Astronomy 150:
Killer Skies

This Class (Lecture 16):
Killer Sun

Next Class:
The Sun is dangerous today

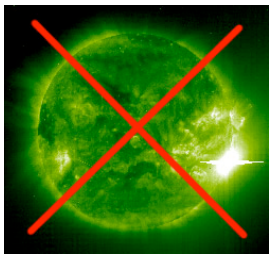
HW6 due on Monday!

Music: *It Overtakes Me*– The Flaming Lips

Why aren't there any green stars?

1) There are.
2) We just can't see them, so they don't fit into our scheme of objects.

3) http://www.youtube.com/watch?v=BvjeP3SfD1g



Night Obs

Dates:

- Monday, Oct. 4th ✔
- Tuesday, Oct. 5th ✔
- Wednesday, Oct. 6th
- Thursday, Oct. 7th
- Monday, Oct. 11th
- Tuesday, Oct. 12th
- Wednesday, Oct. 13th
- Thursday, Oct. 14th

Go to assignment page on class website for more info.

You **MUST** download worksheet before you go.

Can be cloudy, so check webpage before you go.

Question

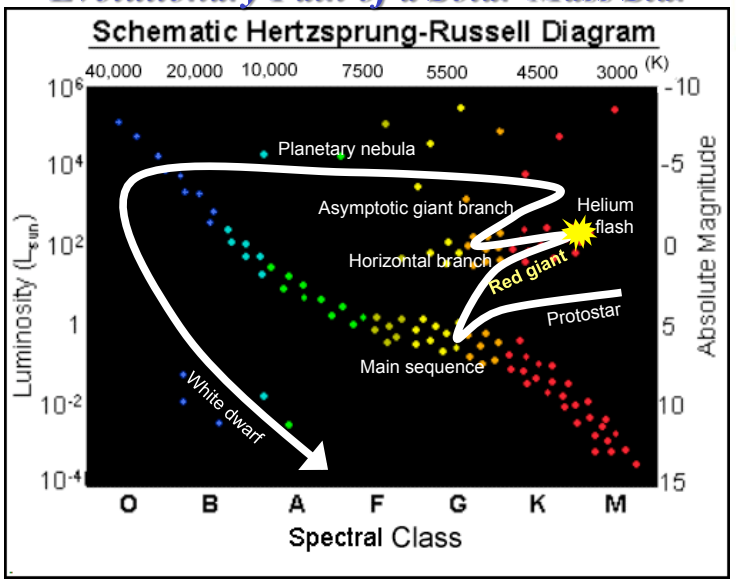
Did you go to the Observatory yet?

a) Yes, it was okay.
b) Yes, it was cool!
c) Yes, it was the highlight of my life so far!
d) Yes, but it was boring.
e) No, but I will do so as soon as I can, I promise. I had other things I had to do, but I really, really want to go and I will make it a **top** priority in my life!

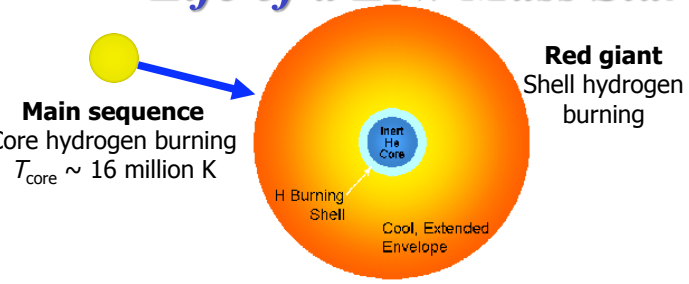
Outline

- The Sun runs out of fuel
  - Red Giant!
  - Horizontal Branch Star
  - Asymptotic Giant Branch
- The dead Sun— White Dwarf

