INST 2403 Activity

Late Stellar Life

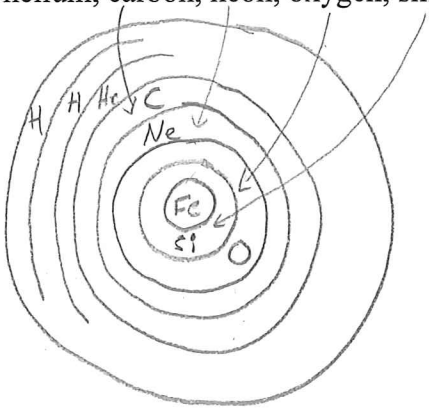
Main sequence (MS) stars convert hydrogen to helium. Eventually, they run out of hydrogen in their core.

1. In general terms, what happens if stars run out of hydrogen in their core? Argue with the concept of hydrostatic equilibrium.

   If no energy is produced, gravity takes over and compresses the star, making it denser and hotter.

2. Use the Stefan Boltzmann law (luminosity depends on size and temperature) to draw the evolutionary tracks of a star of one solar mass into the HRD as it develops away from the main sequence star. In particular, label the following major stages:
   a. Subgiant stage with hydrogen shell burning, in which the star is slightly cooler and several times more luminous than in its MS stage.
   b. Red giant stage with intensive hydrogen shell burning. The stars is cooler and about 100x more luminous than in the MS stage.
   c. Helium flash and horizontal branch, where the star gets hotter and smaller when is starts fusing hydrogen to carbon in its core.
   d. An asymptotic branch giant with helium shell burning because the core is full of carbon ash. The stars outer layers are only 3000K, but the luminosity soars to above 10,000x the luminosity of the sun.
   e. After the asymptotic giant phase, the star becomes so bloated that its outer layer become opaque for radiation. The star sheds its outer layers which form a planetary nebula. This is an explosive event, where the star's material heats up dramatically to beyond 30,000K, while keeping its high luminosity.
   f. Eventually, the outer layers expand cool, exposing the burned-out core of the star as a white dwarf. This is a very small object about 7,000-10,000K at its surface.

3. How do more massive stars develop? Their lives do not end with when a carbon core develops, because their greater mass can squeeze and heat up this core enough so that carbon can fuse to oxygen, and eventually oxygen will fuse to even heavier elements. With many different elements burning in different shells, the star resembles an onion. Sketch such an onion star and label its layers: non-burning hydrogen, burning hydrogen, helium, carbon, neon, oxygen, silicon, ~~neon, silicon~~, iron.



4. This build-up of more complex atomic nuclei stops at iron. Why?

Because energy is absorbed, not emitted when iron fuses to form heavier nuclei.

5. How do these massive stars end their lives?
   a. Stars which are much more massive than the sun, but not excessively massive?

Supernova which yields a neutron star.

   b. The most massive stars, with masses larger than about 25 solar masses.

Supernova which yields a black hole.