Chapter 16
Lives of Low Mass Stars

Low mass stars: post Main Sequence
- Observations of star clusters show that a star becomes larger, redder, more luminous after its time on the main sequence is over

Mirror Principle:
Core contracts, envelope expands
- After H burning, He ash remains in core
- As the core contracts, H begins fusing to He in a shell around core
- Luminosity increases: increasing fusion rate in shell does not stop the core from contracting

Thought Question
What happens in a low-mass star when core temperature rises enough for helium fusion to begin?
A. Helium fusion slowly starts up
B. Hydrogen fusion stops
C. Helium fusion rises very sharply

Hint: Degeneracy pressure is the main form of pressure in the inert helium core

Next energy source: Helium burning
Helium fusion does not begin right away because it requires higher temperatures (larger charge leads to greater repulsion):
Combine three He nuclei to make one carbon.

Helium Flash
- Thermostat is broken in low-mass red giant because degeneracy pressure supports core
- Core temperature rises rapidly when helium fusion begins
- Helium fusion rate skyrockets until thermal pressure takes over and expands core again to reach a balance
Life Track after Helium Flash

- Models show that a red giant should shrink and fade after He fusion begins in the core
- Mirror principle: core expands, envelope shrinks

Last stages of nuclear burning

- After core He fusion runs out, He fuses into C in a shell around the C core, H fuses into He in a shell around the He layer
- Double-shell burning stage never reaches equilibrium—fusion rate periodically spikes upward in a series of thermal pulses
- Star large, luminous, and unstable (Sun will grow out nearly to Earth’s radius)

Planetary Nebulae

- Ends with a pulse that ejects the H and He envelope into space as a planetary nebula
- The core left behind becomes a white dwarf (supported by degeneracy pressure)
Life Track of a Sun-Like Star

Life stages of a low-mass star like the Sun
White Dwarfs

- Remaining cores of dead stars
- Electron degeneracy pressure supports them against gravity
- Slowly fade with time
- Sirius and its hot WD companion (Component A brighter in visual wavelengths)

White Dwarfs

- Remaining cores of dead stars
- Electron degeneracy pressure supports them against gravity
- Slowly fade with time
- Sirius and its hot WD companion (Component B brighter in X-ray wavelengths)

Evolution in Close Binary Stars

Mass transfer can radically change stars. Example: Algol (“eye of the Medusa”)

Began as a detached binary

As the more massive star became a red giant, it began mass transfer onto the gainer star.

Eventually the mass gainer became the more massive star, leaving the mass donor as a red subgiant. Algol Paradox
White Dwarfs in Close Binaries

- Mass falls toward white dwarf from binary companion
- Gas orbits white dwarf in an accretion disk
- Friction causes heating and accretion onto white dwarf

Nova

- Temperature of accreted gas may become hot enough for hydrogen fusion
- Fusion begins suddenly and explosively, causing a nova explosion

- The nova star temporarily brightens (Nova Del 2013 from CHARA)
- Explosion drives accreted matter out into space
- If accretion makes WD larger than 1.4 solar masses, then WD may totally explode …

White Dwarf Supernovae

- Collapse triggers carbon fusion in white dwarf.
  - Higher mass white dwarfs are mostly made of carbon.
  - Fusion not just in center, but everywhere in the white dwarf at once.
  - White dwarf is completely destroyed in a second or so!

  Called a Type Ia supernova. We will study other types of supernovae in Ch. 17.