

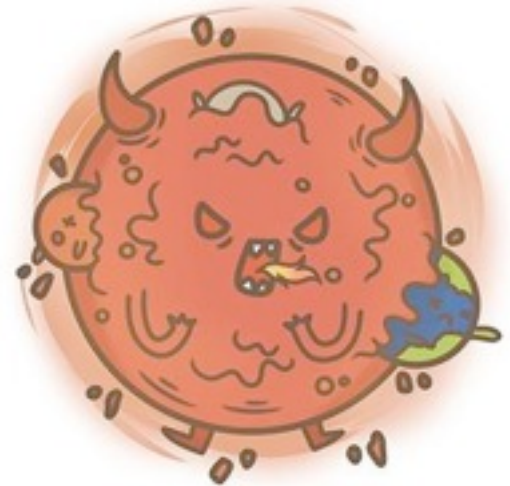
ASTR 150

- ▶ **Homework 5** due Monday after next
- ▶ Night Observing continuing
- ▶ Exam 1 Friday!
- ▶ Last time: The end of the Sun
- ▶ Today: The death of the Sun

LOVE IS...



providing you with warmth and support



...then turn into a red giant and swallow you up 8 billion years from now

accordingtodevin

Music: *Why Does the Sun Really Shine?* – They Might Be Giants

Hour Exam 1

Hour Exam 1 Friday, Oct 11, in class

information on [course website](#)

40 questions (cover material up to to and including Oct 4th)

May bring 1-page of notes

- ▶ both sides
- ▶ printed, handwritten, whatever

Most useful study materials

class notes

iClicker questions

homework questions

study guide

old exam

Focus on concepts, main ideas

Night Observing

Night Observing ongoing this and next week

- ▶ if you do it, need to go **one** night
- ▶ allow about **1 hour**

When: **W,Th,M,T,W: 7-9pm**

3 observing stations:

- ▶ Large telescope in observatory dome
- ▶ 2 outdoor telescopes
- ▶ Night sky constellation tour

Subscribe to Night Observing Status Blog

<http://illinois.edu/blog/view/413>

Get weather cancellation updates

Assignment details on [class website](#)

Read rubric before you go!

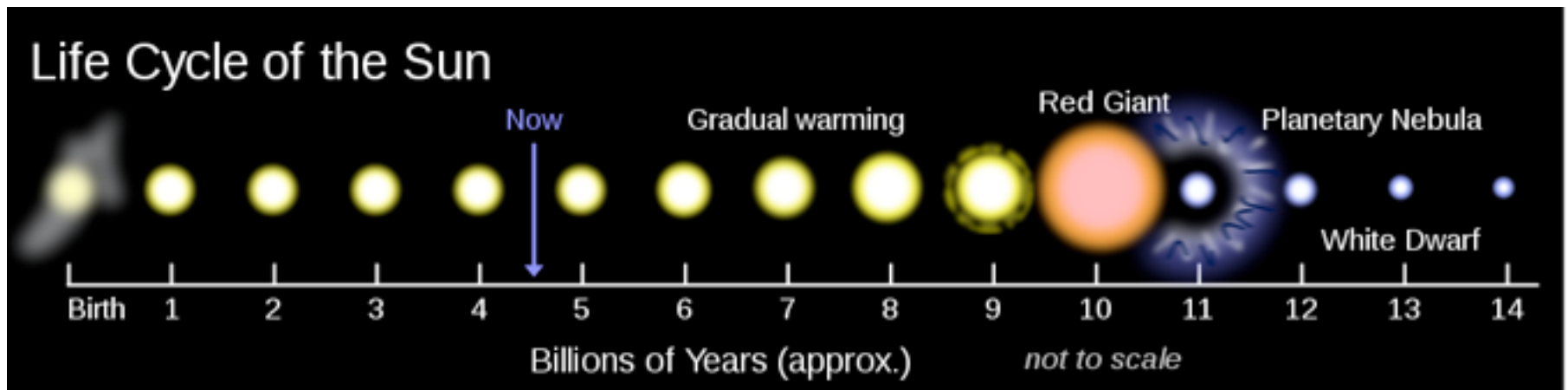
- ▶ Complete report due on or before Oct. 25



Sun's Evolution

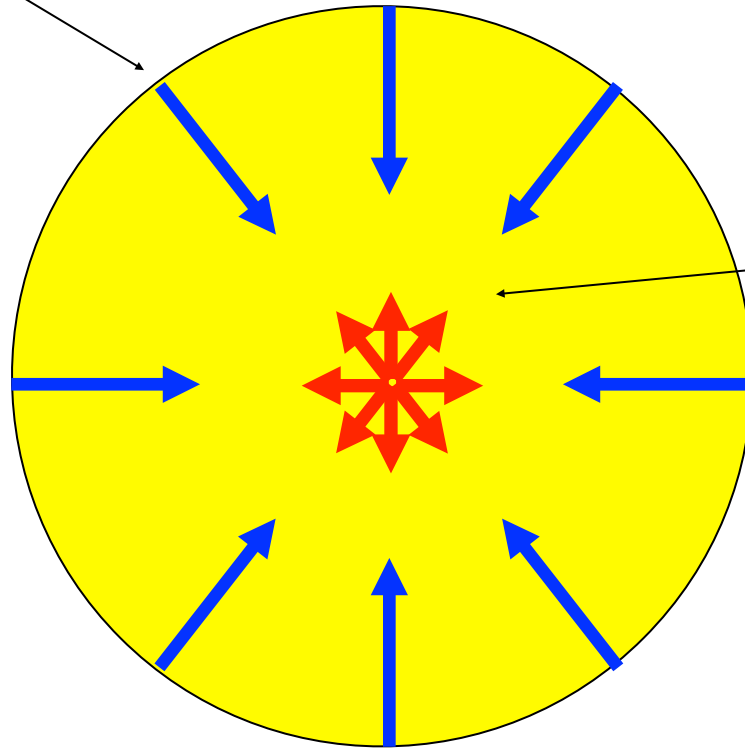
Sun evolves very slowly as it consumes Hydrogen in its core and as it does

- ▶ Core shrinks (less particles), which makes it hotter
- ▶ Fusion efficiency increases
- ▶ More energy into outer envelope
- ▶ Sun grows slightly larger
- ▶ Sun gets slightly brighter..... until H is gone...