Evolutionary Path of a Solar-Mass Star



Life of a Low Mass Star



Question

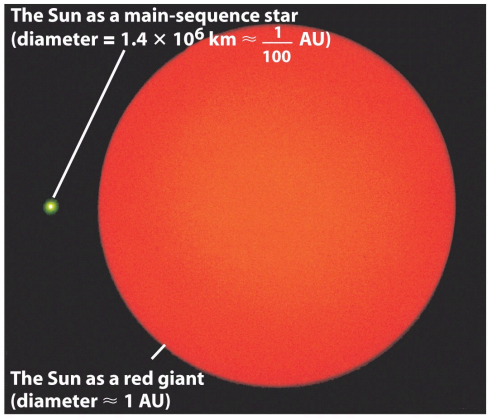
As the Sun moves off the main sequence what happens in the core?

a) Hydrogen burning stops
b) Helium burning stops
c) TNT burning stops
d) We don't know, but it makes the Sun red.

In 6-7 Billion years

- The Sun will expand to 100-250 times bigger than it is now!
- The same mass but now it's bigger.

http://www.youtube.com/watch?v=3rH4bMylBKg



The Sun today and as a red giant

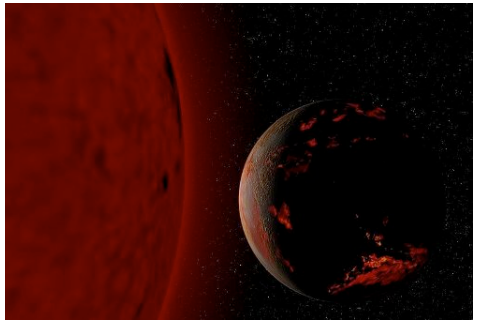
In 6-7 Billion years

- The surface gravity decreases and the Sun has more luminosity.
- The solar wind turns into a stellar wind, and it looses material as it expands, about 10^7 times more than now.
- It's blowing it all away!

http://www.astropix.com/wp/wp-content/uploads/2006/12/2006_02.JPG

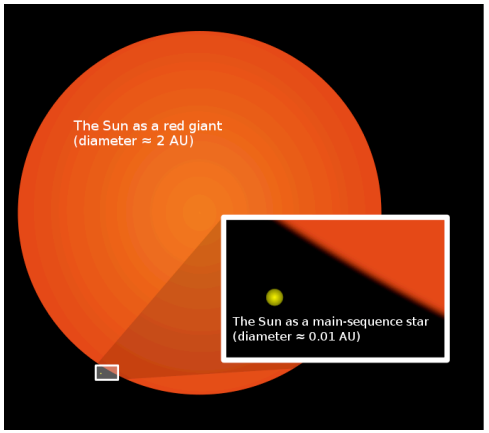
In 6-7 Billion years

- During the time it expands it loses a significant fraction of mass.
- So, the planets move outward.
- Planets race away as the Sun expands.
- Who wins?
- We aren't yet sure.



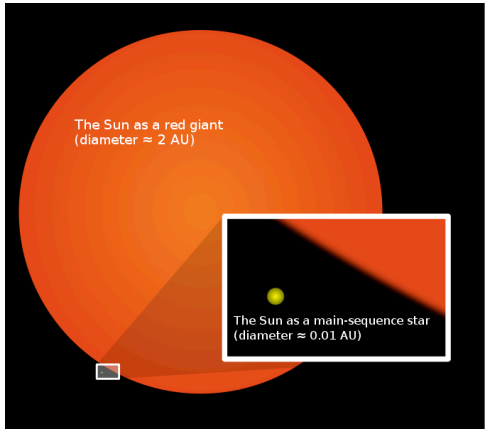
In 6-7 Billion years

- We use to think that the Sun would gobble the Earth.
  - Mercury gone
  - Venus probably gone
  - Earth?
- BUT even if not, with the Earth's oceans and atmosphere gone, crust still melts.
- Not good…



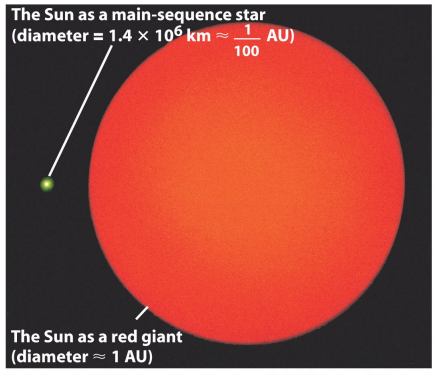
In 6-7 Billion years

- Mars?
  - For sure too hot.
- Jupiter's Moons?
  - Still too hot
  - Europa's water vaporizes
- Even the moons of Uranus and Neptune may be too hot.



