ASTR 1020: Stars & Galaxies

February 27, 2008

- Reading: Chapter 17; sections 17.3-17.4.
- *MasteringAstronomy* Homework on Stellar Evolution is due March 3rd.
- SBO observing nights (extra credit)

Astronomy Picture of the Day

Very Large Array Radio Telescope near Socorro, NM

Today's Topic: Stellar Evolution

Evolution of Low Mass Stars (less than 2x Sun's mass)

Protostars → Main sequence

Most of its life on Main Sequence (billions of years)

What happens when it runs out of hydrogen?

Clicker Question

- A star moves upwards and to the right on the HR diagram. What is probably happening in the core?

A) The core has just started to burn a new element
B) The inner core is collapsing and heating up; shell burning is increasing
C) All nuclear burning is slowing down
D) The inner core temperature is cooling

- **B) The core is collapsing and heating; shell burning is increasing**
- Moving upwards on HR diagram means more luminosity → more nuclear fusion
- This is usually due to the inner core heating due to gravitational collapse

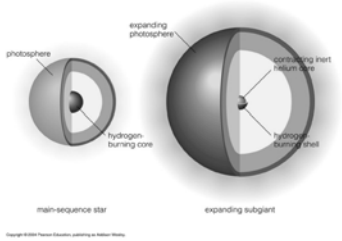
  potential → thermal

Red Giants

- Helium builds up in a non-burning core
- When hydrogen runs out, this core starts to collapse
- With no fusion, there is nothing to withstand gravity ← key theme

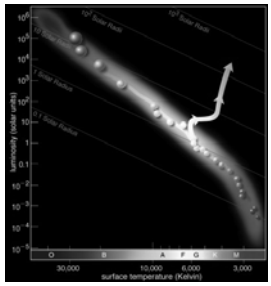
Red Giants

- CORE collapses…
- But layers just above core now also collapse and heat enough to fuse hydrogen
- Hydrogen SHELL burning over collapsing helium core



Red Giants

- As core collapses, hydrogen SHELL burns faster and faster– more energy created
- Luminosity increases, lifts outer parts of star
- Star becomes brighter, larger and cooler!!

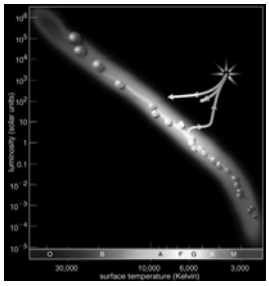


What will happen to the Earth then?

- Red giants have sizes up to 100 x the Sun, 1000 x the luminosity
- Sun will swallow Mercury
- In 5-7 billion years, we will be toast.

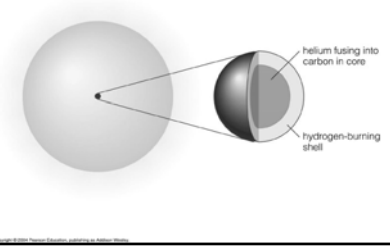
Helium burning

- When core contracts enough to heat to 100 million K, helium starts to fuse into carbon
- He + He + He → C + energy
- Helium "flash"



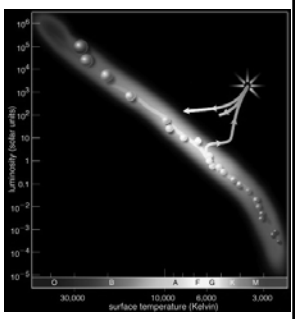
After the helium flash

- Helium burning into Carbon in the core - stable!
- Hydrogen still burning in a shell outside the core



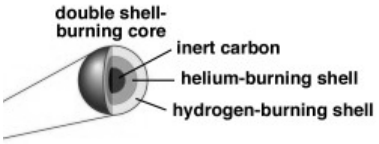
On the HR Diagram

- Helium burning expands the core; Hydrogen shell also lifted and slightly cooled
- Energy output DECREASES slightly after helium flash (still brighter than main sequence)
- Outer layers fall and heat

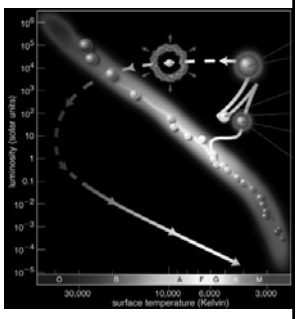


When helium runs out….

