Kilic

PROBLEM 4

a) [3 pts.] Describe the Pre Main Sequence (PMS) contraction of a 1 $M_\odot$ gas cloud up to the ZAMS stage. Draw the path in the HR diagram. What part of the HR diagram is this? Why is the path here and not in some other part of the HR diagram? Relate what is happening inside of the PMS object to its observable parameters in the HR diagram.

b) [3 pts.] Now describe the evolution of a 5 $M_\odot$ star from the time it arrives on the main sequence until it reaches the top of the second giant branch (or AGB). In particular, give the position in the HR diagram at various stages. Describe in detail the physics of the red giant phase (first ascent of the giant branch). What is the final fate of this star? How do we know?

c) [2 pts.] How does the evolution of a 5 $M_\odot$ star differ from that of a 1 $M_\odot$ and 25 $M_\odot$ star? Compare the evolution of a 1 $M_\odot$ star with solar metallicity to that of a 1 $M_\odot$ star with low metallicity (*i.e.* a Pop II star). What are the final fates of stars of 1 and 25 $M_\odot$?

d) [2 pts.] Assuming that $(L/L_\odot) = (M/M_\odot)^\alpha$ where $\alpha = 3$, estimate the time spent on the main sequence for the 1, 5 and 25 $M_\odot$ stars. Describe the structure (*e.g.* the location of the convection and radiation zones) of these three stars while on the main sequence. Do not forget to indicate the energy sources in these stars.

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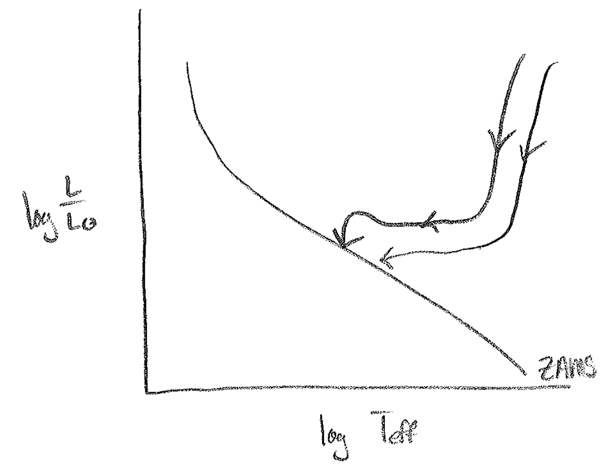
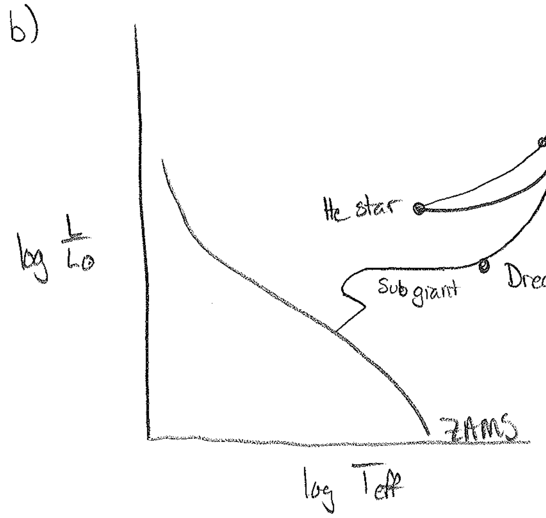
Astro #4

a)



These lines are known as Hyashi tracks, and they describe the pre-Main Sequence (PMS) evolution of a proto star. As the proto-star forms from a gas cloud, it changes from an object that is cool, has a high opacity, + is fully convective, into a warmer object w/ a radiative core.

b)



As the 5 $M_\odot$ star leaves the main sequence, due to its convective core, it must burn up almost all of the H in the core before becoming a shell burning star. Once this transition occurs, the He ash core begins to contract, and the envelope of the star becomes convective and grows. The star is now in the Red Giant (RG) phase of its life. During the phase, the convective enevelope will reach into the core and dredge up material and bring it to the surface, all the while the core continues to contract. Once the central temp reaches ~ 10^8 K, He fusion begins, where the core stops contraction and the envelope shrinks while the star stabilizes as a He-burning star. Once the He in the core is depleted, the C/O core shrinks until it becomes degenerate, while the envelope continues to grow and is eventually expelled from the star. The star ends its life as a C/O white dwarf.

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#4 (cont.)

c) There are only minor differences b/w the evolution of a 1 $M_\odot$ star and that of a 5 $M_\odot$ star, as they go through the same evolutionary phases, but the transition of the 1 $M_\odot$ to a He burning star is different, as the core must first become degenerate before He fusion begins, leading to He flashes instead of a smoother transition. Both end as C/O WD.

However, due to the higher mass of the 25 $M_\odot$ star, its evolution is quite different. The 25 $M_\odot$ star is massive enough to begin fusing elements all the way up to Fe with very little change in radius or temperature. While there is some mass loss, as the star begins to approach the Eddington limit in the Red supergiant phase, there is still enough mass left to die as a Type II SN.

The effect of metallicity on a star is important, but it only plays a small role in a stars evolution. Due to the additional energy levels to absorb photons provided by the metals in a star, metal rich stars have a higher opacity and appear dimmer than their metal poor companions of a similar mass. Metal poor stars also tend to live shorter lives than metal rich stars.

d) 1 $M_\odot$ - radiative core, convective envelope

5 $M_\odot$ + 25 $M_\odot$ - convective core, radiative envelope

Energy source of all MS stars is H-fusion and gravitational collapse energy being radiated away

Time on MS: 1 $M_\odot$ ~ 10 billion yrs

5 $M_\odot$ ~

25 $M_\odot$ ~