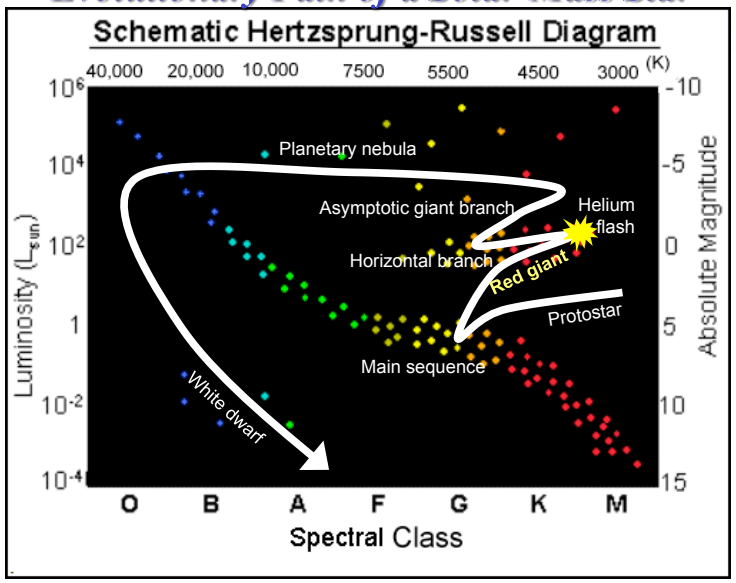
Mitigation

- We would have to move the Earth out to Pluto or further!
- Probably not possible.
  - Interactions with Jupiter may eject us from Solar System
- Even then, Sun no longer in equilibrium, may oscillate in size or brightness.
- BUT, we got billions of years to figure it out!

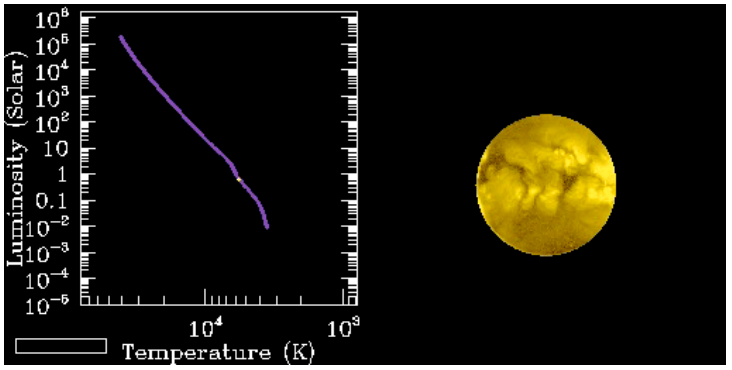


The Sun today and as a red giant

Evolutionary Path of a Solar-Mass Star



Evolutionary Path of the Sun

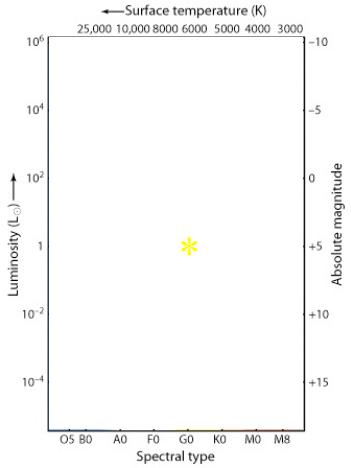


http://rainman.astro.uiuc.edu/ddr/stellar/index.html

Question

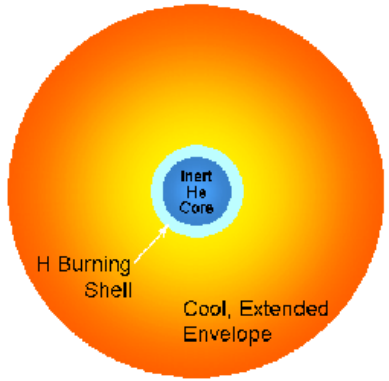
As the Sun evolves into a red giant, its position on the H-R diagram will move…

a) Up and to the left
b) Down and to the right
c) Down and to the left
d) Up and to the right



