ASTRONOMY 1102 – 1

Instructor: Juhan Frank

Answers to HW6, Fall 1999

1) *Evolution of the Sun* Molecular cloud → protostar → contracting protostar with fully convective envelope → H ignition → zero age main sequence → main sequence, burning steadily H to He for 10^{10} yr → subgiant → first "ascent" of the red giant branch as an RGB star, inert He core + H shell burning → Helium flash → Horizontal Branch (HB) star, burning He to C steadily in the core + H shell burning → when He in core exhausted, second "ascent" as an Asymptotic Giant Branch (AGB) star, inert C core + H shell burning + He shell burning → ejection of planetary nebula (PN) → central star of PN → hot white dwarf (WD), all nuclear burning ceases → cooling WD → black dwarf.

2) The PN a and b are symmetric shells, probably ejected by a single AGB star.

3) a) Intermediate mass and massive stars.

b) low mass stars.

c) low mass and intermediate mass stars.

d) high mass stars.

e) high mass stars.

f) high mass stars during the SN explosion.

g) high mass stars.

h) white dwarfs in accreting binaries, when they exceed the Chandrasekhar limit.

i) the most massive of the high mass stars.

4) Because the different stages of burning in multiple shells occur so rapidly that there is no time for the effects of changes in the core and surrounding shells to propagate out top the surface.

5) Because the conditions leading to C detonation occur when a WD exceeds the Chandrasekhar mass, and are therefore the same or very similar for different initial WDs. The energy liberated in the process is always the same, therefore the peak luminosity is always the same. In other words: we know their absolute magnitude; we observe their apparent magnitude and we can deduce the distance.

6) The "Algol Paradox" is the fact that in Algol itself (and other similar binaries) the less massive of the stars is a red giant and is more evolved than their more massive main sequence companion, in contradiction to single star evolution which predicts that the more massive star always exhausts its supply of H first and evolves away from the main sequence first. The paradox is resolved by allowing mass transfer between the stars, so that the more massive star today was actually the less massive star in the past.

7) Because to increase pressure in a degenerate gas, the density must increase, confining each particle to a smaller and smaller volume. In accordance with the Uncertainty

Principle of Quantum Mechanics, the velocity of the particles must increase to provide the pressure. But the velocity cannot exceed the speed of light, so there is a maximum degenerate pressure. Since neutrons have more mass, they can be packed tighter together, and therefore their maximum degenerate pressure is higher.

8) A white dwarf (accretor) accreting hydrogen rich material from a companion (donor) will accumulate H until conditions are ripe for a sudden explosion fusing the H to He. The amount fused is $\sim 10^{-5} - 10^{-4} M_{\odot}$ while in a SN is higher $\sim 1 M_{\odot}$ is fused and the energy liberated is consequently much higher. X-ray bursts occur as a result of the sudden ignition of He acumulated on the surface of a neutron star during accretion. As the H-rich material from the companion lands on the neutron star H is fused steadily into He. When enough He has been accumulated it explodes fusing to C. It is the analog of nova but on a neutron star.

9) A rapidly spinning, highly magnetic neutron star, emitting a beam of radiation of all frequencies, from radio to gamma-rays. We observe the pulses only if we happen to be in the path of the sweeping beam.

10) Because C and O are the direct result of successive fusions of He nuclei. 3 He $\rightarrow$ C, 4 He $\rightarrow$ O. Nitrogen nuclei are produced by less frequent reactions.