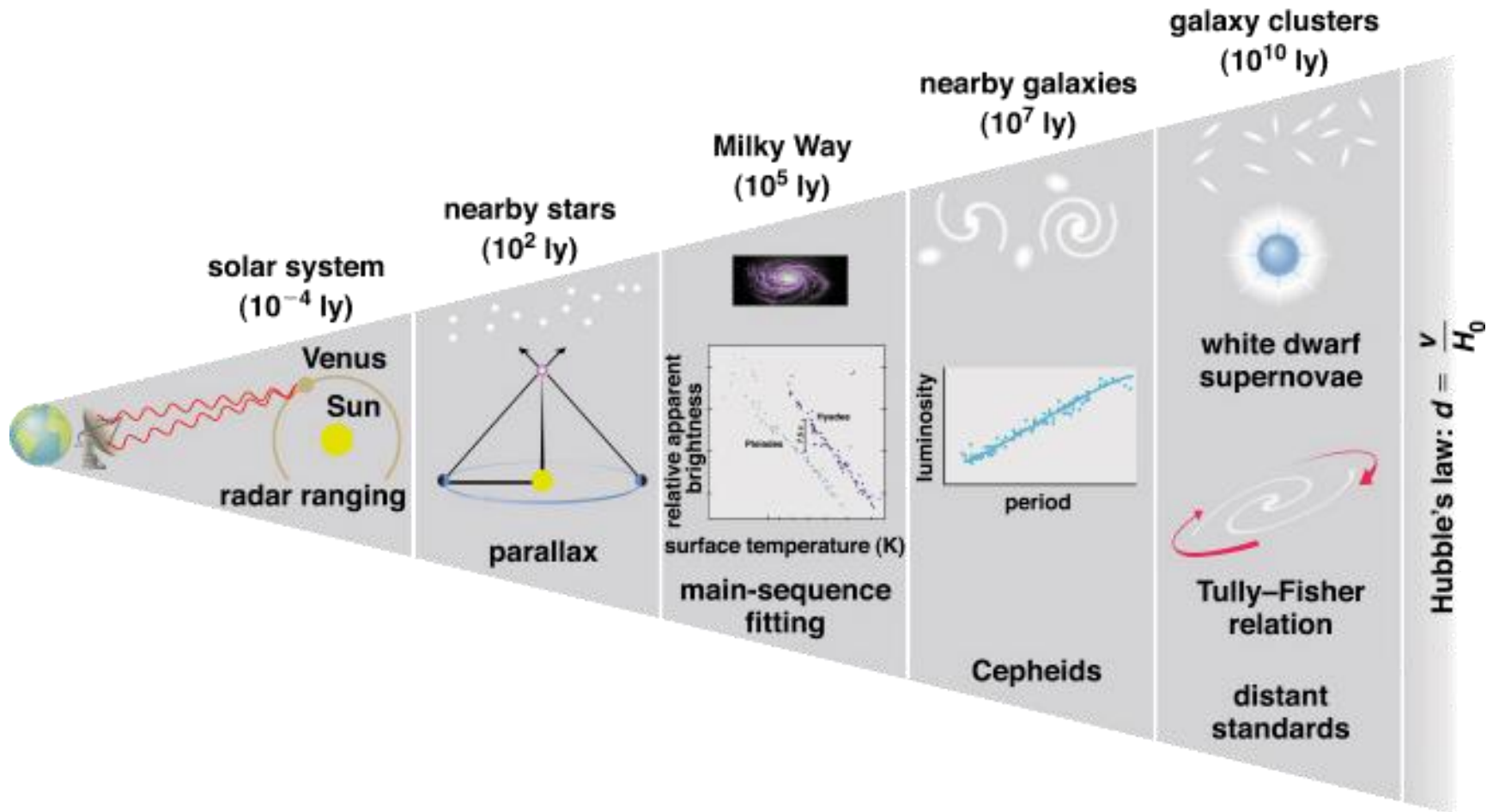


Get Temperature from
the spectra

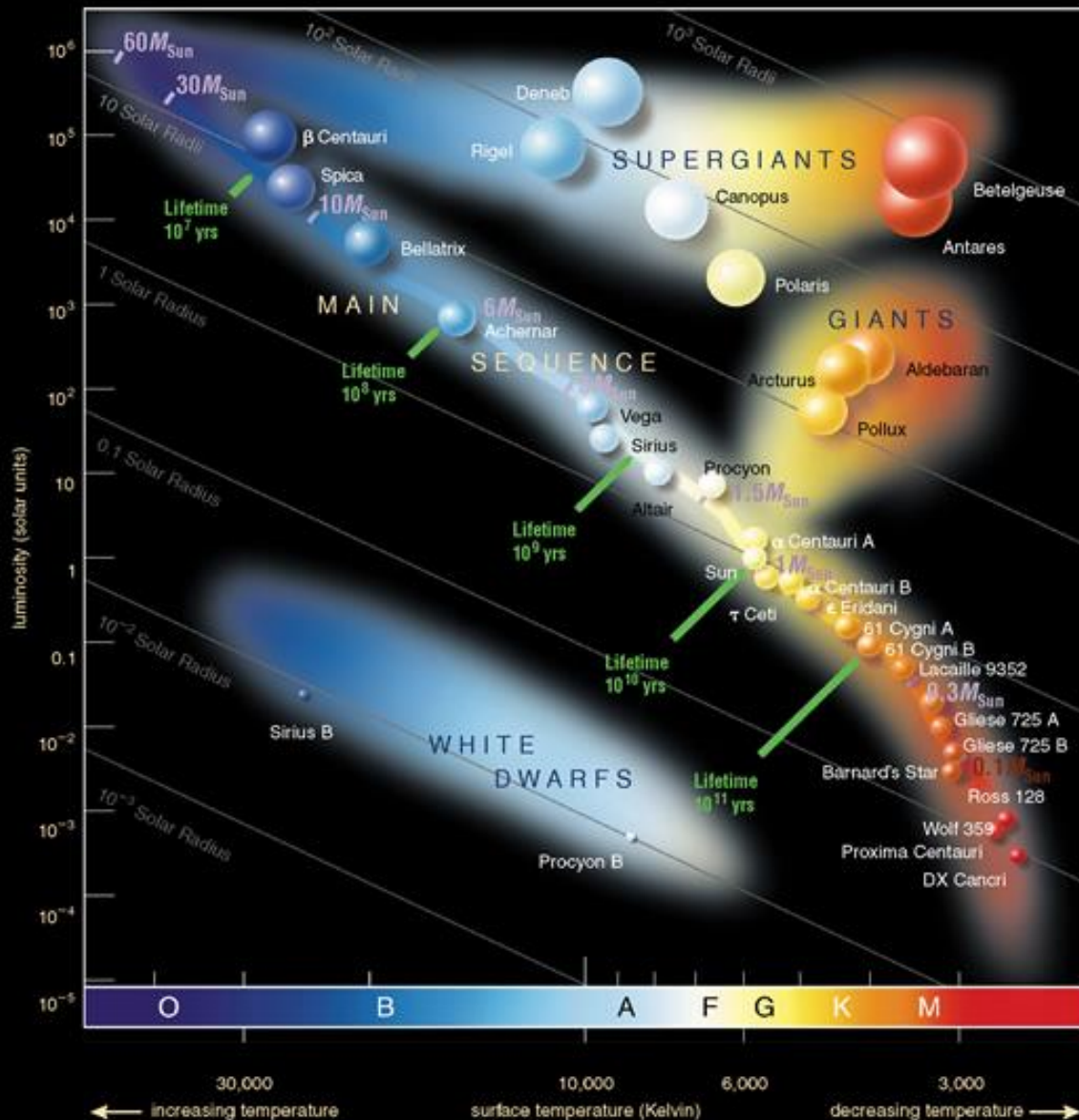
Get Luminosity from
the Temperature –
Luminosity
Correlation.

Get Distances greater than 100 light years!