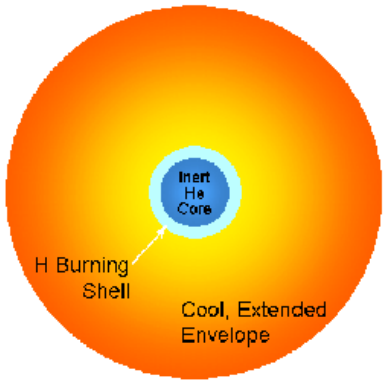
Contraction Junction

- In core, contraction increases density
- Hotter, and hotter, and hotter until…



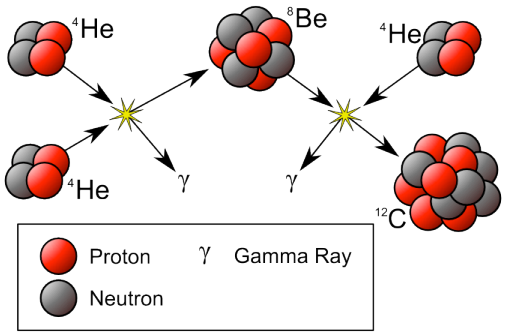
Contraction Junction

- 100 million degrees F
- Core heats ⇒ He fusion ignites
- He ⇒ C & O



Helium Burning

- When the core of the star reaches 100 million degrees, it can start to fuse helium (the ash of hydrogen burning) into carbon
- Called the Triple-Alpha Process
  - Converts 3 heliums into one carbon + energy

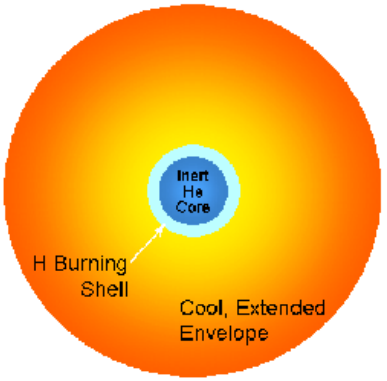


Helium Burning

- As helium fuses into carbon, carbon slowly accumulates in the core.
- Collisions between carbon-12 and a helium nucleus can create the stable nucleus of oxygen-16, which increases with the carbon concentration.
- So process of burning helium creates C and O "ash".

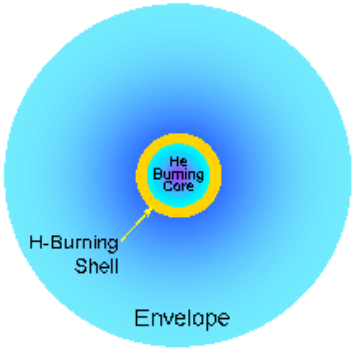
Helium Flash: 7.7 Billion Years

- Helium Flash (~few min)
- Note: explosion energy trapped in outer layers so don't see anything special from the outside
- As much energy released as all of the rest of the stars in the Galaxy.
- Core turns normal and it calms down.