The Battle between Gravity and Pressure

Gravity pushes in



With end of H fusion, gravity thinks it's winning

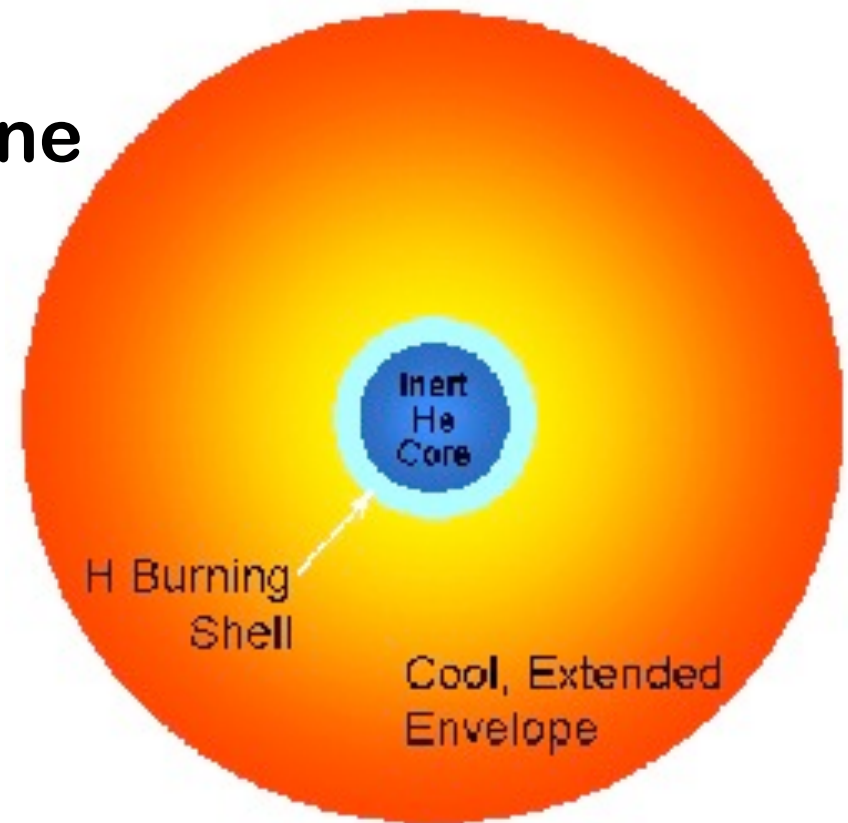
Unbalanced forces

The Red Giant Phase: 6 Billion Years

When the hydrogen is gone
in the core, fusion stops
Equilibrium is shot.

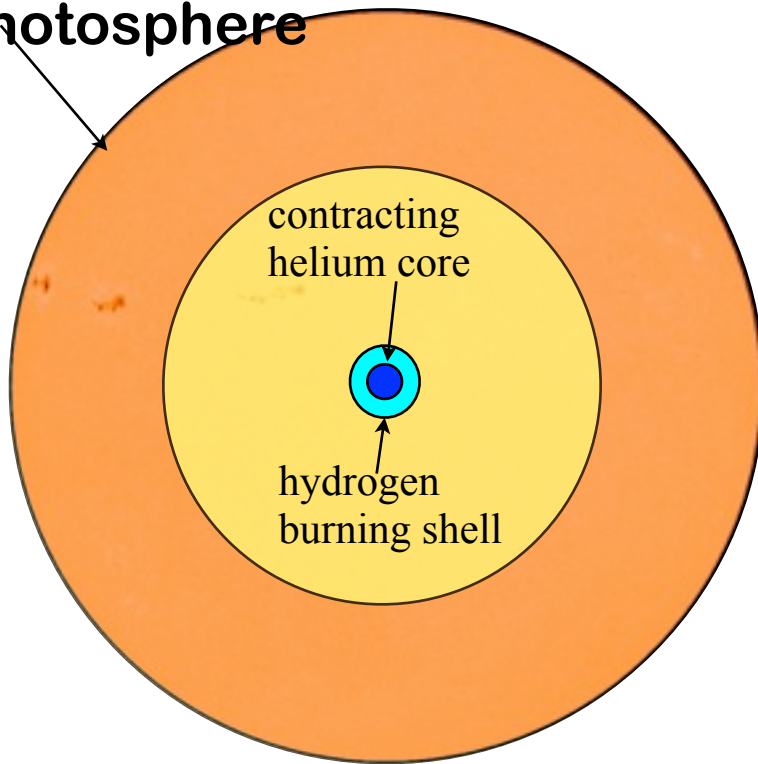
Core starts to contract
under its own gravity

This contracting heats
the core, and hydrogen
fusion starts in a shell
around the core



When the hydrogen runs out...

Expanding
photosphere



Star expanding into red giant

**Extra energy pushes the
outer layers of the star very
far outwards**

As fusion ignites in a
shell around the core,
Luminosity \uparrow

So increased energy
output from core
region, which means
that the envelope of
the Sun will expand
and cool, which makes
it big and red

Luminosity increases because the core thermostat is broken—the increasing fusion rate in the shell does not stop the core from contracting

As the core is not hot enough to fuse helium, gravity squeezes it to a relatively tiny size. Suppose you represented a typical giant star as the size of a baseball stadium. Its helium core would be only about the size of a baseball. Yet, it would contain about 10 percent of the star's mass.

