

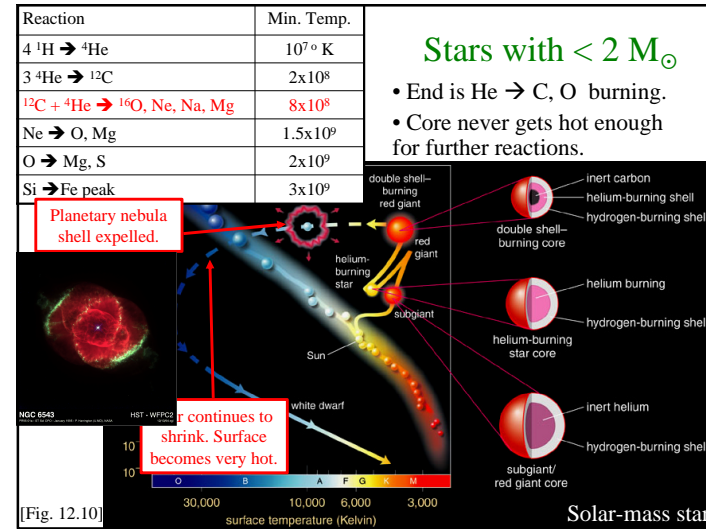
White Dwarfs & Other Ends—March 21



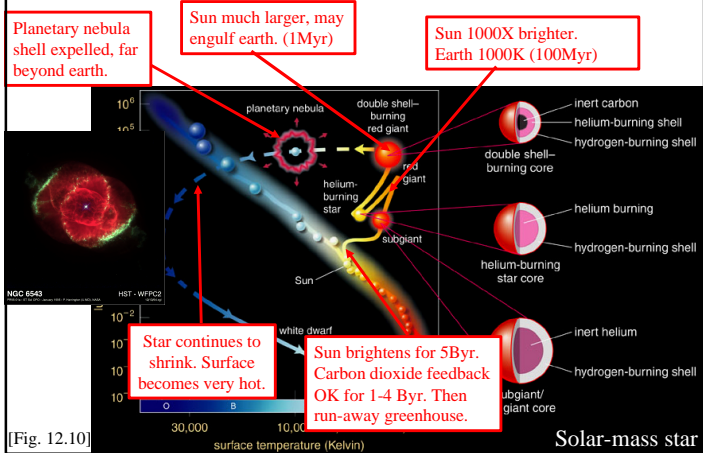
Sirius A, a main-sequence star
Sirius B, an earth-sized white dwarf

Cygnus Loop
Supernova 20,000 yr ago

- When the sun dies, it becomes a white dwarf. Why is a white dwarf different from a main-sequence star?
- What causes pressure?
 - In a main-sequence star, gas particles move because they are hot. (Normal gas)
 - In a WD, electrons move because they are close to each other. (Degenerate gas)
- Other ends
 - Neutron star
 - Black hole
 - Supernova



What happens to the earth?



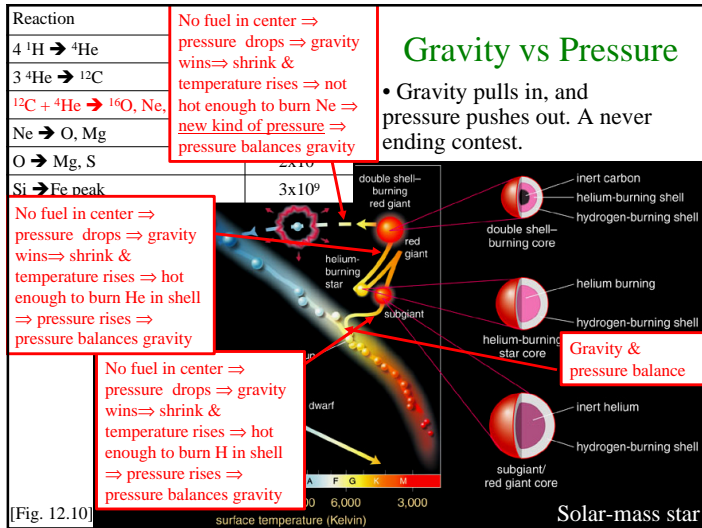
Planetary Nebulae

Planetary nebulae, former red giants, blow away outer 25% of their mass.

The remnant in the center becomes a white dwarf.

Pictures from Hubble Space Telescope





Pressure in a normal gas

- What is pressure?
 - Think of gas particles in a balloon as baseballs in the balloon.
 - Baseballs move and hit walls of balloon
 - Baseballs push on the balloon
- Normal gas
 - Pressure is greater at hotter temperature
 - Baseballs move faster at hotter temperature
 - Baseballs hit walls faster & more often
 - Pressure is higher

Pressure in a degenerate gas

- What is pressure?
 - Think of gas particles in a balloon as baseballs in the balloon.
 - Baseballs move and hit walls of balloon
 - Baseballs push on the balloon
- Degenerate gas
 - Pressure is not greater at hotter temperature
 - Baseballs move because they are close together
 - Quantum mechanics: uncertainty relation
 - Speed \times confinement = Planck's constant
 - Pressure is greater if gas is confined to smaller region
 - In a smaller star, baseballs move faster
 - Baseballs hit walls faster & more often
 - Pressure is higher

White dwarf

- Degenerate gas
 - Pressure is not greater at hotter temperature
 - Baseballs move because they are close together
 - Quantum mechanics: uncertainty relation
 - Speed \times confinement = Planck's constant
 - Pressure is greater if gas is confined to smaller region
 - In a smaller star, baseballs move faster
 - Baseballs hit walls faster & more often
 - Pressure is higher
- A teaspoon of white dwarf weighs several tons
- To get the largest amount of WD matter, choose the smallest one.

- Q Why does the sun end up as a carbon white dwarf?
 - a. There is not enough mass to burn neon.
 - b. The sun becomes degenerate
 - c. The sun loses too much mass as a planetary nebula
 - d. It takes too long to burn neon.