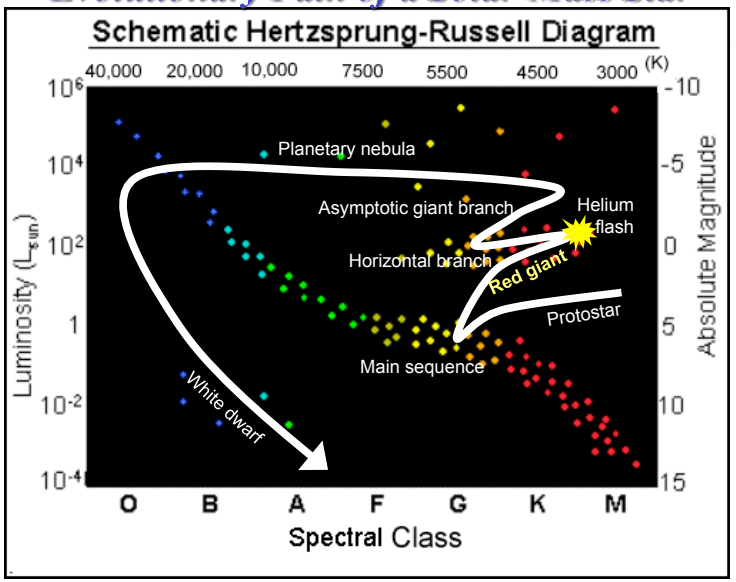


The Horizontal Branch

- Helium burning stabilizes the core
- The outer envelope shrinks, heats up, and dims slightly
- But helium doesn't last very long as a fuel
  - Horizontal branch lifetime is only about 10% that of a star's main sequence lifetime
  - Our Sun will burn helium for about a billion years
  - Also He burning is unstable

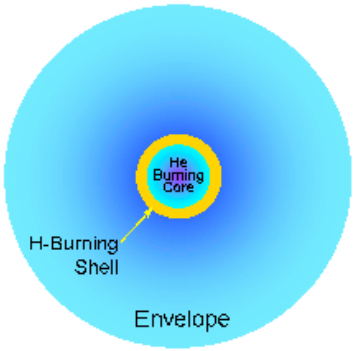


Evolutionary Path of a Solar-Mass Star

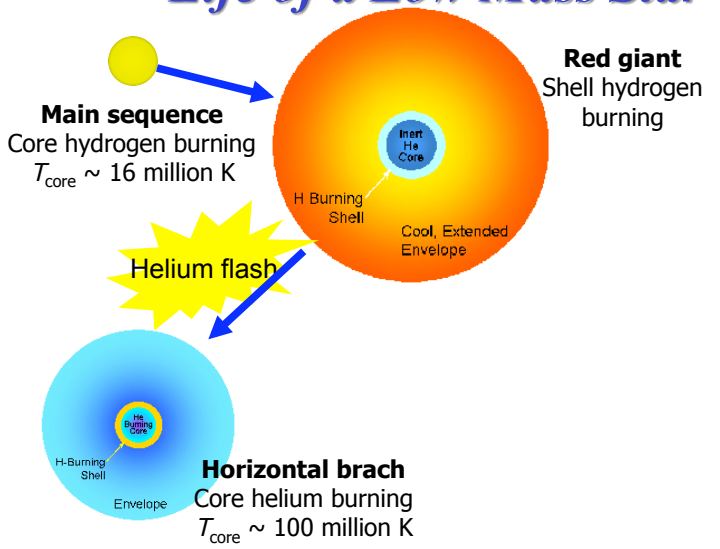


Mitigation

- If we moved the Earth, we have to move it back.
- Temperatures will drop out by Pluto.
- But our descendents have less time to figure this out, as the change is faster.
- Need to move back in a few million years.



