Death of Stars

Fate determined by Mass

3 categories:
- low-mass red dwarfs
- medium mass sunlike
- massive upper-main sequence

Intermediate steps
- giant - supergiant
- supernovae
- planetary nebula

3 outcomes:
- white dwarf
- neutron star
- black hole

**Medium-mass stars**

**Main Sequence**
- 90% of life
- H fusion ⇒ He (ash)
- accumulates in core
- too cold for He fusion

**Hydrogen fusion shell**
- expands to 10-1000 Sun's diameter - Giant or Supergiant - 10%
- Helium core contracts

**Degenerate matter**
- ionized gas - e⁻ + nuclei
- Quantum mechanics states filled
- resists compression
- P does not depend on T
- also found in White Dwarfs

Compression ⇒ increase T

**He fusion** when M > 0.4×M_{sun}

H fusion shell + He fusion core
- briefly halts contraction
- when M < 3×M_{sun}
- starts with Helium flash
sudden burst of He fusion
briefly more energy output
than entire galaxy
Carbon and oxygen
accumulate in core
not hot enough for C,O fusion
aging ⇒ eject planetary nebula
nothing to do with planets
through telescope:
  greenish-blue disk like Uranus
0.2 - 3 ly across
lifetime 1000 - 10,000 yr
  figure 13-08a
*White Dwarf* - remains of sunlike stars
  which ejected surfaces as planetary nebula
billions in our galaxy
no longer generating energy, just cooling
degenerate matter
  C, O, & electrons
  3,000,000 g/cc
tea spoon ~ 15 tons
adding mass
decreases size
when cool ⇒
  *black dwarfs*
quiet death

*Low-mass stars*
*Red Dwarfs* $M < 0.4\times M_{\odot}$
mixed by convection
  no H shell or He core
very long lives
  longer than age of universe
would become white dwarfs

*Massive Stars*
b brief spectacular lives
die in violent explosions

Large $M \Rightarrow$ higher $T$
more fusion possibilities
at $25\times M_{\odot}$ fuses
  $H$ in 7 million yr
  $O$ in 6 months
Si → Fe

can not fuse

quick collapse

less than 0.1 sec

shock wave expands outward

blows apart in bright flash

**Supernova**

partly fueled by radioactive decay

fades within months or yr

AD 1054 seen by Chinese

AD 1572 Tycho Brahe

AD 1604 Kepler

Supernova 1987A

**supernova remnant**

expanding gas collides with interstellar medium

**Binary stars**

complex evolution

transfer of mass