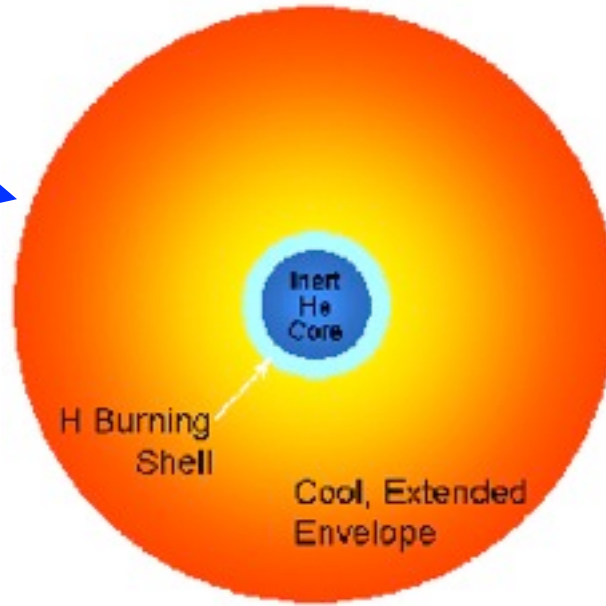
Life of a Sunlike Star



Main sequence

Core hydrogen burning

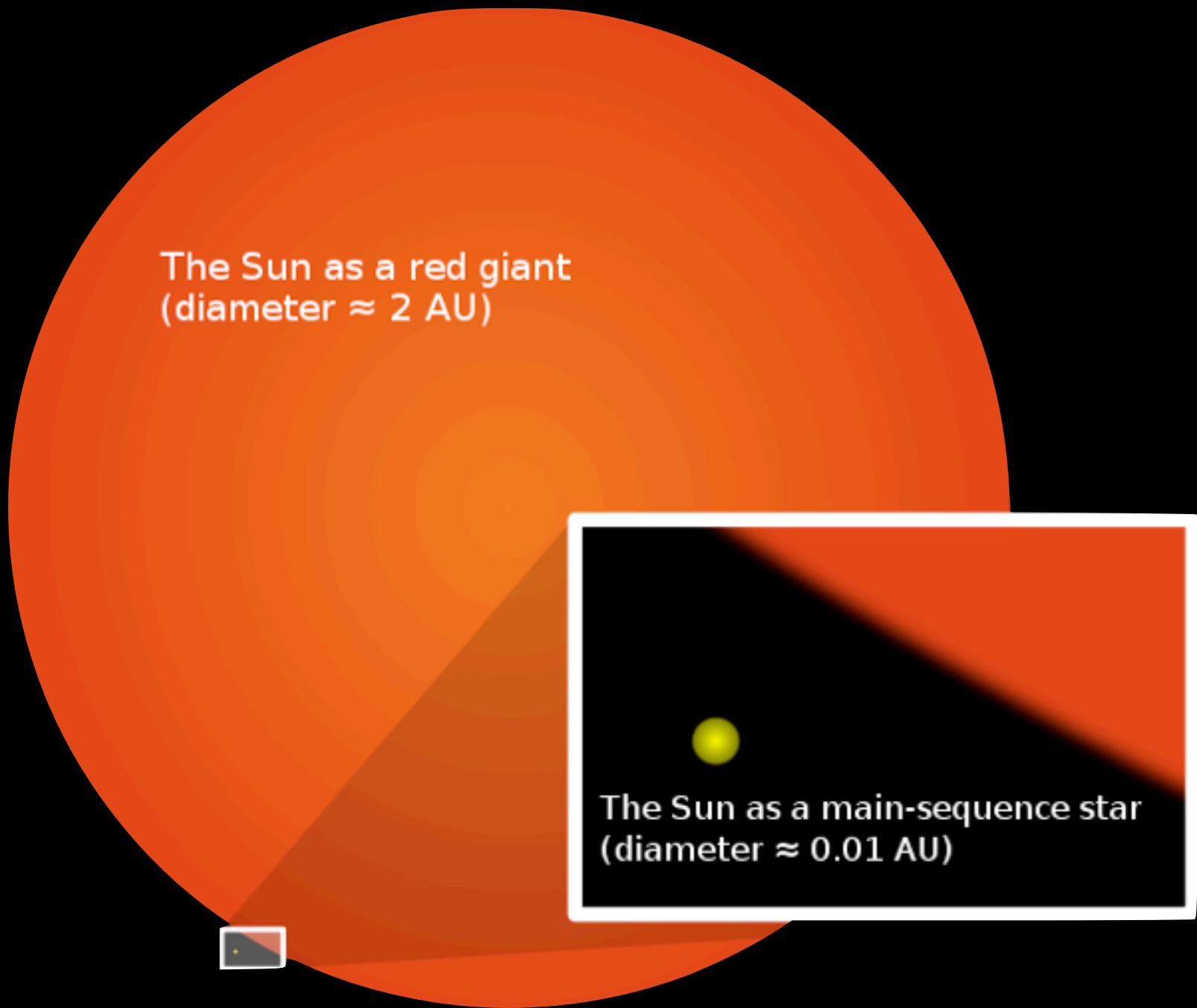
$T_{\text{core}} \sim 16$ million K



Red giant

Shell hydrogen burning

The Red Giant process takes 50-100 million years.



Stars like the sun become giant stars of 10 to 100 times the sun's present diameter.

Brighter: $2350 L_{\text{sun}}$

Cooler: 3107 K

Sun is 2300 times brighter than today, but the surface temperature is half that of the Sun today, so the color is red.

IClicker Question

What is occurring in the core of a Red Giant?

- a) Fusion
- b) Fusion of H into He
- c) Fusion of He into C and O
- d) Nothing

IClicker Question

What is occurring in shell around the core of a Red Giant?

- a) Fusion**
- b) Fusion of H into He**
- c) Fusion of He into C and O**
- d) Nothing**

Too Fast, but Red Giant Expansion



<http://www.youtube.com/watch?v=fOM7DMxOiAk&feature=related>

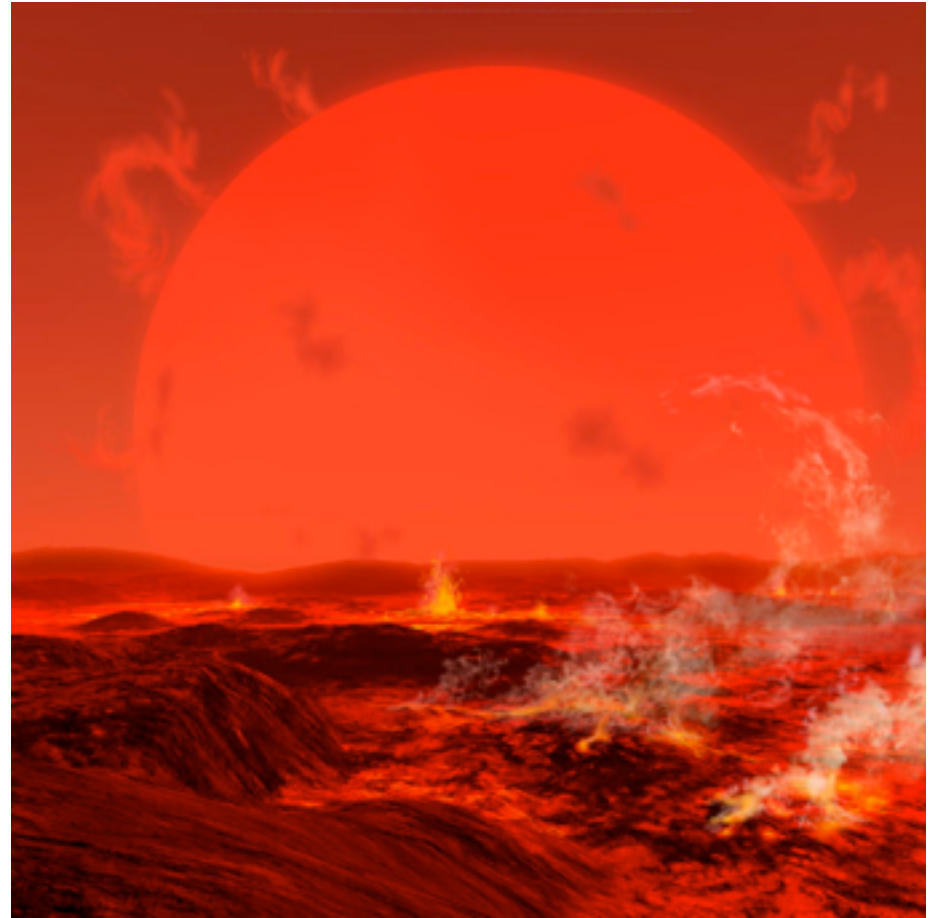
Its the end of the world as we know it, and I feel fine!

The Sun's growing luminosity:

- ▶ Drive away Earth's atmosphere
- ▶ Melt the surface rocks

Earth's surface:

- ▶ Fused rock
- ▶ Open to space
- ▶ Noon temperature 600°C (1100°F)



Sunrise on Earth 7 billion years from now?

13

Even if the Earth is not swallowed up, conditions on its surface will become impossible for life to exist. The Sun's increased luminosity will heat the Earth's surface so much that the water oceans and atmosphere will evaporate away.

Whether or not the expanding sun becomes large enough to totally engulf Earth, its growing luminosity will certainly:

Evaporate Earth's oceans

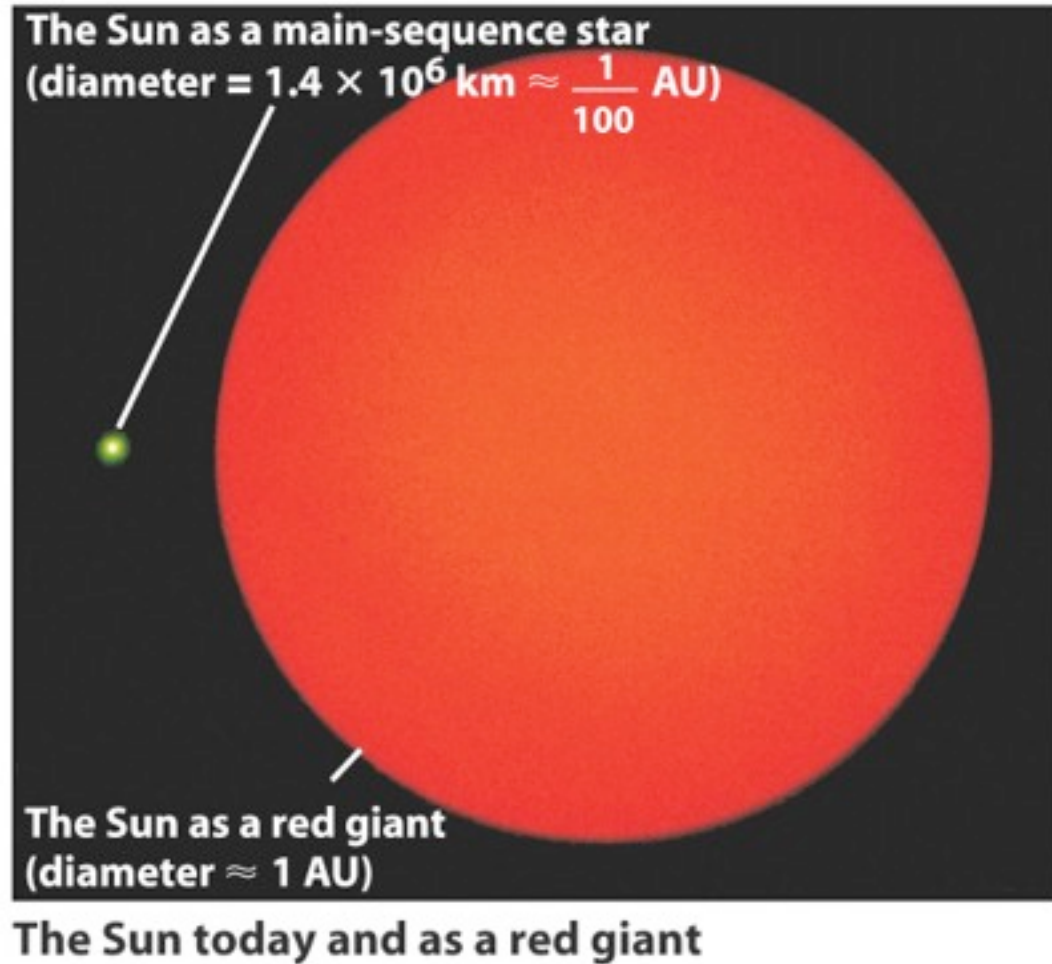
Drive away its atmosphere

Even vaporize much of Earth's crust and drive the vapor away into space

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.



Neil De Grasse Tyson says it best...



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

In 6 Billion years

The surface gravity decreases and the Sun has more luminosity.

The solar wind turns into a stellar wind, and it loses 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

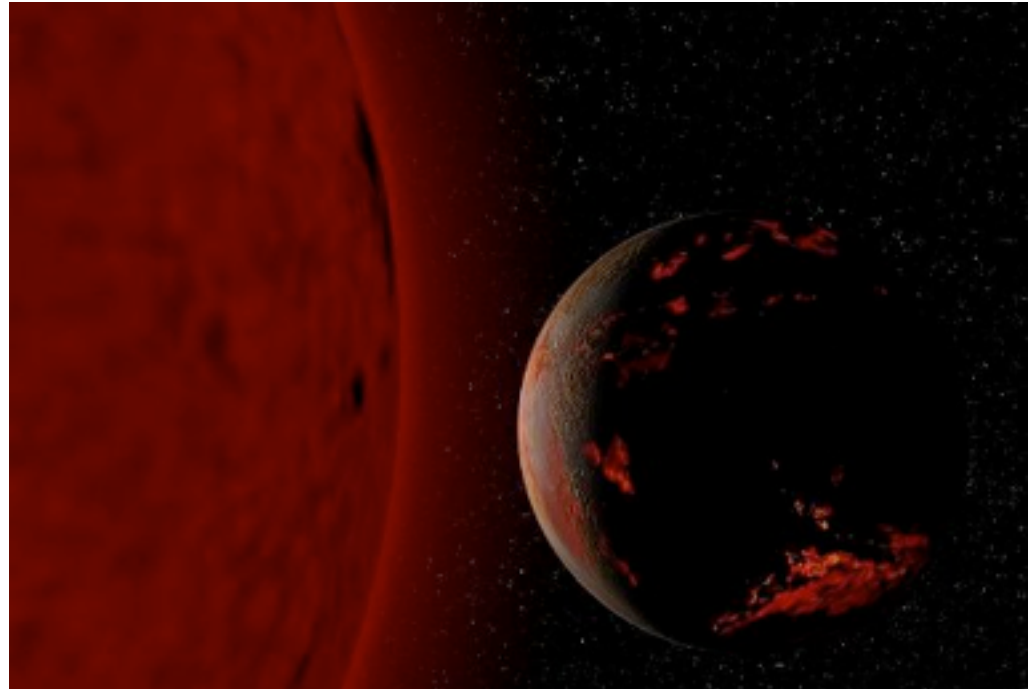
In 6-7 Billion years

During the time it expands it loses a significant fraction of mass.

So, the planets move outward.

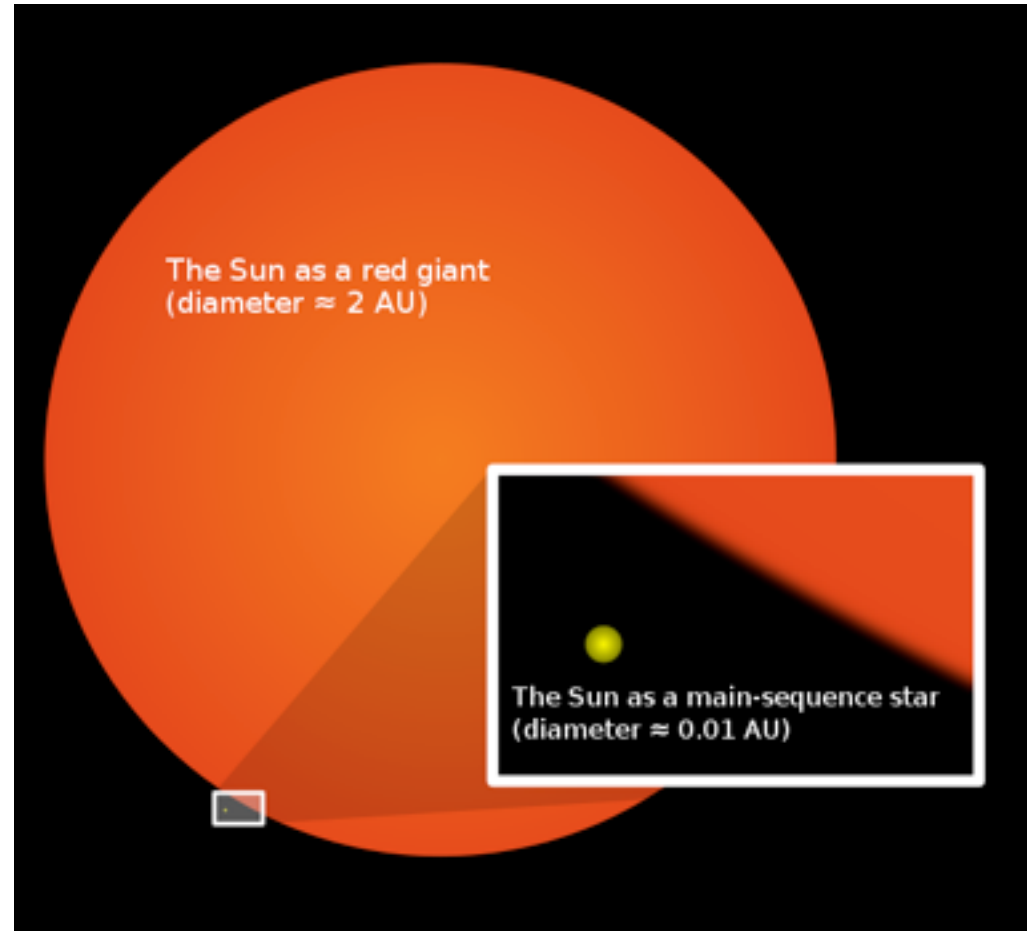
Planets race away as the Sun expands.