Life of a Low Mass Star



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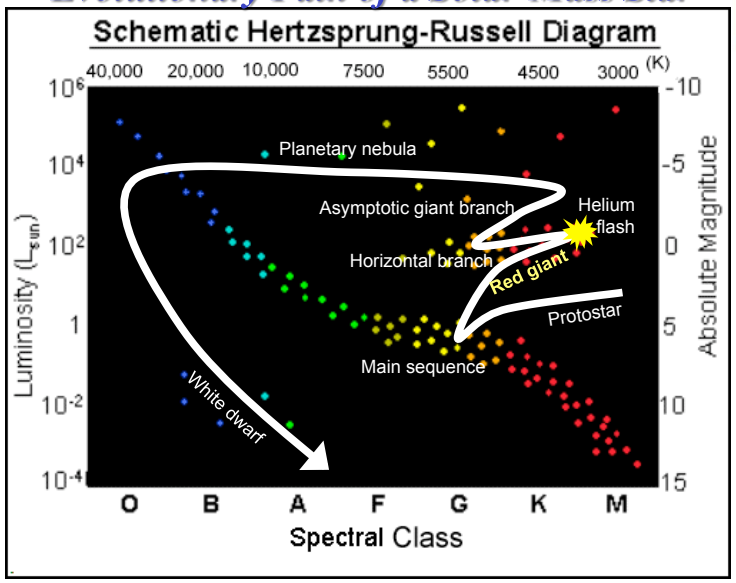
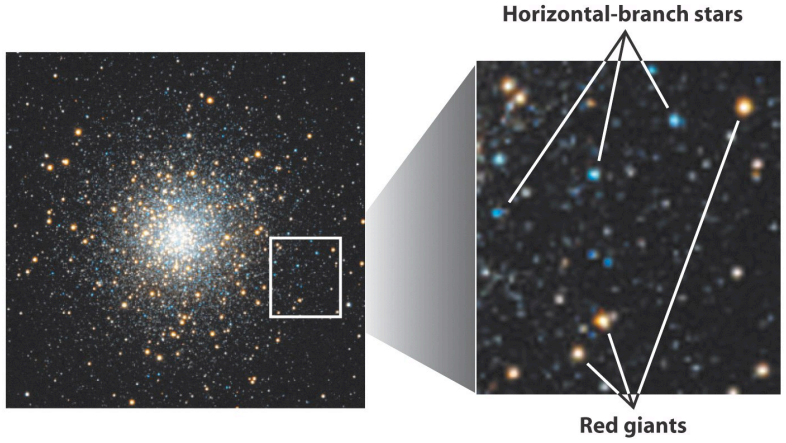
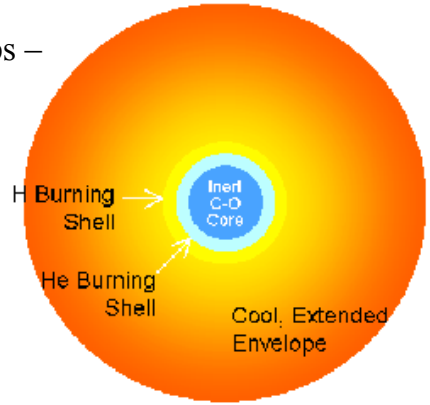


Aging Stars



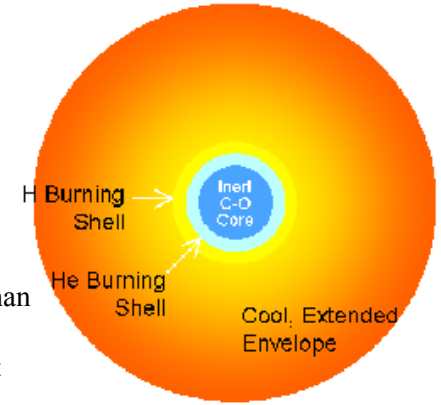
When Helium Runs Out… 7.8 Billion Years

- Fusion in the core stops – the helium has been converted to carbon and oxygen
- Stellar core collapses under its own gravity again
- Shell starts fusing helium
- Star starts to grow and cool again