The Distance Ladder



The HR Diagram



Stellar Evolution

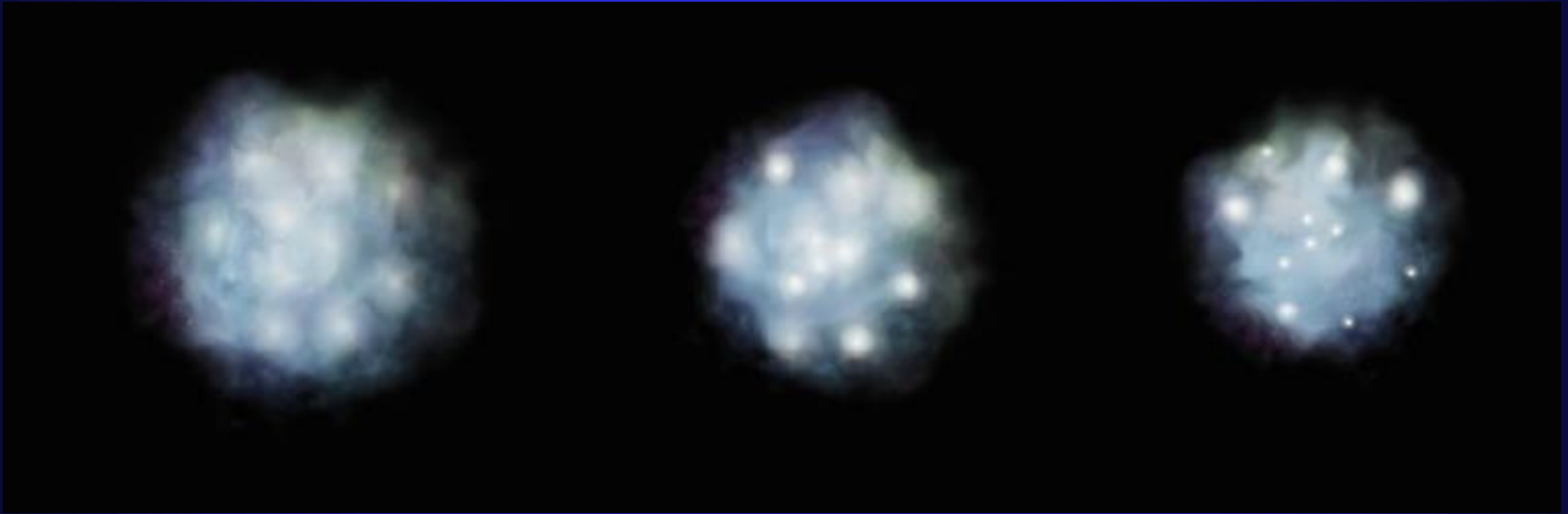
The single factor determining a star's life-cycle is...



Mass

Birth

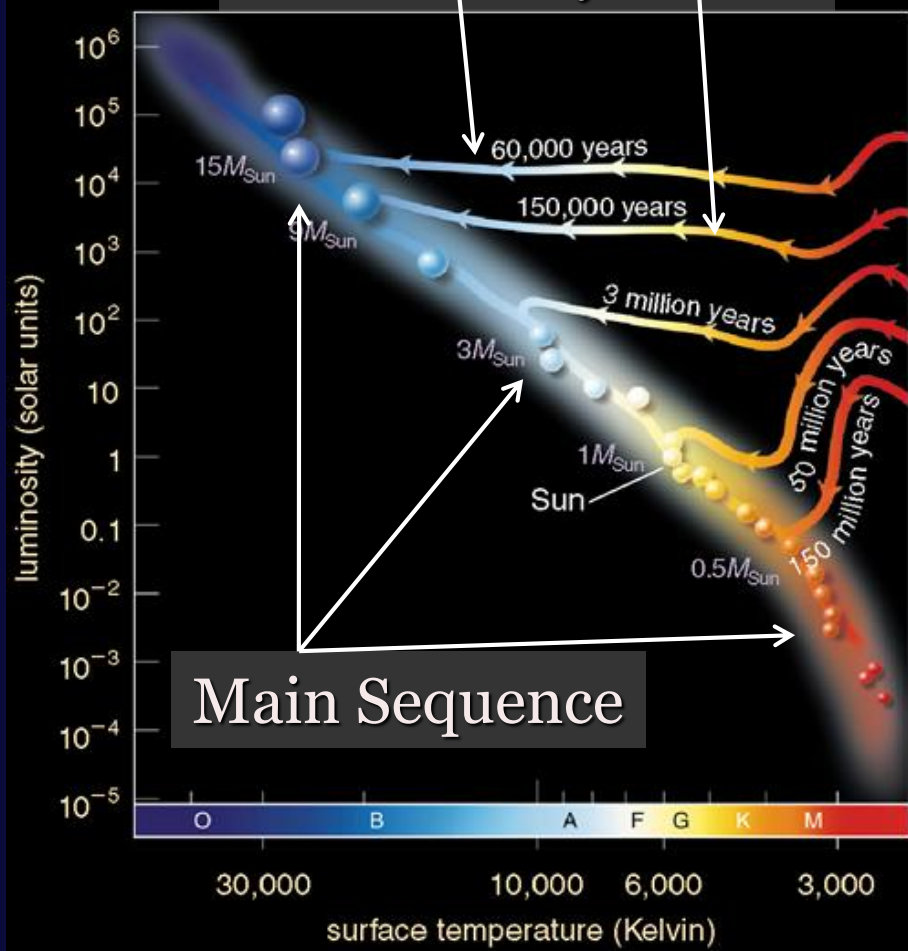
Stars are born in clusters



Clouds fragment as they collapse

Protostars

Evolutionary Tracks



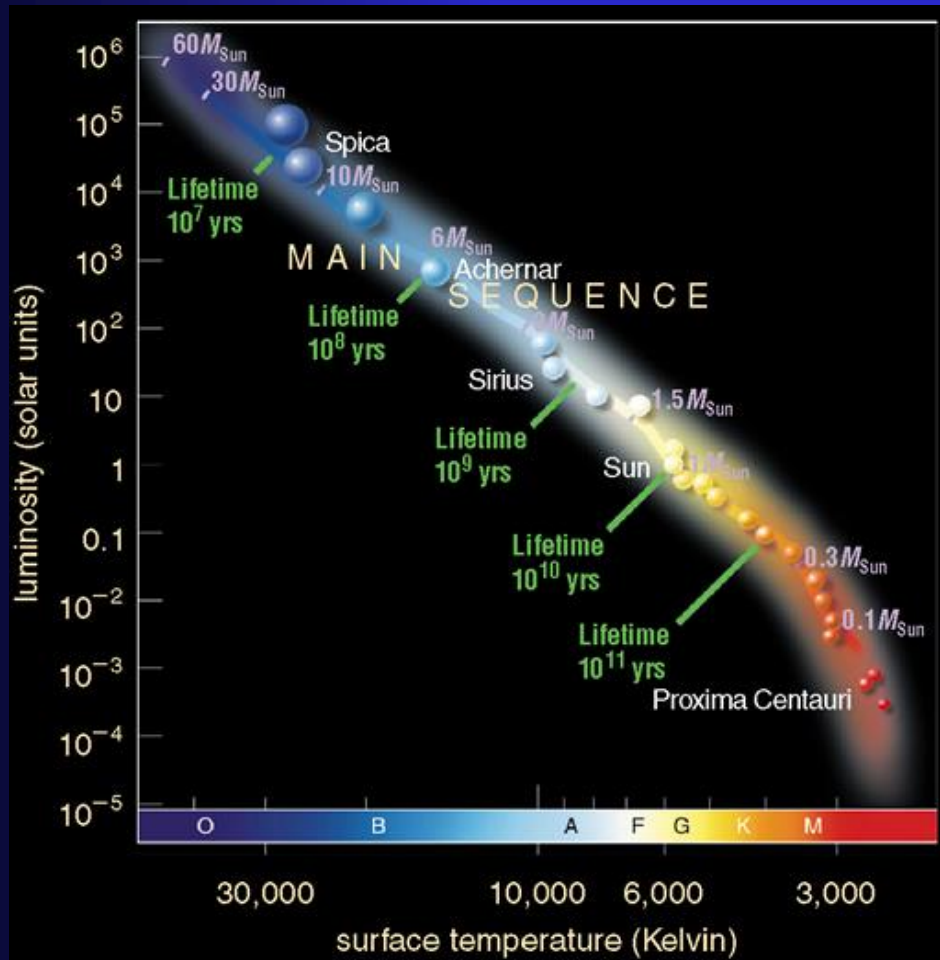
Not fusing helium yet

Energy is from
gravitational
potential

Fusion begins when
the star hits the
Main Sequence

The Main Sequence

Fusing Hydrogen into Helium in their Core



Brighter main sequence stars are more massive

Massive stars die more quickly

Main Sequence lifetime depends **only** on mass

Stars on the Main Sequence:

- A) Evolve up the MS towards the hot blue corner.
- B) Evolve down the MS towards the cold red corner.
- C) Move in along the MS in a direction determined by their mass.
- D) Stay in the same place on the MS until they run out of Hydrogen.