Who wins?
We aren't yet sure.



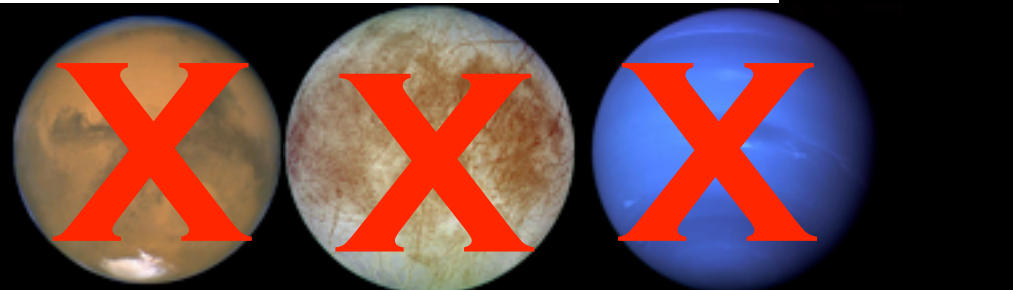
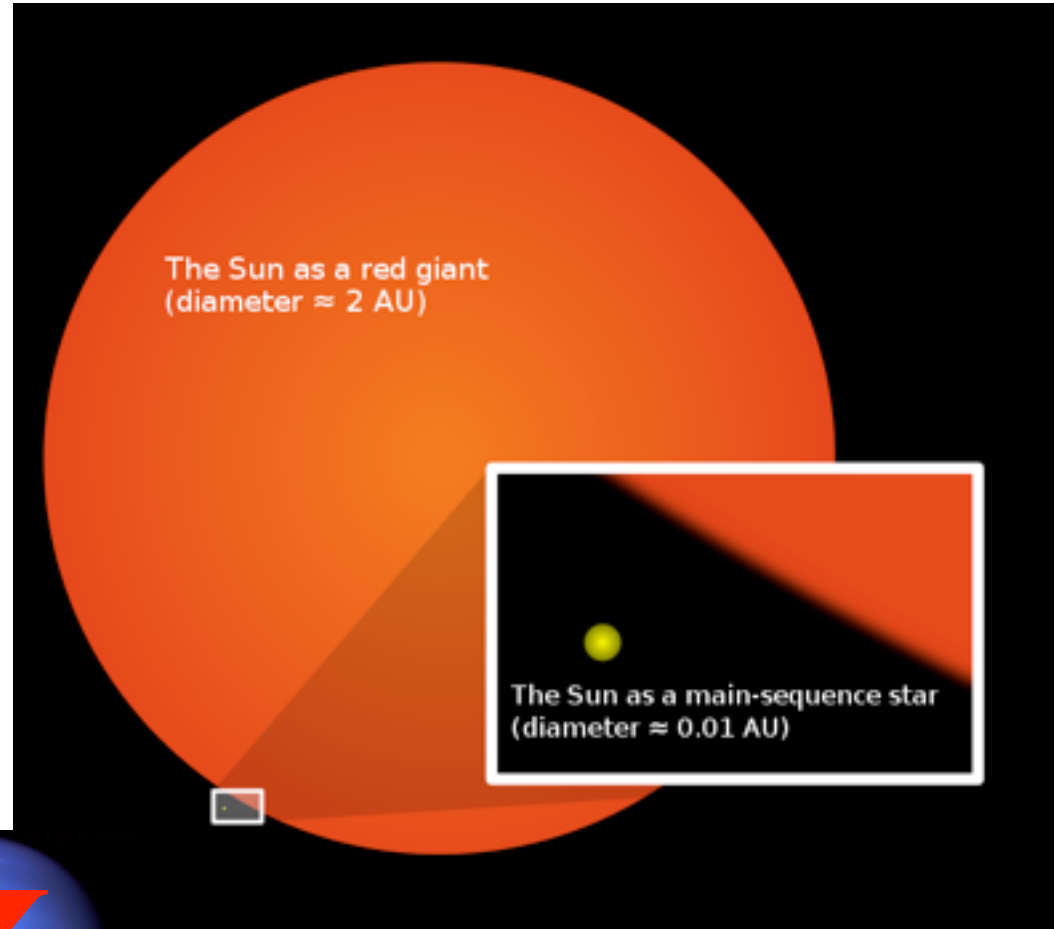
In 6-7 Billion years

- We used to think that the Sun would gobble the Earth.
 - Mercury? **Gone.**
 - Venus? **Probably gone.**
 - Earth? **Maybe gone.**
- But: even if not, with the Earth's oceans and atmosphere gone, crust still melts.
- Not good...

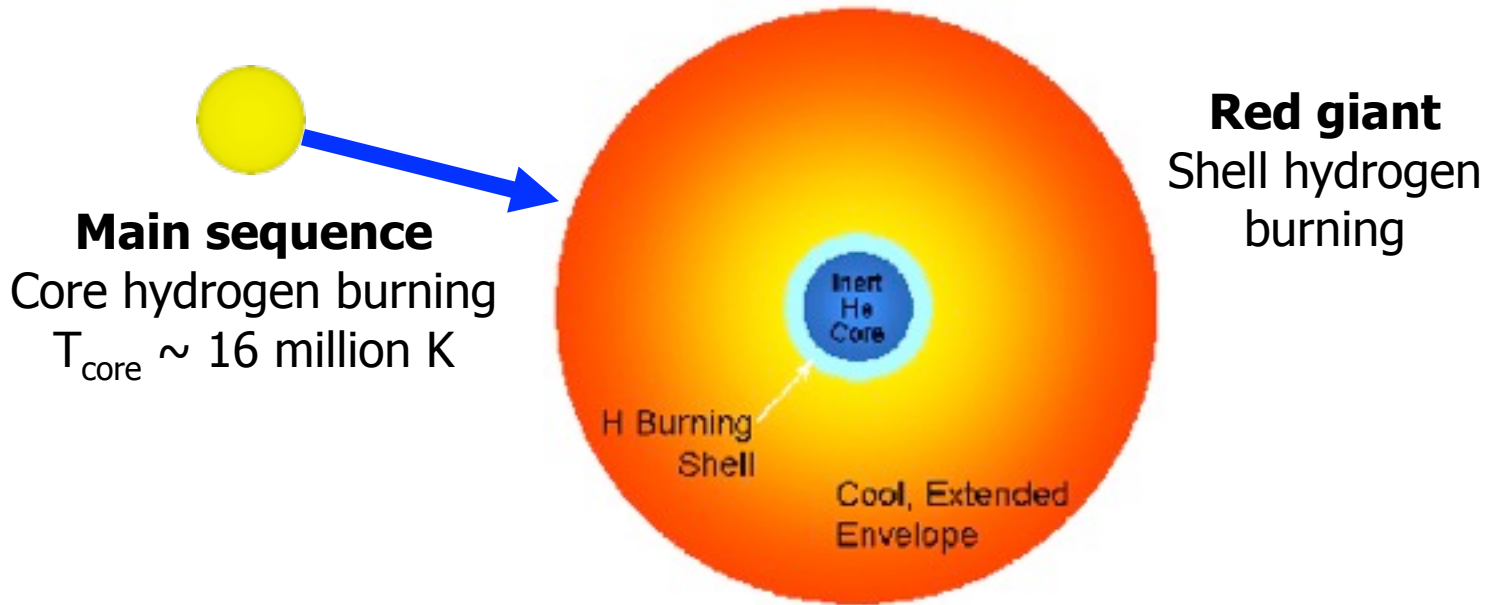


Moving In 6-7 Billion years?

