Problem set #5

Problem 1 *Globular cluster star population*

When you look at a globular cluster through a small telescope with your eye, the individual stars you can see are largely red giants.

(a) Why is this so?

(b) Why aren't you seeing any high-luminosity massive main sequence stars?

Problem 2 *The expansion of the Crab Nebula*

The radius of the Crab Nebula (M1) is about $3'$ and it is expanding at a rate of $0.21''$/year. Observations have revealed that the radial expansion velocity of the nebula is approximately 1300 km s^{-1} with respect to the central pulsar star.

(a) Calculate the distance to the Crab Nebula under the assumption that the expansion of the nebula is spherically symmetrical.

(b) At the position of the Crab Nebula a supernova has been observed in the past. Use the expansion velocity to determine when did this explosion roughly take place. The supernova was so bright (observed with naked eyes for 23 days in the daytime sky by Chinese and Arabs) that we accurately dated the event on 4th of July, 1054 AD. Estimate the error between this date and what you found, and explain where this discrepancy comes from.

(c) Optional: check online if the Crab Nebula is visible in the night sky over Munich during May-June 2019 (assume a wonderful spring). Hint: find the hosting constellation.

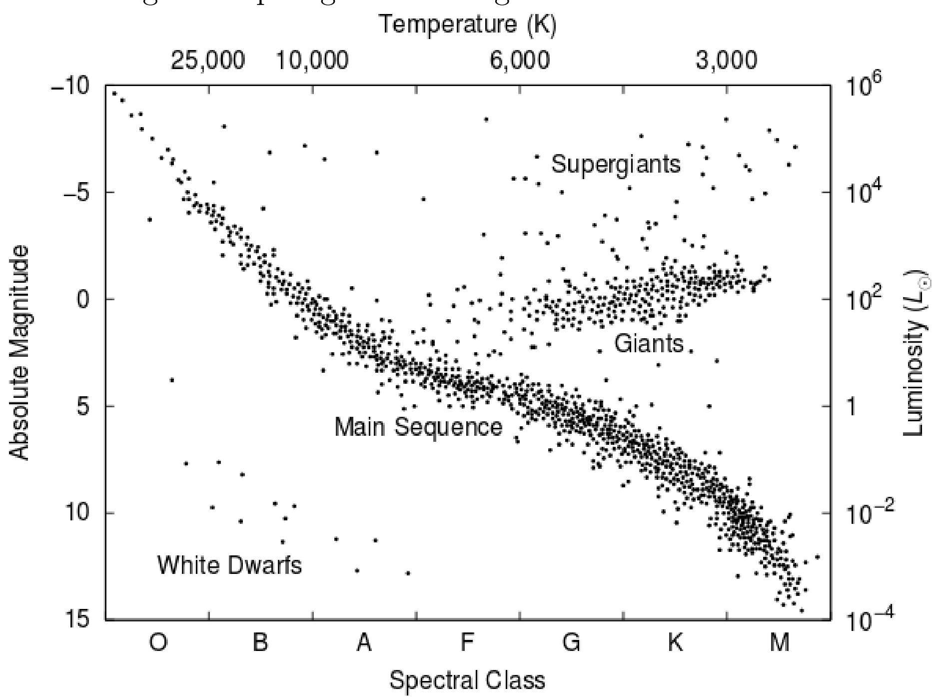
Problem 3 *Neutron stars*

(a) Should the number of white dwarves in our galaxy be much greater, greater, similar, or smaller than the number of neutron stars?

(b) A white dwarf of 1.2 solar masses and radius 1/72-th of the Sun, rotates with a period of 25 minutes. If it collapses into a neutron star with 15 km radius conserving mass and angular momentum, estimate the rotation period. How much is the rotation speed at the surface of the star?

Problem 4 *Hertzsprung-Russell diagram exploration*

Consider the following Hertzsprung-Russell diagram:



(a) You observe a star (let's call it Alderaan) that is bluish in color. You measure its spectrum, and find that the spectrum F_λ reaches a peak at an ultraviolet wavelength of 1500 Å. What is the temperature and spectral type of this star?

(b) You observe a star (let's call it Bespin) that is reddish in color. You measure its spectrum, and find that the spectrum F_λ reaches a peak at a red/infrared wavelength of 7800 Å. What is the temperature and spectral type of this star?

(c) Assume that Alderaan and Bespin have the same observed brightness, and also that Bespin is 10 times closer than Alderaan. If you determine that Alderaan is a main sequence star, what kind of star (white dwarf, main sequence, giant, or supergiant) is Bespin?

Problem 5 *Helium flash*

When the Sun leaves the main sequence, it will go into its "red giant" phase, with a degenerate inert helium core surrounded by a shell of hydrogen which is fusing to helium. Helium "ash" builds up in the core, contracting it, until it is dense and hot enough to ignite helium fusion. At this point, the helium core has a radius of roughly 7000 km, and a mass of about 1/3 the mass of the Sun. The excellent thermal conduction of the degenerate helium core allows much of the helium to fuse all at once, resulting in the helium flash. This fuses (say) a tenth of the helium up to carbon, and expands the core out to a radius of about 70 000 km, over the course of minutes or hours.

(a) Even though this helium flash happens very quickly, and is a tremendous thermonuclear explosion, no direct effect is seen right away in the luminosity of the star. Where is all the energy from that fusion going? Hint: read the full problem.

(b) Do an order of magnitude energy calculation to show that your answer to (a) is plausible. Helium is fused to carbon via the "triple-alpha" process. The mass of one helium-4 atom is 4.002 603 2 u and the mass of one carbon-12 atom is 12.000 000 0 u (by definition). Hint: the potential energy in a sphere is $E_g = -GM^2/R$.