We observe a **Main Sequence** star that is 10 times more luminous than the Sun. Which of the following is true.

- A) The star is bluer, hotter, and more massive than the Sun.
- B) The star is bluer, hotter, and less massive than the Sun.
- C) The star is redder, hotter, and more massive than the Sun.
- D) The star is redder, colder, and less massive than the Sun.

Star A and B are the same age. They are $10M_{\text{sun}}$ and $5M_{\text{sun}}$ respectively. Which of the following is true

- A) Star A will die first because it has much less fuel.
- B) Star B will die first because it has less fuel to consume
- C) Star A will die first because its ratio of fuel consumption to mass is much higher.
- D) They will live about the same amount of time.

The Main Sequence

Imagine a cluster of stars ALL with the same birthday. In the cluster are:

A few massive stars (O and B)

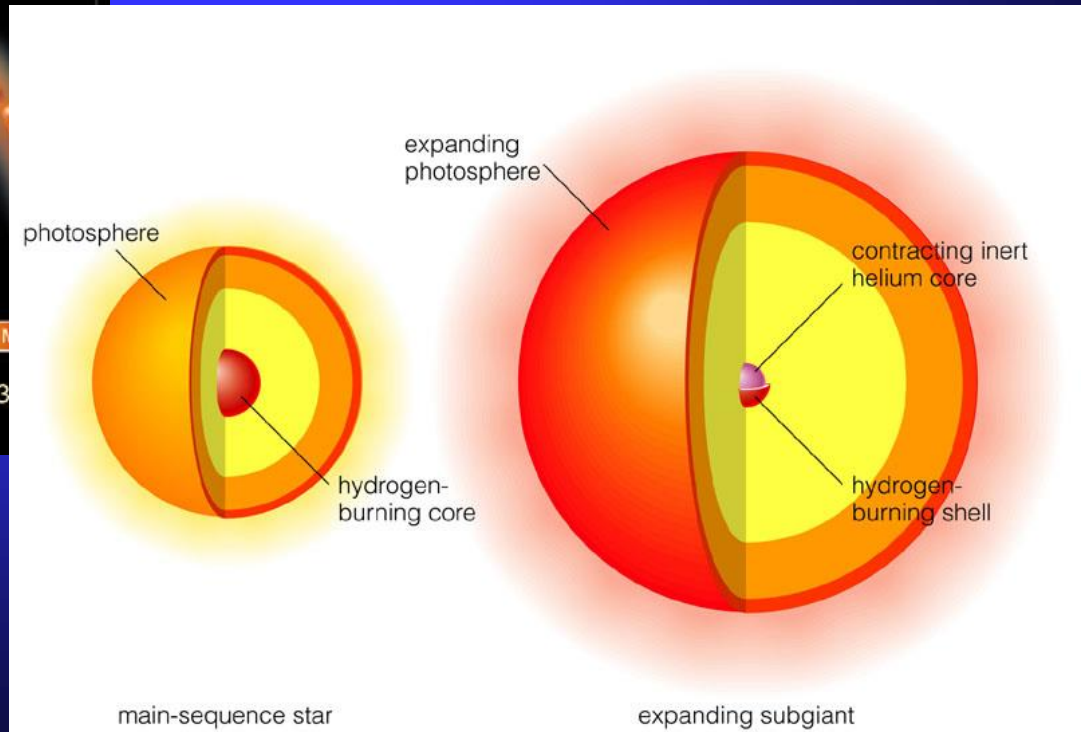
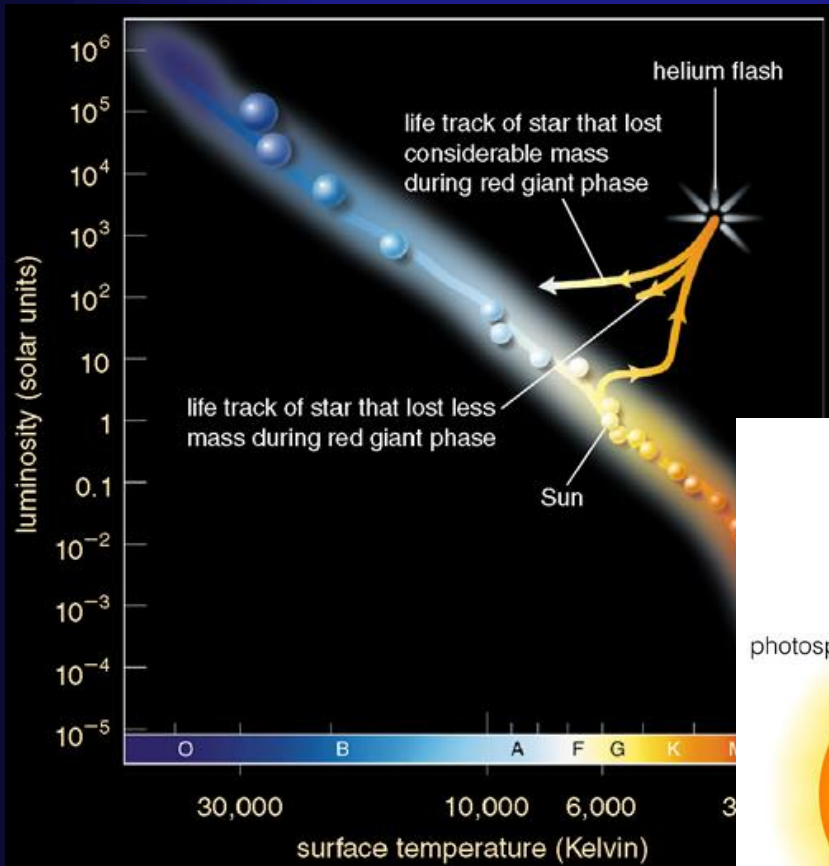
A few hundred solar like stars (G,K)

A few thousand low mass (M)