- 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.



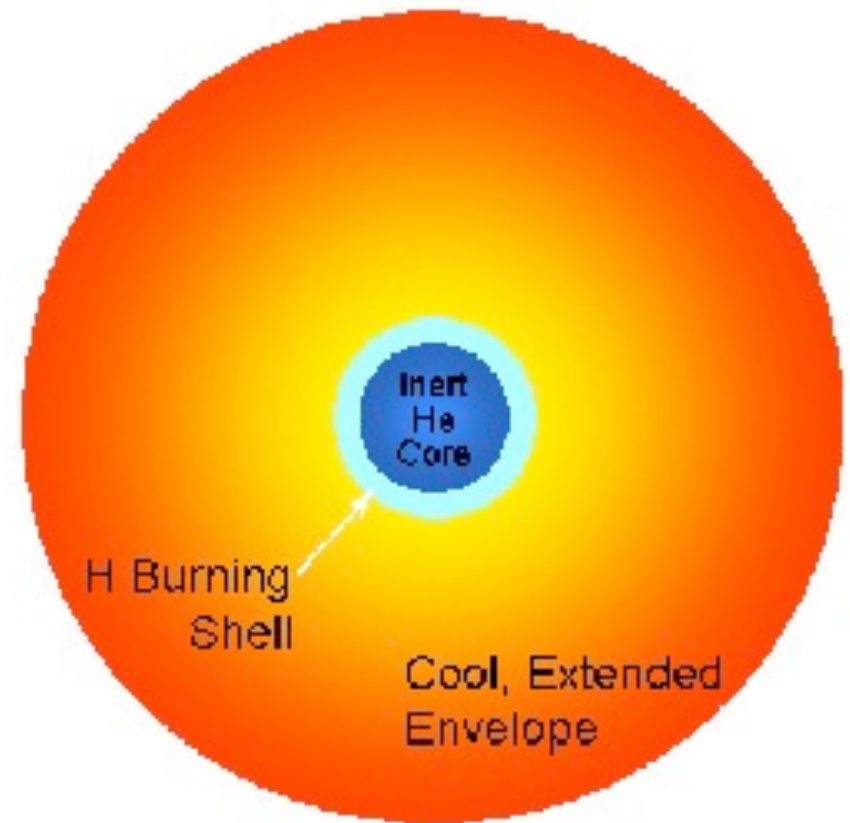
Life of a Sunlike Star



- ✓ Sun hydrogen exhausted
- ✓ Core filled with inert (for now) helium
- ✓ Core contraction ignited H burning shell
- ✓ Sun bloated to red giant
- ✓ Mercury & Venus gone
- ✓ Pluto looking like attractive real estate

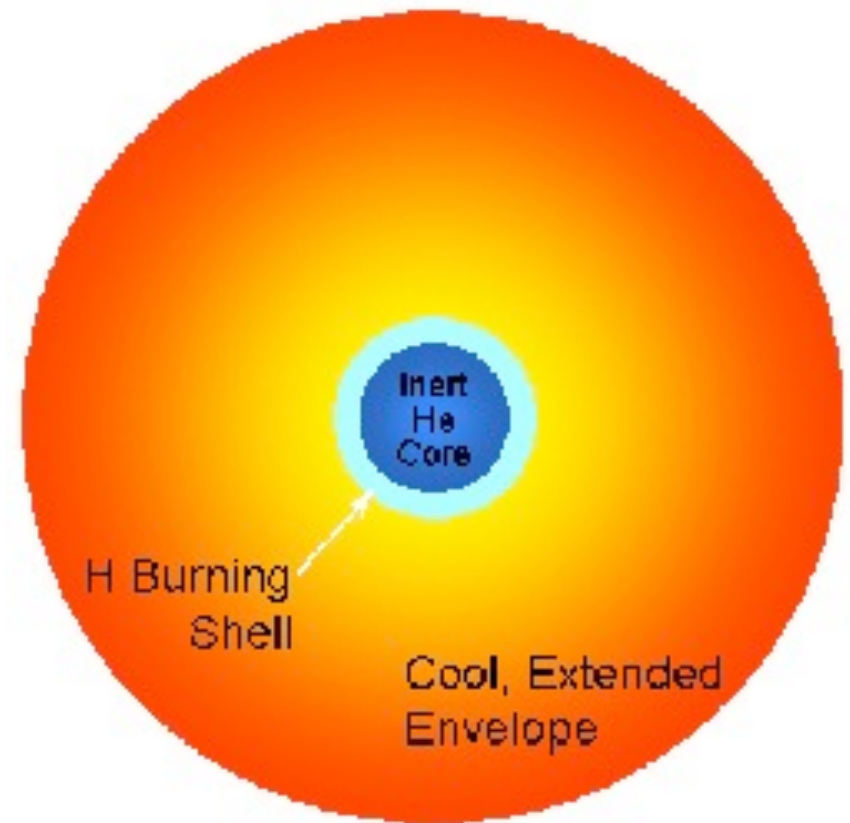
Contraction Junction

In core, contraction
increases density
Hotter, and hotter, and
hotter until...



Contraction Junction

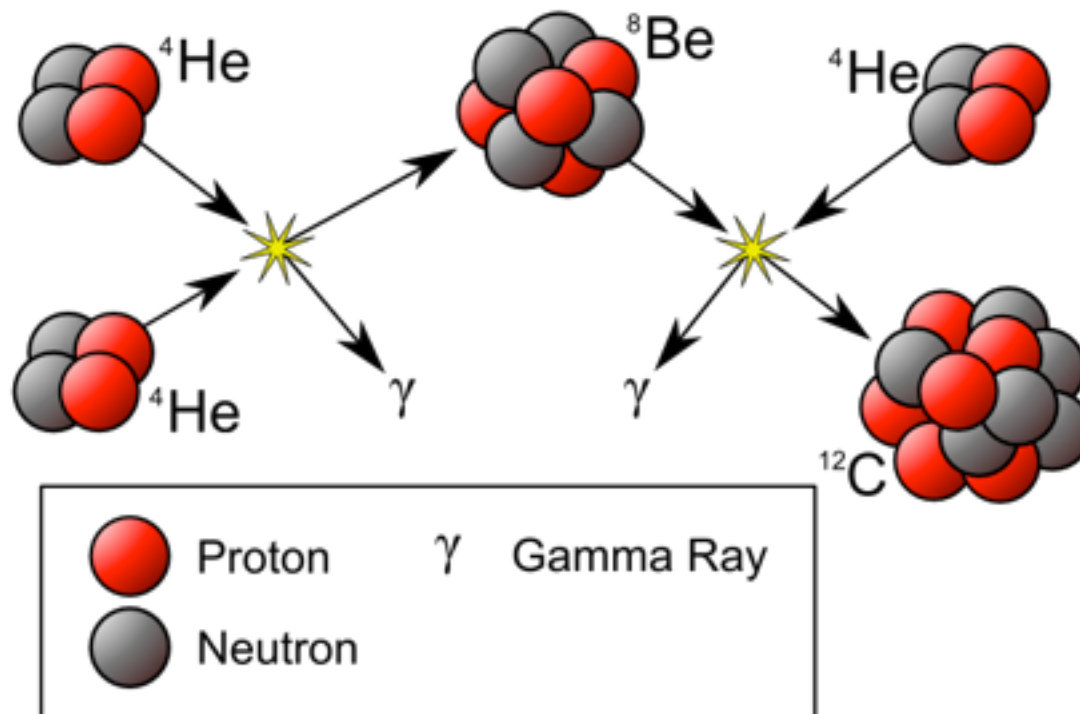
100 million degrees F
Core heats \Rightarrow He fusion
ignites
He \Rightarrow C & O



