Astronomy 421 – Problem set 6

Due Tuesday, Nov. 8

1. Estimate the Kelvin-Helmholtz timescale for a 5 Msun star on the subgiant branch and compare your result with the amount of time the star spends between points 4 and 5 in Fig. 13.1 (see also Table 13.1).
2. The Helix nebula is a planetary nebula with an angular diameter of 16' that is located approximately 213 pc from Earth. (a) Calculate the diameter of the nebula. (b) Assuming that the nebula is expanding away from the central star at a constant velocity of 20 km/s, estimate its age.
3. The age of the universe is 13.7 Gyr. (a) Compare this value to the main sequence lifetime of a 0.8 Msun star. Why isn't it useful to compute the detailed post-main-sequence evolution of stars with masses much lower than the mass of the Sun? (b) Would you expect to find globular clusters with main-sequence turn-off points below 0.8 Msun? Explain your answer.
4. Using the technique of main-sequence fitting, estimate the distance to M3 (see Figures 13.17 and 13.19).
5. Estimate the Eddington limit for η Carina and compare your answer with the luminosity of that star. Is your answer consistent with its behavior? Why or why not?
6. During the Great Eruption of η Car, the apparent visual magnitude reached a characteristic apparent magnitude of $m_V \sim 0$. Assume that the interstellar extinction towards η Car is 1.7 magnitudes and that the bolometric correction is essentially zero.
    a. Estimate the luminosity of η Car during the Great Eruption.
    b. Determine the total amount of photon energy liberated during the twenty years of the Great Eruption.
    c. If 3 Msun of material was ejected at a speed of 650 km/s, how much energy went into the kinetic energy of the ejecta?
7. The angular extent of one of the lobes of η Car is approximately 8.5". Assuming a constant expansion of the lobes of 650 km/s, estimate how long it has been since the Great Eruption that produced the lobes. Is this likely to be an overestimate or an underestimate of the true age? Justify your answer.
8. Taking the distance to the Crab to be 2000 pc, and assuming that the absolute bolometric magnitude at maximum brightness was characteristic of a Type II supernova, estimate its peak apparent magnitude. Compare this to the maximum brightness of the planet Venus (m ~ -4), which can be visible in the daytime under favorable conditions.
9. The neutrino flux from SN 1987A was estimated to be 1.3×10^{14} m^{-2} at the location of the Earth. If the average energy per neutrino was approximately 4.2 MeV, estimate the amount of energy released via neutrinos during the supernova explosion.
10. Calculate the Lorentz factor for a proton with an energy of 10^{20} eV.