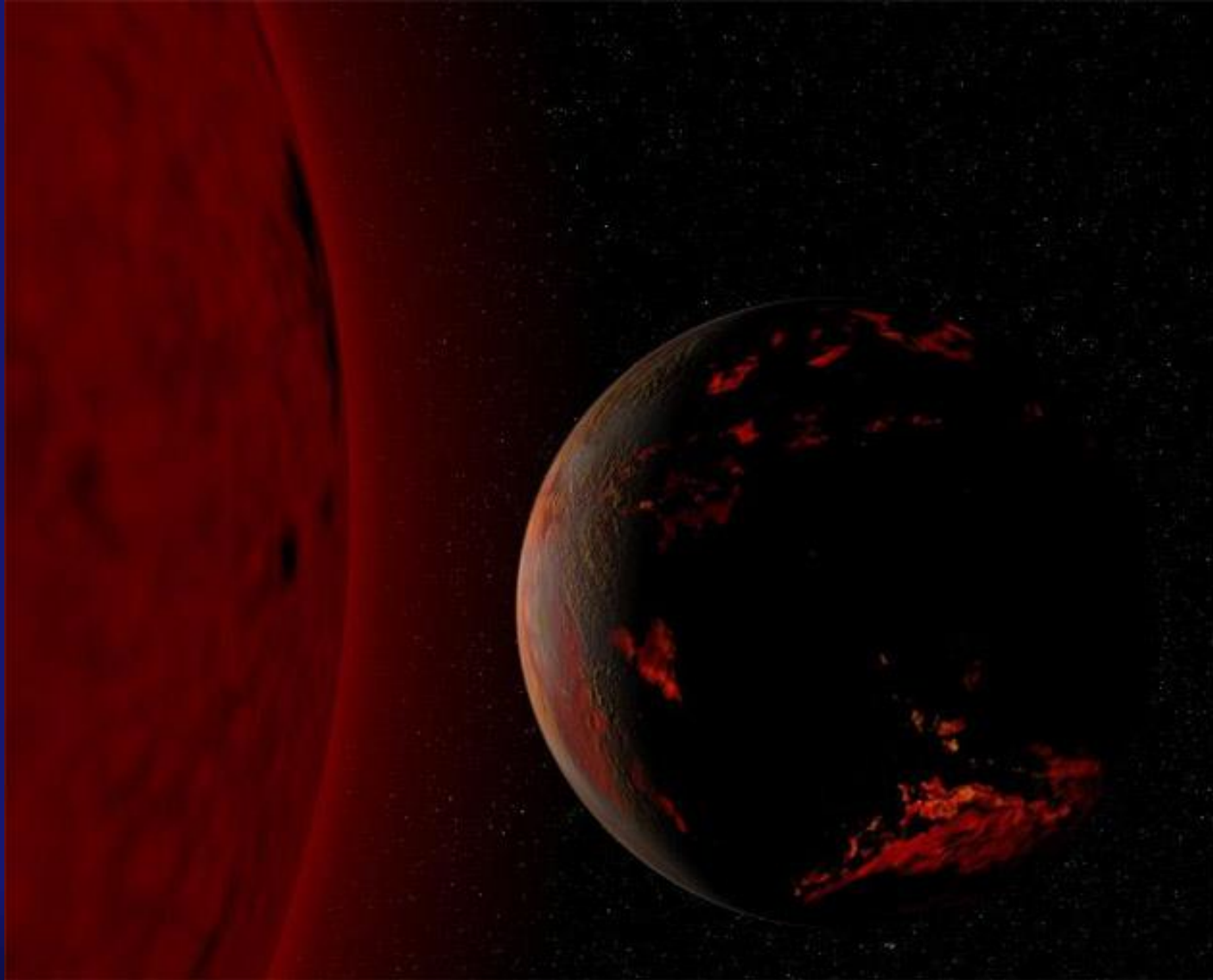
What is the dominant color of the cluster when it is new? Why?

What is the dominant color is the cluster when it is old? Why?

Stellar Evolution



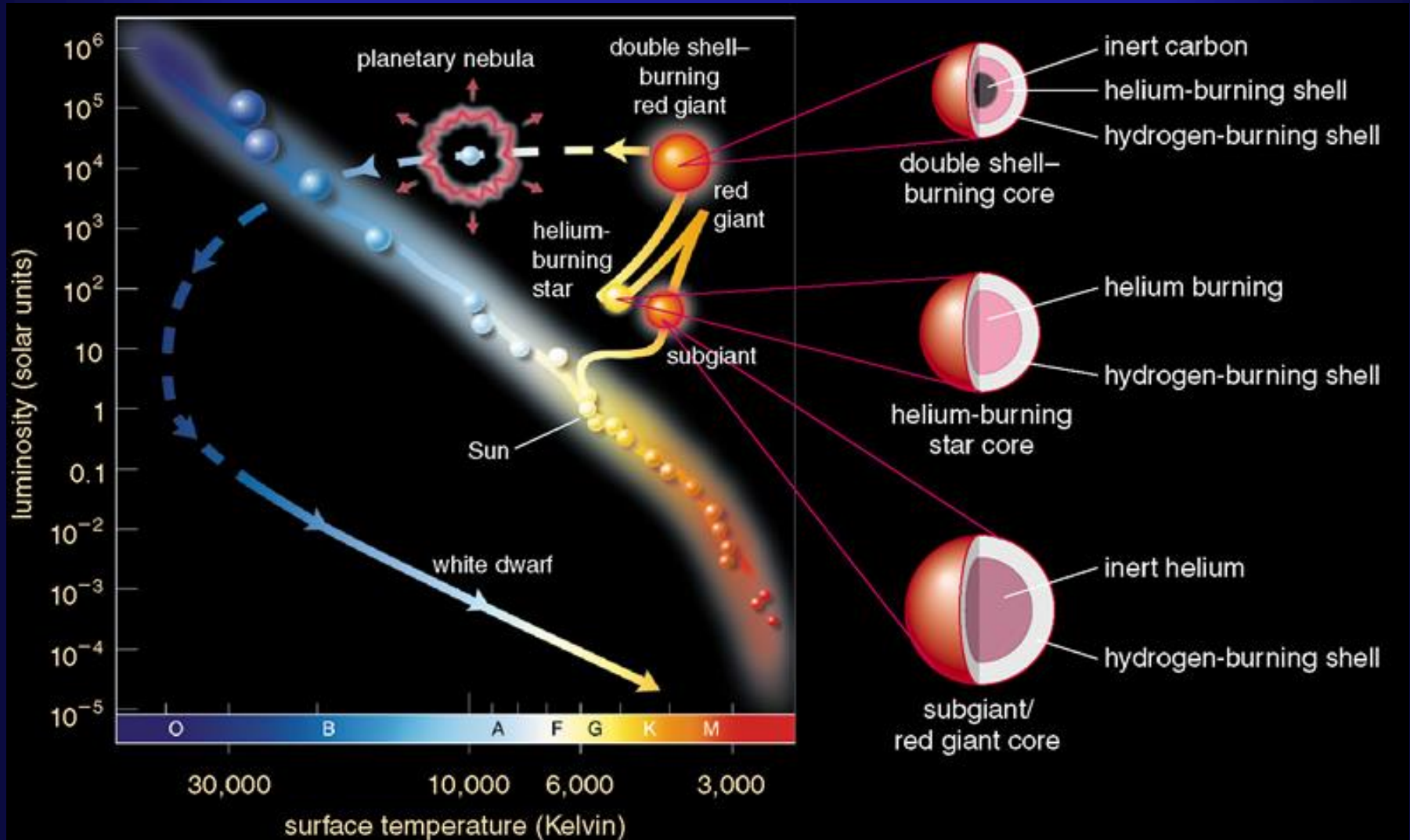
Bye Bye Terrestrial Planets



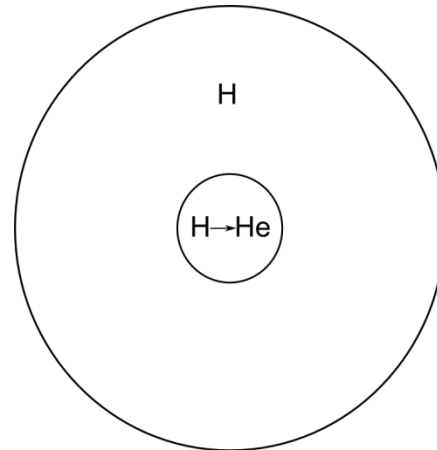
During its **Main Sequence** Lifetime, a star:

- A) Evolves up the main sequence towards the upper left of the HR diagram.
- B) Remains in roughly the same spot on the HR diagram.
- C) Evolves down the main sequence towards the lower right of the HR diagram.
- D) has a very complex motion on the HR diagram.