Helium Burning

When the core of the star reaches 100 million degrees, particle collisions very violent, can then **fuse helium** (the ash of hydrogen burning) into **carbon**

helium “ash” now becomes “fuel” -- **the Sun recycles!**



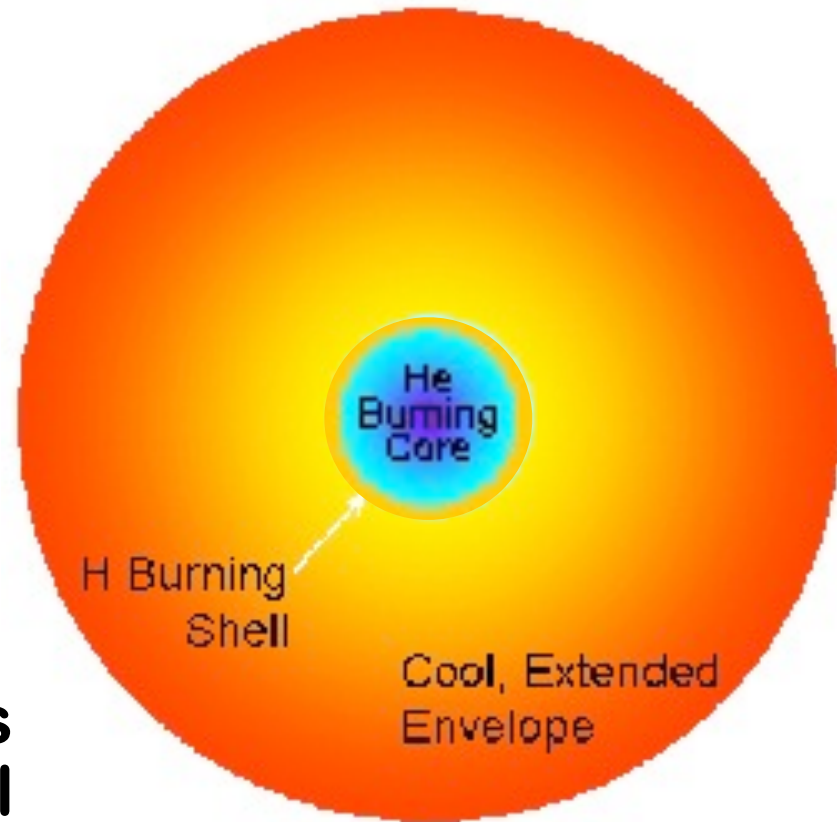
Helium Burning

- 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”.



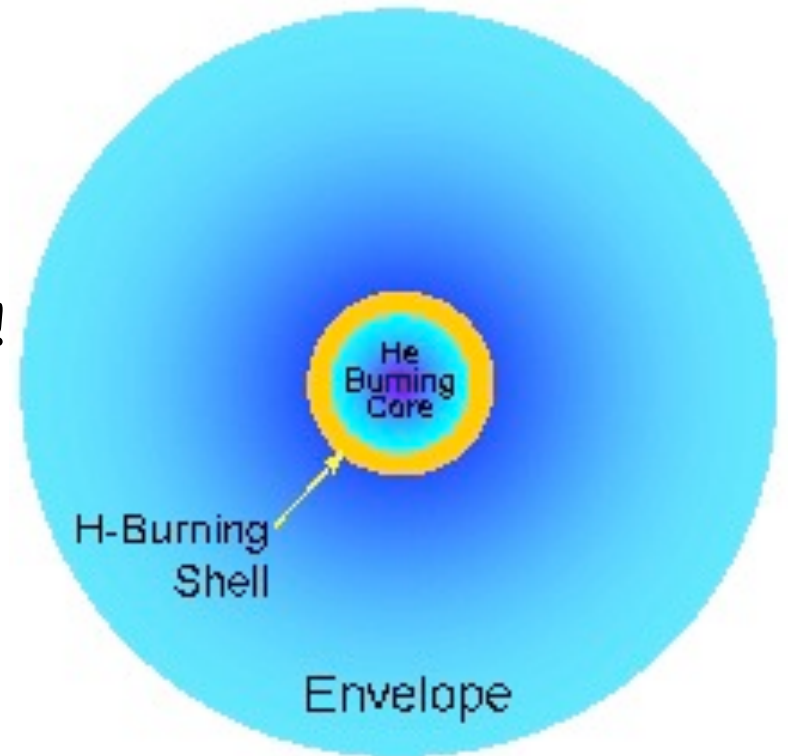
Helium Flash: 7.7 Billion Years

- Helium Flash: explosion at core of Sun when helium finally ignites all at once
- very rapid: ignites in ~few min
- Note: explosion energy trapped in outer layers so don't see anything special from the outside
- During time of explosion, as much energy released as all of the rest of the stars in the Galaxy.
- Core turns normal and it calms down.

