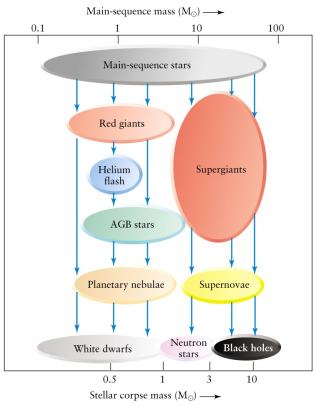
Lec #38: 21 NOV 11 Chapter 6.10

Stellar Remnants
- Supernovae and Supernova Remnants
- Last-Minute Nucleosynthesis
- Degenerate Corpses (great name for a band!)

After Thanksgiving
- Clusters and Age Determination
- Star Formation (Chapter 2)
- EXAM #3



no significant mass change during main sequence lifetime

significant mass can be lost during red giant phases

corpse type (and mass) related to main-sequence mass and to how much mass was lost in red giant phase

A Closer Look at Pressure

- Neutral gas. Pressure from physical collisions between particles.
- Plasma (ionized gas). Additional pressure from "long-range" collisions between charged particles.
- Radiation pressure. Photons have momentum and exert pressure when absorbed and emitted.
- Atomic and Molecular bonds can push back (e.g. solids can resist gravity)
- Electron degeneracy pressure
- Neutrons can pack "shoulder to shoulder"
- What happens when they "break"? Anything else?

Stellar Corpses

- < 1.4 $M_\odot$ White Dwarf
  - progenitor: < 8 $M_\odot$ (winds & planetary nebula)
- 1.4 - 3 $M_\odot$ Neutron Star
  - progenitor: 8 - 25 $M_\odot$ (winds & supernova ejecta)
- > 3 Msun Black Hole
  - progenitor: > 25 $M_\odot$ (winds & supernova ejecta)

- We can see white dwarfs, but...
- can we "see" neutron stars and black holes?

What Causes the Star to Explode?

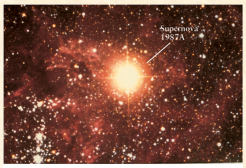
- fusion shells --> Iron core
  - (1 day): core Silicon burning -> Iron
  - Iron will not produce energy by fusion or fission
- (1/4 second): "core collapse"
  - gamma rays disintigrate iron into protons, neutrons, electrons
  - electrons and protons smashed into neutrons (lots of neutrinos emitted)
  - nothing left but tightly-packed neutrons, much more dense than even a white dwarf
- (milliseconds): "core bounce" + neutrinos ==>
- (~10 seconds): SUPERNOVA

Supernova and Nucleosynthesis

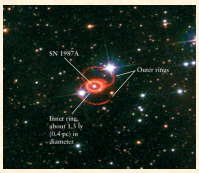
- Outward propogating pressure wave compresses, shocks, heats star's outer shell. It also drives envelope outwards, reversing collapse
- AHBL:
  - more light produced than Sun produces throughout its 10 billion year main sequence lifetime!
  - as bright as entire host galaxy!
  - energy in neutrinos 100x more than in light!
- Rapid burst of nucleosynthesis
  - drives more fusion reactions in envelope
  - neutron capture (R process) builds up heavier nuclei
- Brightens, expands, then fades
  - heavier nuclei --> lighter nuclei by radioactive decay
  - also heats expanding envelope, keeping it bright

Supernova 1987A in the Large Magellanic Cloud!

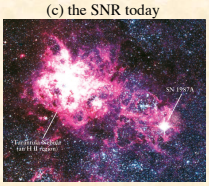
(a) Before the star exploded



(b) After the star exploded

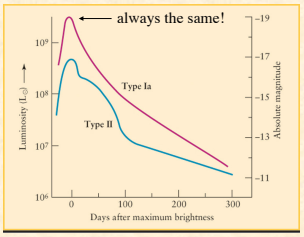


(c) the SNR today



Supernovae: Several Ways To Do It

- light curve indicates which type of SN
- envelope of star enriched in fusion products
- radioactive decay performs nucleosynthesis "in reverse"



I: No Hydrogen Lines

II: Hydrogen Lines