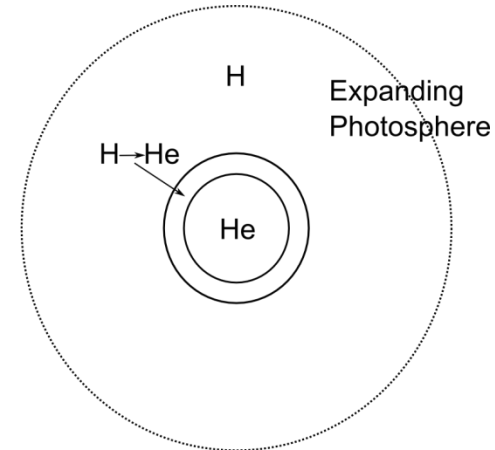
Low Mass Evolution



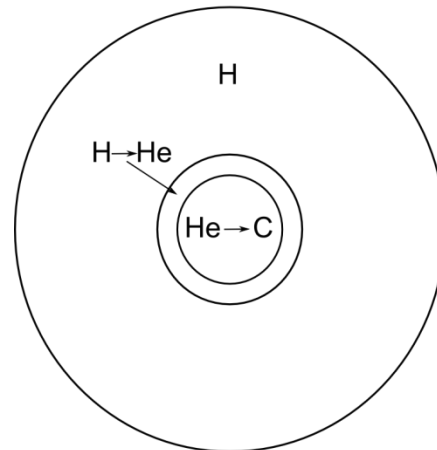
Low Mass Evolution



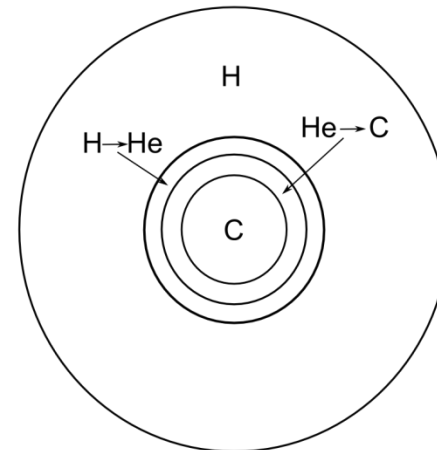
Main Sequence



Red Giant

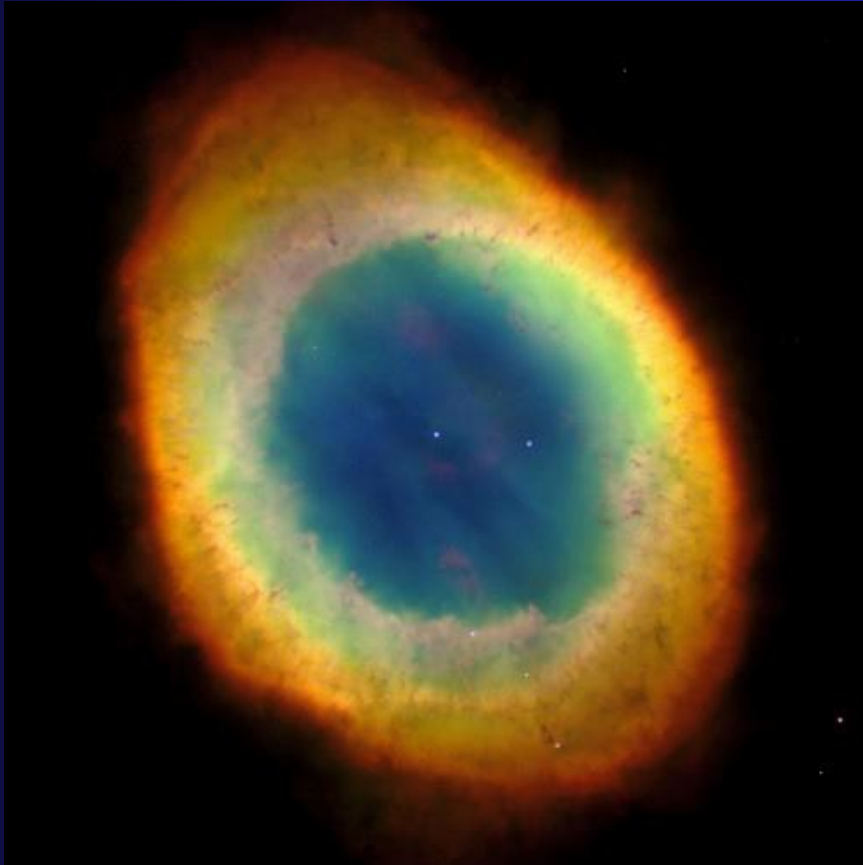


Horizontal Branch
or
Helium Burning

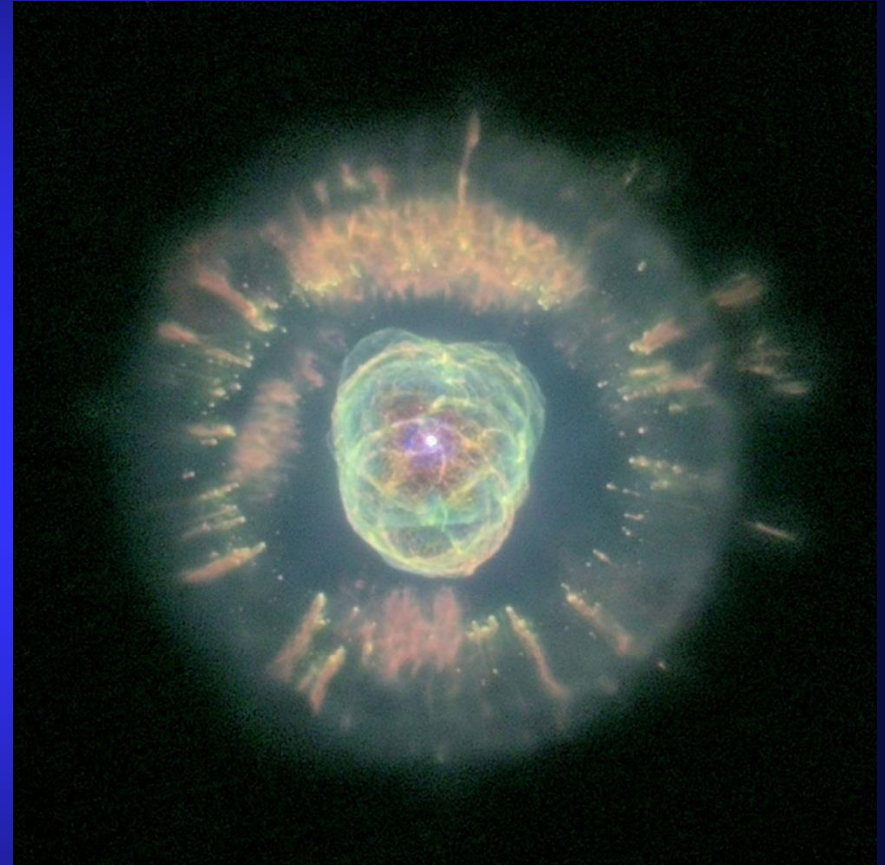


Asymptotic Giant Branch
Or
Double Shell

Planetary Nebula



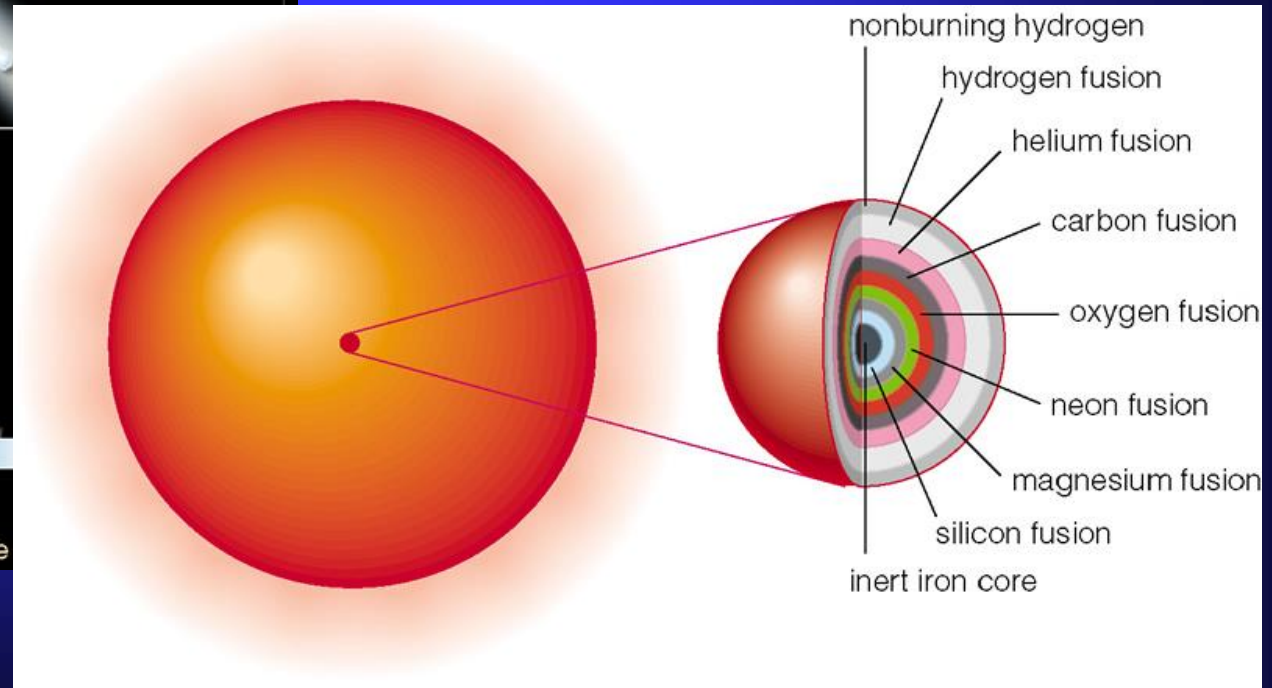
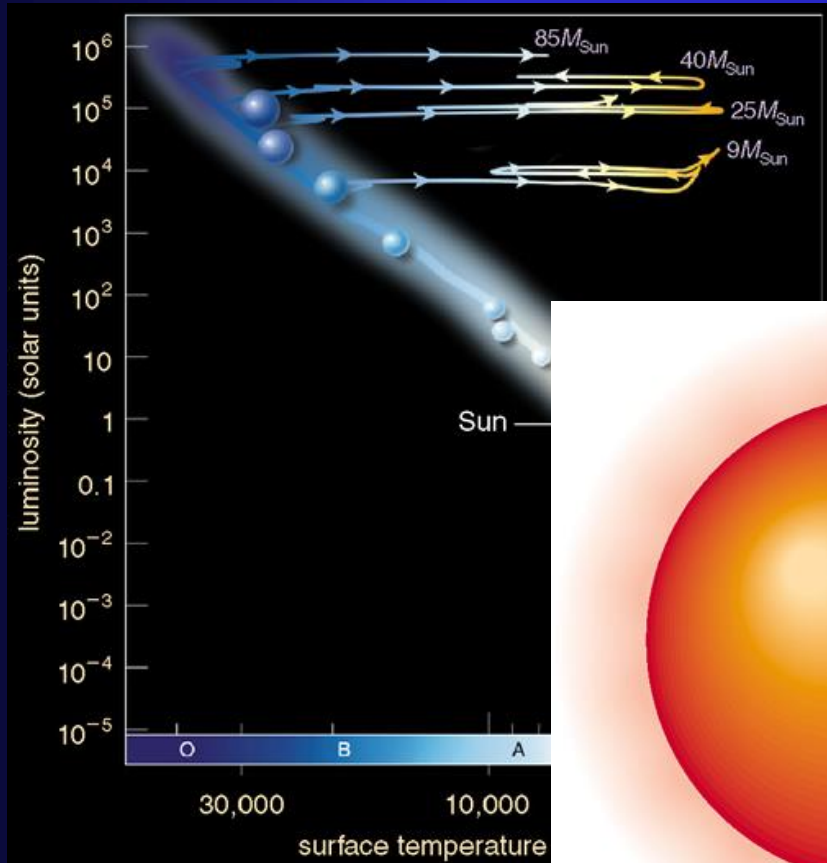
Ring Nebula



