Today +

- Discuss how a star may be born: getting to the MS
- Look at post-MS evolution of a low-mass star
- 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 18.1 about white dwarfs formed at end of evolution of low-mass stars
- Term project on Extra-Solar Planets using Planet Finder now distributed: recitation in G116 on Mon
“Grand design spiral” – M51 Whirlpool

Disk stars/gas rotate through “traffic jams”

Bright O & B stars mark the spiral pattern: regions of star birth

Reading clicker – Starbirth

• 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

Beauty and richness of the ISM

Emission nebulae around star birth regions -- in dark clouds of obscuring dust and gas

Gravitational collapse of “molecular clouds”

Battle between (1) gravity pulling inwards building clumps, (2) pressure of heated gas pushing outwards to resist further collapse → Need big clouds & cooling

Simulation of giant cloud collapse and birth of stars
What is the energy source that heats a contracting protostar?

A. Friction
B. Pressure, as the gas and dust are compressed
C. Gravitational potential energy released as the material is pulled inward
D. Fusion
E. Kinetic energy

Stages in building the PROTOSTAR

Too much angular momentum – jet it away!

Actual edge-on disk and jet (Hubble ST)

Many jets from young stellar objects

Often protostar is still hidden in cocoon of dust – and jets are episodic (Herbig-Haro objects)

On reading: When starlight passes through interstellar dust

- A. It gets fainter
- B. The blue light tends to scatter sideways while the red continues to us
- C. Wavelengths all get longer (redder)
- D. All of the above
- E. A and B

More massive protostars get to MS faster!
Collapse of molecular cloud makes many small stars, fewer massive O & B stars.

What happens to nuclear fusion when the hydrogen in a star's core runs low?

- 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

1: Low-Mass Star on MS
H burning in core

Longest phase:
10,000 MY = 10 BY
if solar mass

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

Overview of what will happen:

MS → Red Giant I → Horiz Branch → Red Giant II (or Supergiant)
MS $\rightarrow$ subgiant $\rightarrow$ red giant

Contracting core in red giant gradually becomes "electron degenerate" -- what does that mean?

Oops!
Thermostat is missing in degenerate gas
Could get exciting!

Complex aside:
"Degeneracy" pressure

DEGENERACY AND STELLAR EVOLUTION

Heat nuclear (Temp ↑)
$\rightarrow$ Pressure $\rightarrow$ Gas Expansion
$\rightarrow$ Cool Down: "Thermodynamic Stability"

Heat Deleterious (Temp ↓)
$\rightarrow$ Pressure Decreased
$\rightarrow$ No Thermostat

If nuclear fusion stops in core...

Normal Case: Single, Low M.S. Star

Degenerate Case: "Thermal Ignition"
$\rightarrow$ Pressure Decrease $\rightarrow$ Fusion $\rightarrow$ Cooling $\rightarrow$ Thermostat
$\rightarrow$ EXPLOSIVE!

DEGENERACY PRESSURE
...Controlled structure of quarks and leptons...!

"Pauli Exclusion Principle"

$\rightarrow$ Massive Density through Coupling

Equation...

1. INCOMPATIBILITY of LIGHT: DEGEPHASE
   ...\text{Decay} ...

2. Core of low-mass ($\leq 0.8M_{\odot}$) RED GIANT:
   ...\text{Decompose Electron}

3. Neutron star or pulsar:
   ...\text{Decompose Neutrons}