Today

- Consider red giant (RG I) phase, with H shell burning
- Helium flash goes off in shrinking degenerate core: horizontal branch star with He core burning
- Double shell burning (H and He) yields red supergiant (RG II), blows off planetary nebula
- Read 18.2 about white dwarfs formed at end of evolution of low-mass stars
- Respond to discussion question posted on “shapes of planetary nebulae”
- Monday recitation meets in Duane G116 (computer lab) in support of “Planet Finder” Homework #6 – go there directly

More news

- Observatory session write-ups are due soon – would like all by next Thur 9 March
- Very nice public lecture (free to you) tonight at 7:30pm in Fiske planetarium: Jason Glenn on “Revealing galaxy formation in the early universe”

Clicker Poll of Advice

- How do you take notes (or listen) during lectures?
  - A. I get most of it by just listening
  - B. I write down some notes, then go back to book to look things up
  - C. I listen, take some notes, then get copies of lecture slides from course website
  - D. I enjoy talking with my buddies, and they tell me later if I missed anything

Clicker – starbirth: what has stuck?

- The vast majority of stars in a newly formed star cluster are ________ ?
  - A. less massive than the Sun
  - B. very high-mass, type O and B stars
  - C. red giants
  - D. about the same mass as Sun
What happens to nuclear fusion when the hydrogen in a star’s core runs low?  

E.

- A. It stops
- B. It shifts from the core to a shell around the core
- C. Other elements start to fuse
- D. The star goes out of balance and becomes a red giant
- E. B and D

Overview of what will happen:

MS → Red Giant I → Horiz Branch → Red Giant II (or Supergiant)

Life track in H-R diagram of solar-mass star

- Many meanders, but MS phase longest, red giant phase(s) shorter, finally white dwarf left to cool slowly

2: Subgiant to Red Giant (first visit)

- H burning in shell, makes much more energy
- Vast expansion, RG phase lasts ~ 500 MY
- Huge convective envelope

Contracting core in red giant gradually becomes “electron degenerate” — what does that mean?

MS → subgiant → red giant
Oops!
Thermostat is missing in degenerate gas

Could get exciting!

Complex aside:
“Degeneracy” pressure

Degeneracy pressure analogy

Limited quantum mechanical states (exclusion principle) (see S4.5)

3: Helium Flash
He core burning — removes electron degeneracy

→ He core burning with thermostat
→ “horizontal branch star”

4: Horizontal branch star
He core burning, H shell burning

Short phase, lasts ~50 MY

Triple-alpha fusion:
3 He → C

Helium flash → He fusion to C in core (horizontal branch)
Discussion:
What does it tell us? Why is it useful?

5. Red Supergiant
Double-shell burning of H and He

Phase could be very short if He burning is erratic (unstable) — then lasts only a few MY, and blows off outer shells

6. Planetary Nebula
Outer shells of red supergiant “puffed off”
Great pictures!

“Naked” white dwarf emerges
Life after brief “planetary nebula” stage ....

Hot central core emerges as

WHITE DWARF

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7. White Dwarf

Inert C core, He & H shells

electron degeneracy pressure holds it up

Very dense, size of Earth

max mass of 1.4 M_{\odot}