Eskimo Nebula

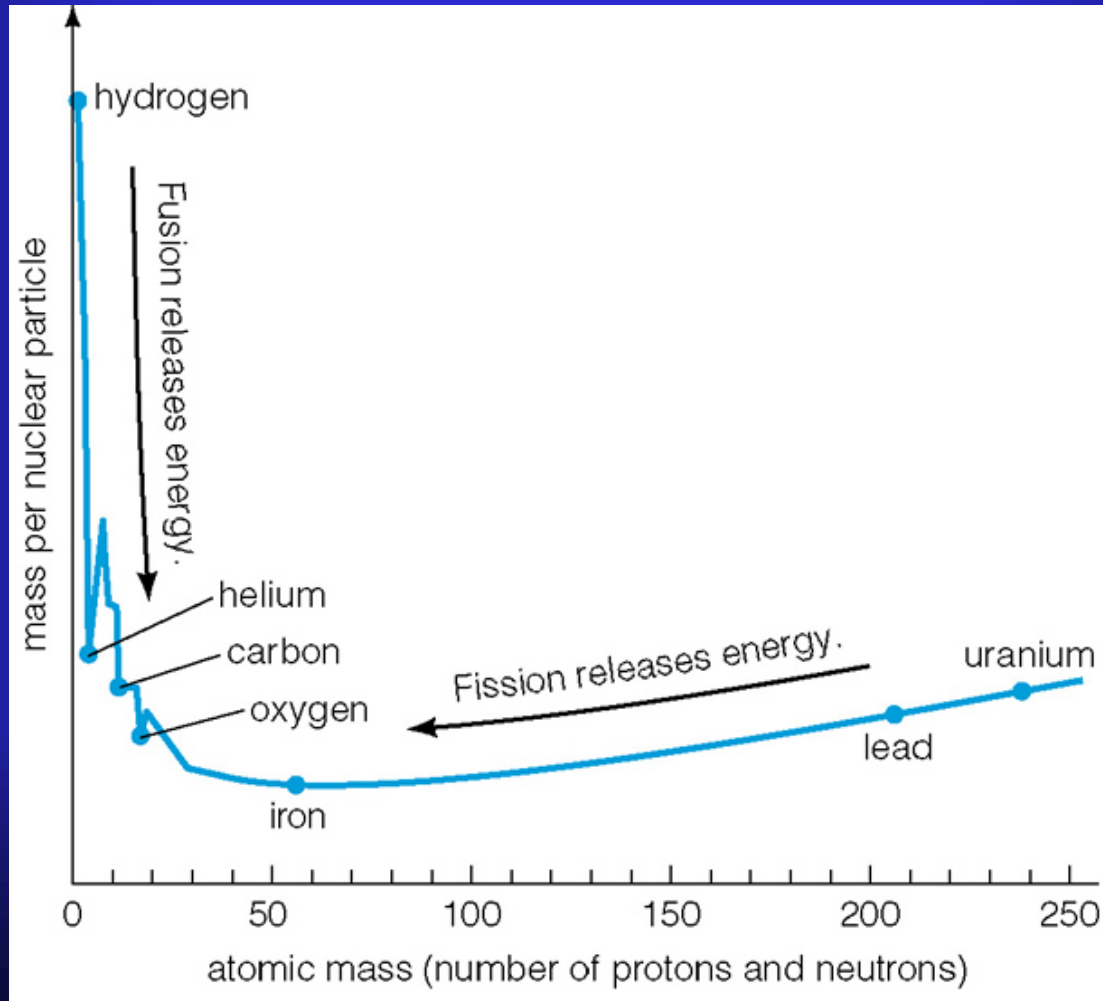
High Mass Evolution

High mass stars keep on fusing



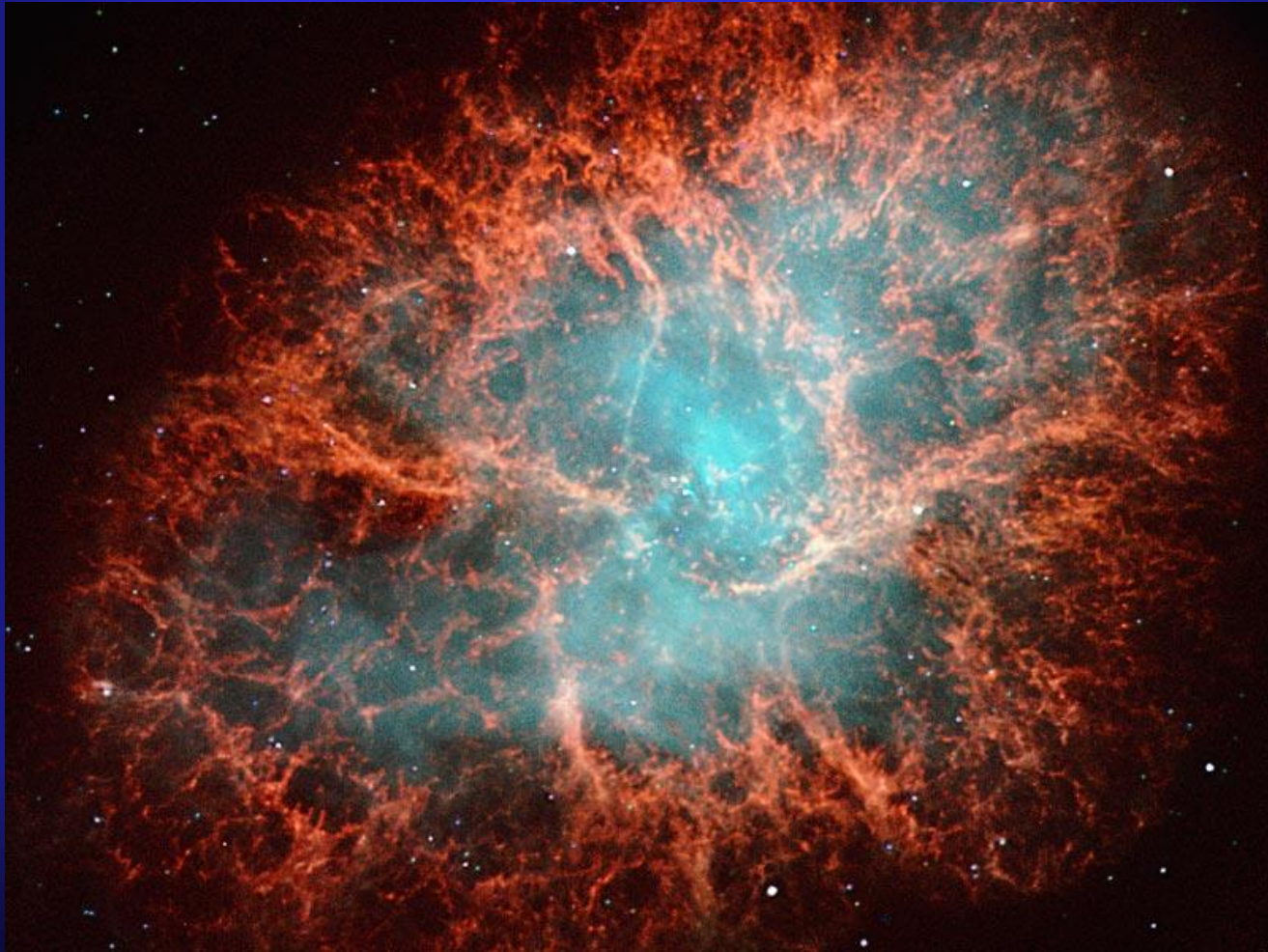
Why Stop?

We can't get energy out anymore



Super Nova

The Crab Super Nova Remnant



The Formation of Elements

hydrogen 1 H 1.0079																	helium 2 He 4.0026				
lithium 3 Li 6.941	beryllium 4 Be 9.0122															boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180
sodium 11 Na 22.990	magnesium 12 Mg 24.305															aluminium 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80				
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29				
caesium 55 Cs 132.91	barium 56 Ba 137.33	57-70 *	lutetium 71 Lu 174.97	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]			