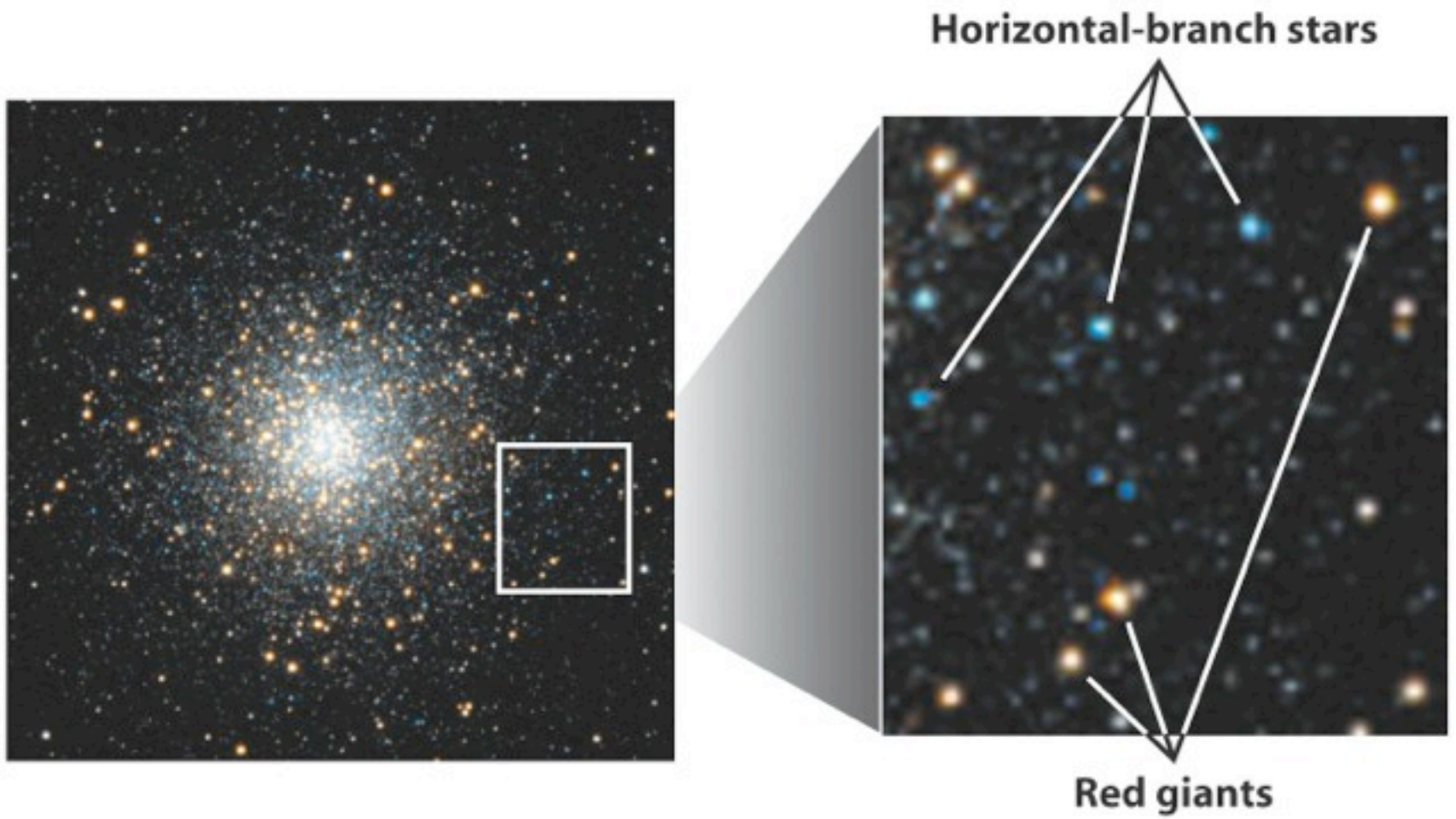


The Horizontal Branch

- Stars in helium burning phase:
 - “horizontal branch”
- Helium burning stabilizes the core
 - but **destabilizes outer layers!**
- 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



Aging Stars



IClicker Question

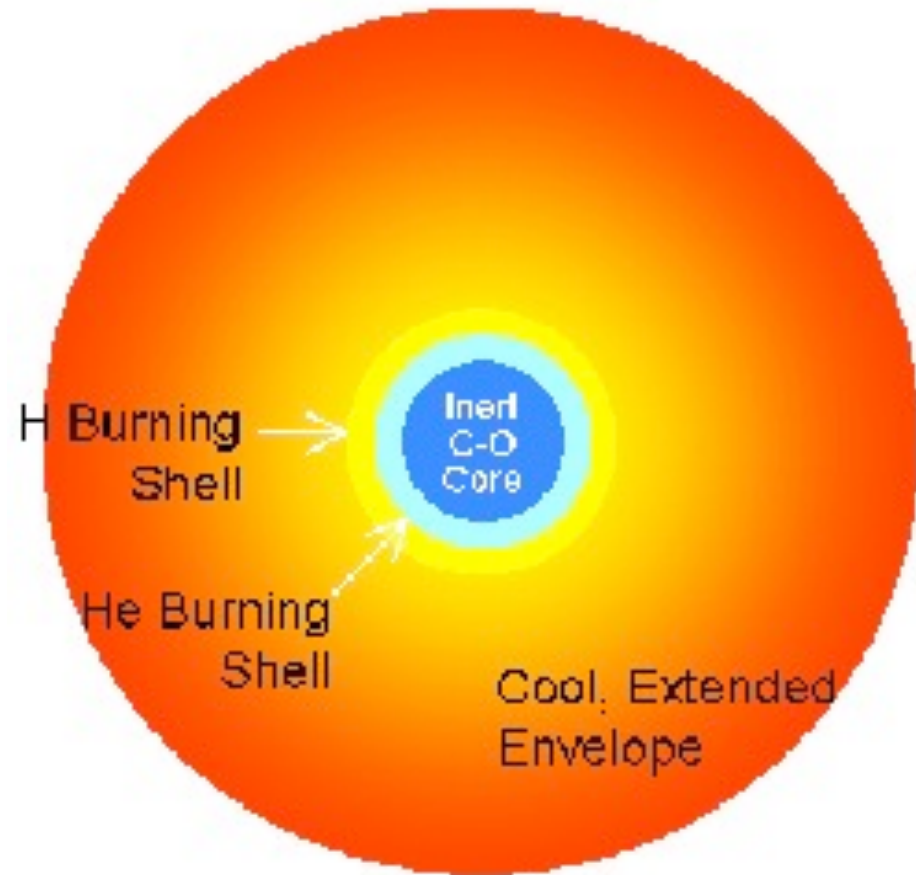
What is occurring in the core of a horizontal branch star?

- a) Fusion
- b) Fusion of H into He
- c) Fusion of He into C and O
- d) Nothing

When Helium Runs Out...

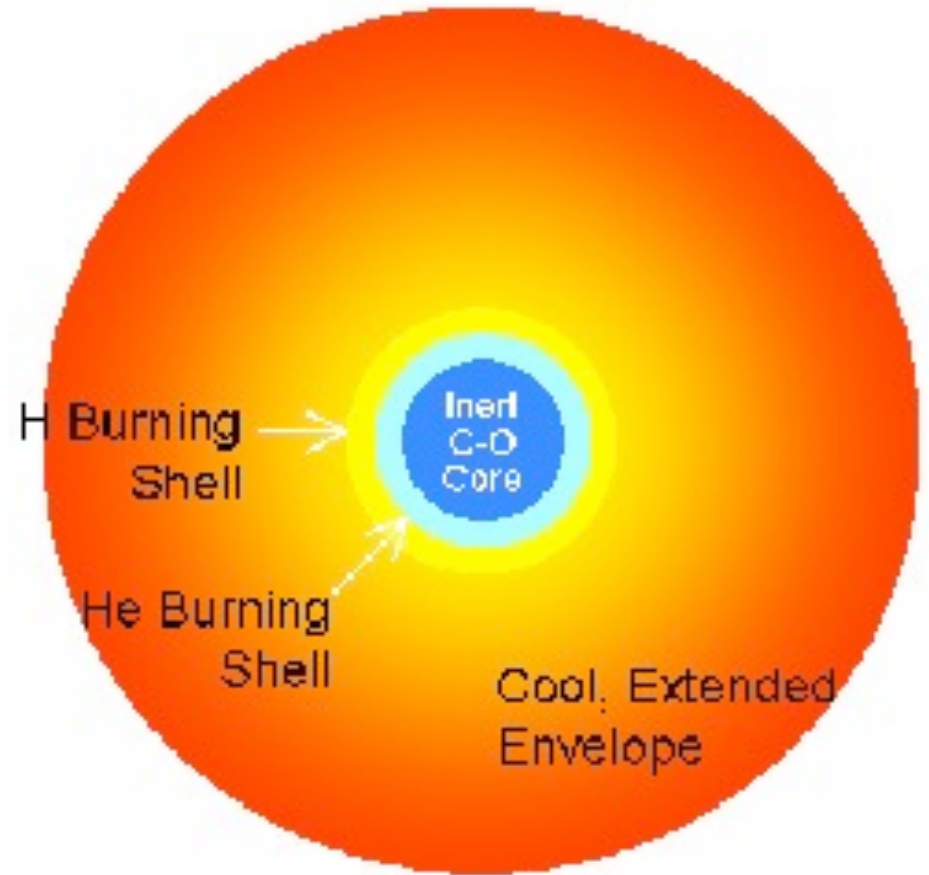
7.8 Billion Years from Now

- Fusion in the core stops – the helium has been converted to carbon and oxygen
- Stellar core collapses under its own gravity again
- Inner shell develops, starts fusing helium to carbon
- Outer hydrogen burning shell remains
- Star starts to grow and cool again



When Helium Runs Out... 7.8 Billion Years

- Phase after core helium exhaustion 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 at this point.



IClicker Question

What is occurring in the core of an asymptotic giant branch star?

- a) Fusion
- b) Fusion of H into He
- c) Fusion of He into C and O
- d) Nothing

Life of a Low Mass Star