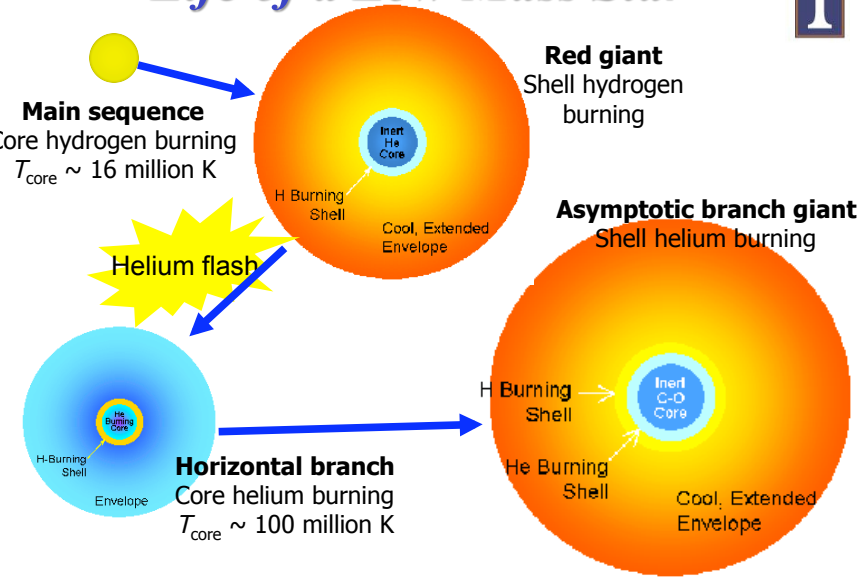


When Helium Runs Out… 7.8 Billion Years

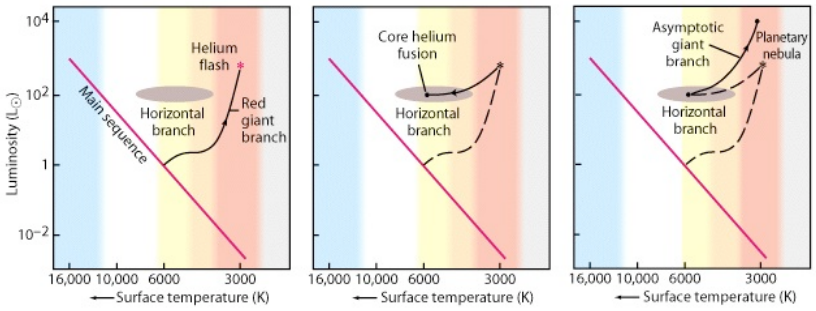
- Called the ***asymptotic giant branch***
- Gets hotter again, have to move Earth back out
- But, expansion is quicker than before, 20 million years.
- Will get more luminous than last time!
- Considering what is about to happen, perhaps best to leave Solar System.



Life of a Low Mass Star



Evolutionary Path of a Solar-Mass Star



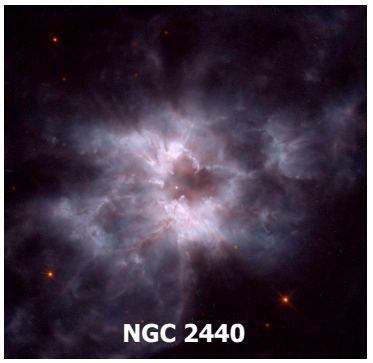
Question

As the Sun becomes an asymptotic giant branch star, what is happening in the central core of the Sun?

a) Hydrogen burning.
b) Helium burning.
c) TNT burning.
d) Nothing is burning, fusion has stopped.
e) We don't know, but it makes the Sun red.

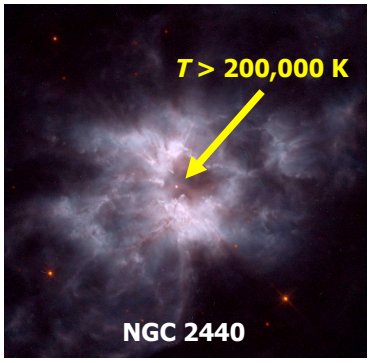
End Game

- At these last stages, the Sun will likely oscillate in size and temperature.
- This is messed up and creates a "Superwind"
- Outer layers of the red giant star are cast off
  - Up to 80% (at least 50%) of the star's original mass