francium 87 Fr [223]	radium 88 Ra [226]	89-102 * *	lawrencium 103 Lr [262]	rutherfordium 104 Rf [261]	dubnium 105 Db [262]	seaborgium 106 Sg [266]	bohrium 107 Bh [264]	hassium 108 Hs [269]	meitnerium 109 Mt [268]	ununnium 110 Uun [271]	ununium 111 Uuu [272]	unubium 112 Uub [277]	ununquadium 114 Uuq [289]								

* Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
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** Actinide series

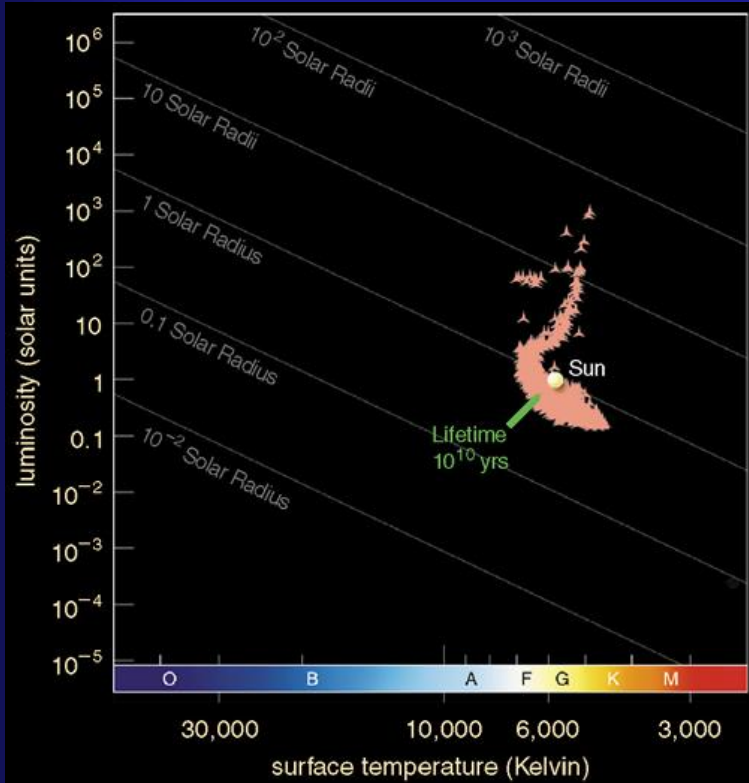
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]
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Big Bang

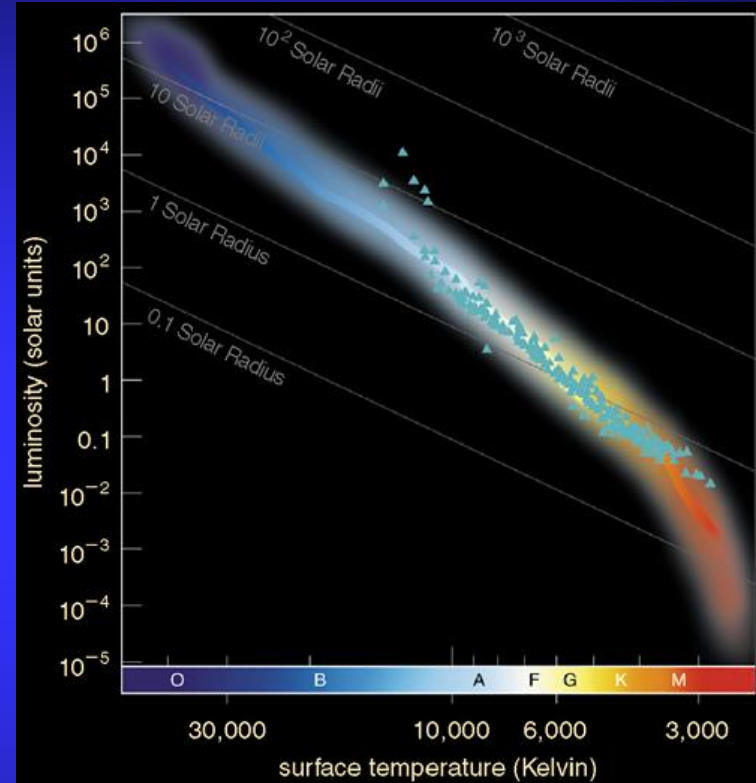
Stellar Fusion

Super Nova

Clusters



A

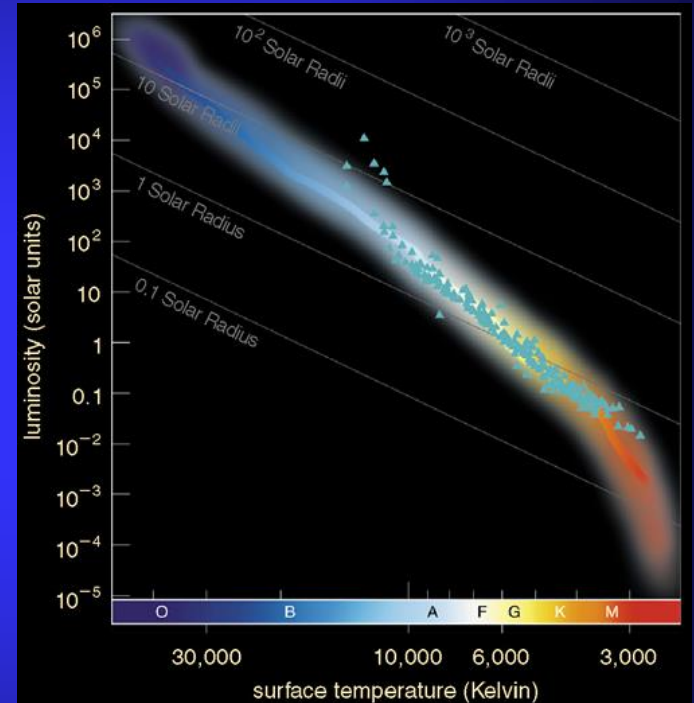


B

Which Cluster is older?

