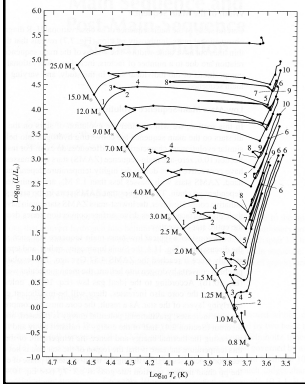
Lec #37: 18 NOV 11 Chapter 6

Main Sequence Evolution
- core hydrogen burning phase

Post Main Sequence Evolution
- hydrogen shell burning
- helium burning
- red giant phases
- pulsation and mass loss

NEXT: Stellar Corpses; Supernovae

Evolution of Low and Intermediate-Mass Stars



Core H burning on MS
- PP v. CNO

Shell H burning -> RGB

He core
- flash ($M < 1.8\ M_\odot$)
- burn ($M > 1.8\ M_\odot$)

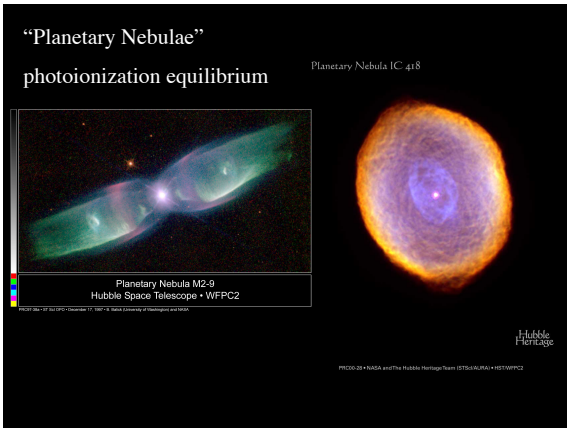
He shell burning -> AGB

C/O core - SN?
- $M < 1.44\ M_\odot$

- **convection** zone dips down to H burning shell; first "**dredge up**" (C enriched material)
- Carbon stars
  - S (C/O ~1) type
  - R, N (C/O > 1) type
- outer layer weakly bound -> strong stellar winds
  - spill carbon-rich dust into ISM
  - considerable mass loss (can affect evolution)
- becomes *unstable* against pulsation
  - He-shell flashes; instability strip (more about this later)
- outer shell puffs off into **Planetary Nebula**
- carbon-oxygen rich **White Dwarf** core remains

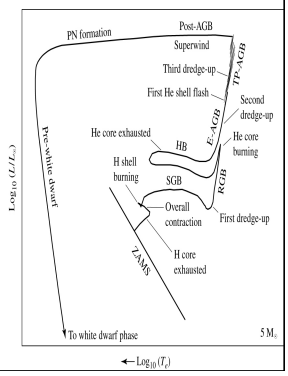
"Planetary Nebulae"

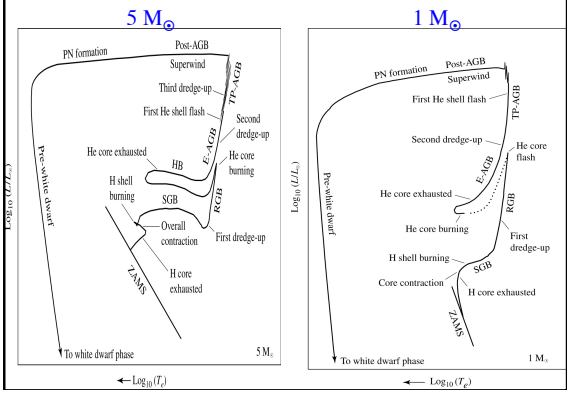
photoionization equilibrium



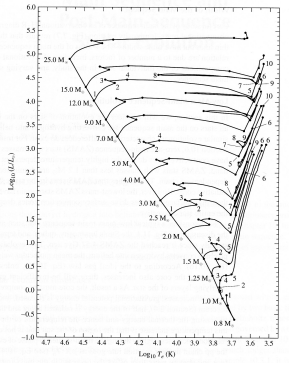
Evolution of Intermediate Mass Stars

- CNO cycle comparable or dominant to PP chain
- Evolution proceeds as in solar-mass stars
- If M >/~ 4 $M_\odot$ no Helium flash; instead...
- core does not become degenerate; Triple-alpha starts ($T>10^8$ K) right away; still create C/O core
- if hot enough, could ignite ^{12}C core in runaway reaction
- unlike He flash, this completely destroys star in a (type I and a half) Supernova explosion





Evolution of High-Mass Stars



Supergiants

Wolf-Rayet Stars

LBV's

SN progenitors

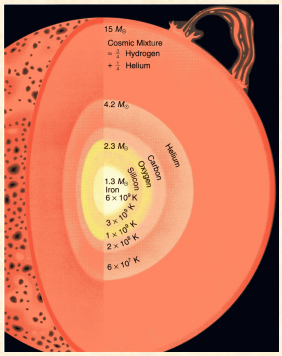
NS & BH parents

nucleosynthesis

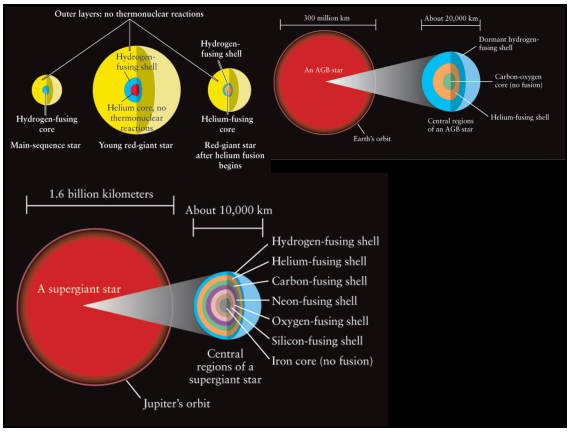
enrich and mix ISM

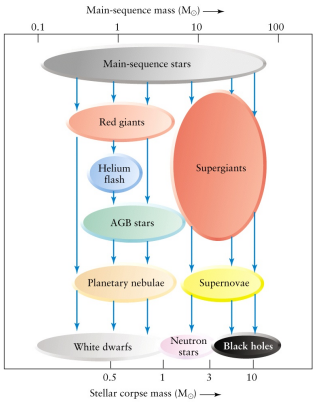
drive/stop star formation

Evolution of High-Mass Stars



- proceed as lower mass stars, but continue core-shell burning all the way up to Si, which produces an Iron core
- for 20 $M_\odot$ star...
  - H 10^7 y
  - He 10^6 y
  - C 300 y
  - O 200 d
  - Si 2 d !!!





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

	MS Energy Production	Core Burning	Shell Burning	He Flash?	Final Core	Corpse
Very Low Mass $10M_J<M<0.08M_\odot$	Kelvin-Helmholz some D fusion	none	none	No	H/He mix	black dwarf
Low Mass Stars $0.08M_\odot<M<0.4M_\odot$	PP chain	H	none	No	He	He-rich white dwarf
Solar Mass Stars $0.4M_\odot<M<4M_\odot$	PP Chain CNO cycle (=~1.2 $M_\odot$)	H He	H He	up to ~? 2 $M_\odot$	C (could detonate at high end)	C/O white dwarf
Intermediate Mass $4M_\odot<M<8M_\odot$	CNO dominates	H, He C O?	H He C?	No	C at low end (Type I SN) Fe at high end	white dwarf or neutron star
High Mass Stars $M>8M_\odot$	CNO dominates	H, He C, O, Si	H, He C, O, Si	No	Fe	neutron star or black hole