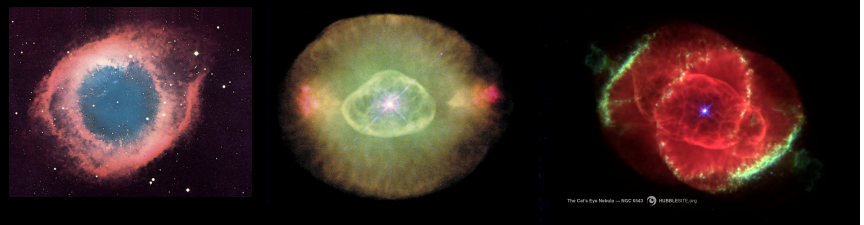


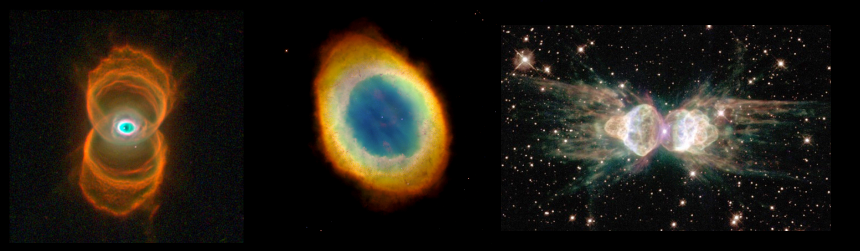
End Game

- "The core remains, made of carbon/oxygen "ash" from helium fusion
  - The core is very hot, above 200,000 K
- Ultraviolet radiation from the core ionizes the cast off outer layers
  - Becomes a *planetary nebula*
  - *Unfortunate name, but some of the most beautiful objects in the sky.*



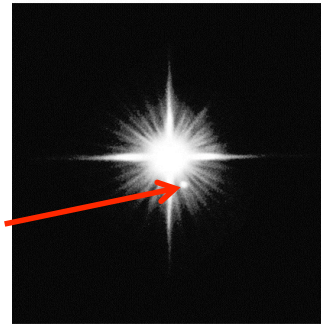
Planetary Nebulae





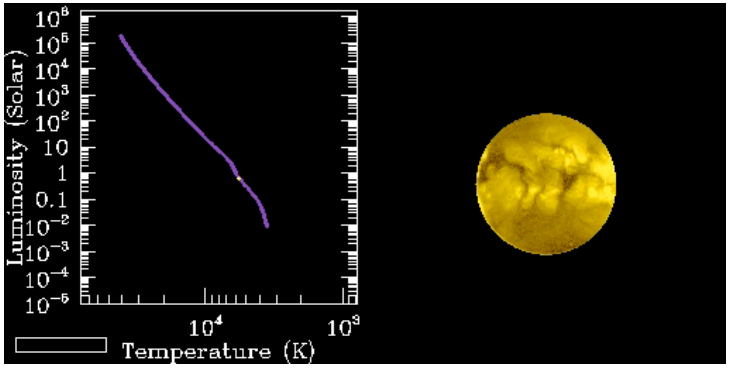
What About the Core?

- Final fate - **White dwarf**
  - Slowly cools off over billions of years
  - Just a hot body
  - No fusion
  - Not really a star in some ways



Sirius B

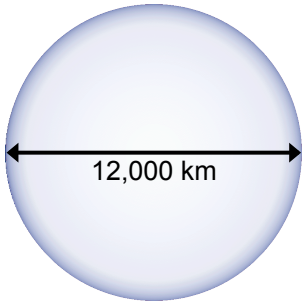
Evolutionary Path of the Sun



http://rainman.astro.uiuc.edu/ddr/stellar/index.html

What About the Sun's Core?

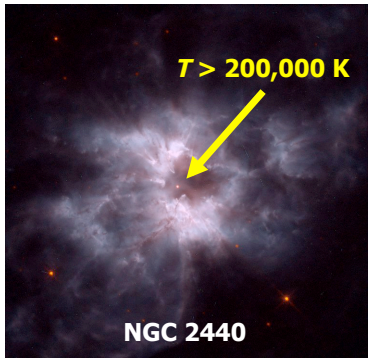
- Nuclear fusion has **stopped**, and gravity begins to win the battle
- Core contracts to the size of the Earth
  - But its about 60% the Sun's mass!
  - Material in the core is compressed to a density of 1,000 kg/cm^3!
  - Very hot, surface temperature >100,000 K



but will usually weigh about 0.6 Solar masses

What Happens to Earth?

- We have detected planets around white dwarfs, but they have presumable had a hard time.
- If you were to visit the wasteland of Earth, the Sun would only be a very bright point of light.
- Not sufficient for life.



Electron Degeneracy

- The electrons get so squashed together that they get pushed into *degenerate states*
  - This creates **pressure** to counteract gravity (Pauli exclusion)
  - Stops contraction

Matter in the core of a normal star

Electron-degenerate matter

1 ton per cubic cm