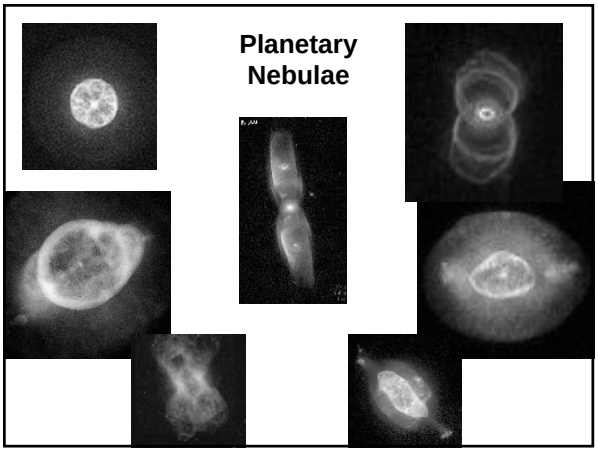
- Carbon core collapses and heats up
- Burning in helium AND hydrogen shells



- Energy generation becomes much higher again
- Outer layers lift and cool
- Star becomes very luminous red giant

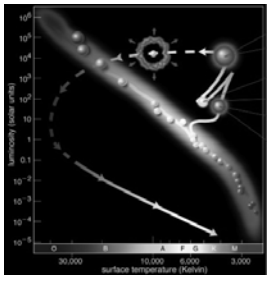


Planetary Nebulae



What's left inside?

- Nebula disperses
- Small, hot carbon "rock" left over = white dwarf (size of Earth)
- Supported by electron "degeneracy" pressure.
- Slowly cools and fades until it becomes a nearly invisible "black dwarf"

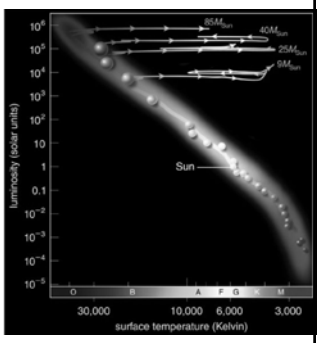


Different Mass Stars

- Low mass: < 2 times the Sun
- Intermediate masses: 2-8 times the Sun
- High masses: > 8 times the Sun

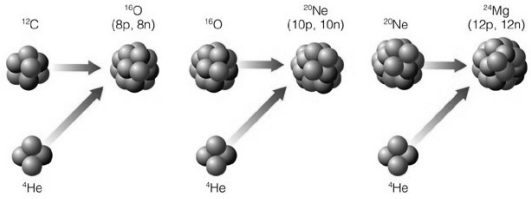
High Mass Stars

- Main sequence lifetimes- much shorter
- Early stages after main sequence- similar to a low mass star, but happen much faster



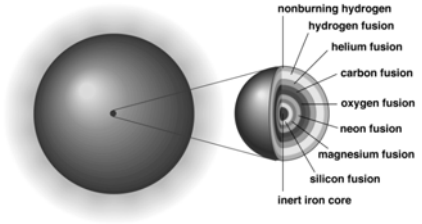
High Mass Stars

- Elements are formed via Helium Capture—
- A helium (2 protons) nucleus is absorbed, energy is released
- The elements are created going up the periodic table in steps of 2



Core structure keeps on building successive shells—

Lesser elements on the outside, heavier ones on the inside



There is no way iron can produce any energy to push back against the crush of gravity in the star's core

- The core of a high mass star accumulates iron as the layers above it burn
- Degeneracy pressure supports the core for awhile until the mass of iron gets too heavy