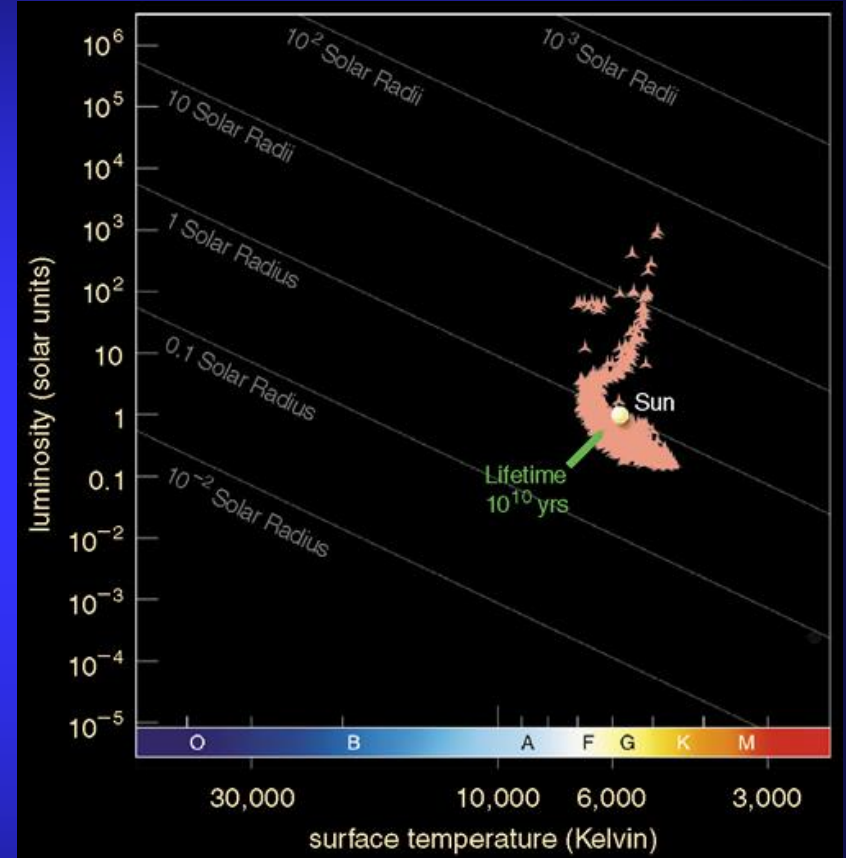
Clusters

Determining the age of a cluster

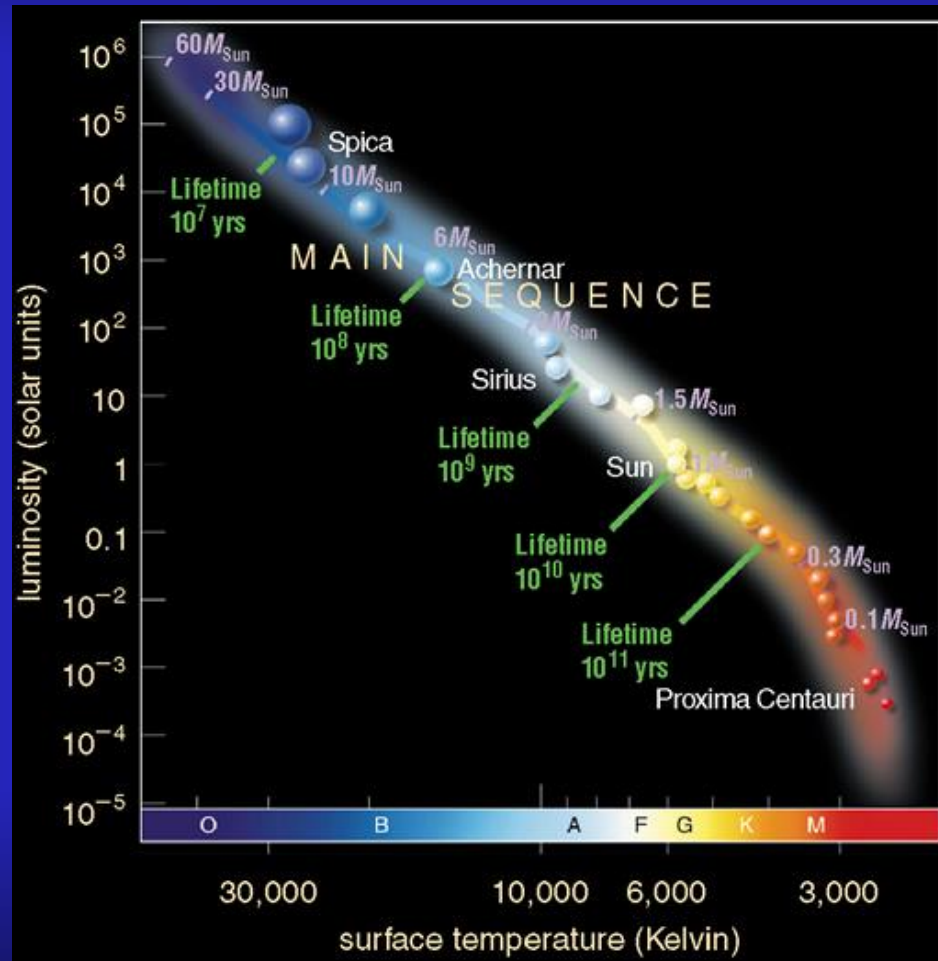


The main sequence turnoff tells us the age

Clusters

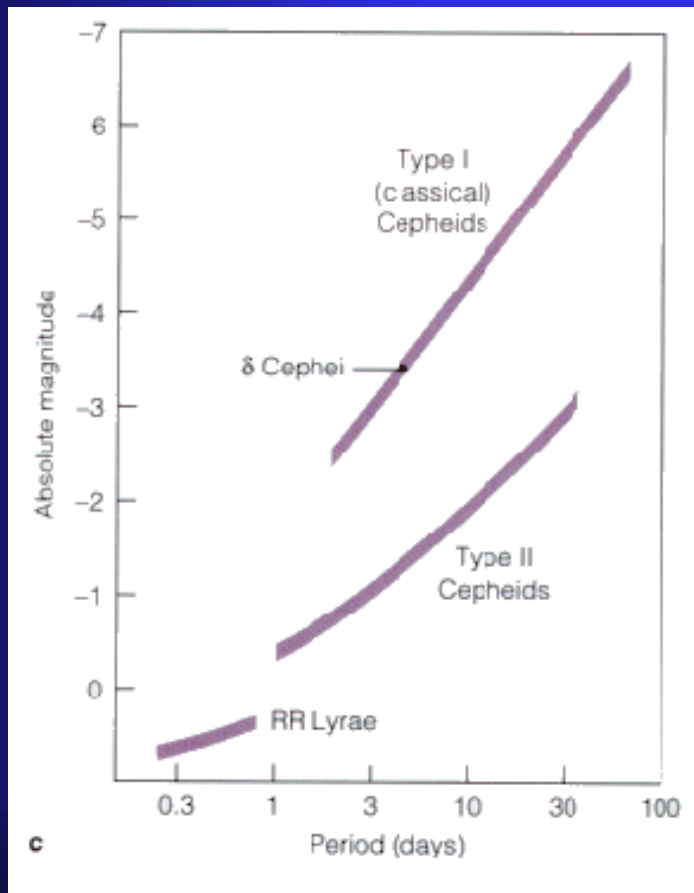


Main Sequence Distances



Cepheid Variables

Cepheids have a luminosity-period relationship



Nova

A binary system can turn into
a nova

