Homework 2
Due: February 18, 2023

3 Assuming that 10 eV could be released by every atom in the Sun through chemical reactions, estimate how long the Sun could shine at its current rate through chemical processes alone. For simplicity, assume that the Sun is composed entirely of hydrogen. Is it possible that the Sun's energy is entirely chemical? Why or why not?

12 The Q value of a reaction is the amount of energy released (or absorbed) during the reaction. Calculate the Q value for each step of the PP I reaction chain (Eqs. 37– 39). Express your answers in MeV. The masses of ${}^{2}_{1}\mathrm{H}$ and ${}^{3}_{2}\mathrm{He}$ are 2.0141 u and 3.0160 u, respectively.

$$ {}^{1}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{2}_{1}\mathrm{H} + e^{+} + \nu_e \tag{37} $$

$$ {}^{2}_{1}\mathrm{H} + {}^{1}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + \gamma \tag{38} $$

$$ {}^{3}_{2}\mathrm{He} + {}^{3}_{2}\mathrm{He} \rightarrow {}^{4}_{2}\mathrm{He} + 2\,{}^{1}_{1}\mathrm{H}. \tag{39} $$

21 Estimate the hydrogen-burning lifetimes of stars near the lower and upper ends of the main sequence. The lower end of the main sequence* occurs near 0.072 $\mathrm{M}_\odot$, with $\log_{10} T_e = 3.23$ and $\log_{10}(L/L_\odot) = -4.3$. On the other hand, an 85 $\mathrm{M}_\odot$ star** near the upper end of the main sequence has an effective temperature and luminosity of $\log_{10} T_e = 4.705$ and $\log_{10}(L/L_\odot) = 6.006$, respectively. Assume that the 0.072 $\mathrm{M}_\odot$ star is entirely convective so that, through convective mixing, all of its hydrogen, rather than just the inner 10%, becomes available for burning.

23 **(a)** Estimate the Eddington luminosity of a 0.072 $\mathrm{M}_\odot$ star and compare your answer to the main-sequence luminosity given in Problem 21. Assume $\overline{\kappa} = 0.001\ \mathrm{m^2\,kg^{-1}}$. Is radiation pressure likely to be significant in the stability of a low-mass main-sequence star?

(b) If a 120 $\mathrm{M}_\odot$ star forms with $\log_{10} T_e = 4.727$ and $\log_{10}(L/L_\odot) = 6.252$, estimate its Eddington luminosity. Compare your answer with the actual luminosity of the star.