P463 Problem Set 2

Assigned: Tuesday, 6 September, 2022
Due: 4:30 pm on Friday, 23 September, 2022

1) **a)** Problem 3.4 of Choudhuri. You may assume the ideal gas equation of state to be valid with $\gamma = 5/3$ and constant mean particle mass $\mu m_{\rm H}$, and use boundary conditions $\rho(r_0) = \rho_0$ and $T(r_0) = T_0$, with r_0 the radius at the base of the convection zone. **b)** Assuming $X = 0.70$ and $Z = 0.02$ and that the gas is fully ionized, estimate the mean particle mass $\mu m_{\rm H}$. **c)** Calculate the mass of the convection zone assuming $r_0 = 0.7 R_\odot$, $\rho_0 = 0.2\,{\rm g\,cm^{-3}}$ and $T_0 = 2 \times 10^6\,{\rm K}$ (integrate numerically if necessary). **d)** Is the solution consistent with the original assumption that $m =$ const inside the convection zone?

2) **a)** Problem 3.6 of Choudhuri (use the internet to check your answer and make sure you are within a factor of two). **b)** Why is it usually acceptable to approximate all the stars in clusters as being at the same distance from Earth?

3) **a)** Problem 3.7 of Choudhuri. Hint: use the proportionality relations derived in the textbook and in class (assuming the stars to be on the main sequence), and use the Sun to calibrate (i.e. to fix the proportionality constant). **b)** What parts of the electromagnetic spectrum do these wavelengths correspond to?

4) **a)** Use the virial theorem to show that the luminosity L emitted by matter falling onto a star of mass M and radius R at the rate $\dot{M}$ can be estimated as $L_{\rm acc} = \frac{GM\dot{M}_{\rm acc}}{2R}$, assuming that the material starts at a radius $r \gg R$. **b)** Recall the Eddington luminosity limit for spherical accretion, assuming the absorption coefficient to be provided by Thomson scattering: $L_{\rm Edd} = \frac{4\pi GMcm_{\rm H}}{\sigma_{\rm T}}$. Derive an expression for the corresponding Eddington mass accretion limit $\dot{M}_{\rm Edd}$. **c)** Compute this limit in $M_\odot\,{\rm yr}^{-1}$ for the cases $R = R_\odot$, $R \sim 0.01 R_\odot$ (white dwarf) and $R \sim 2 \times 10^{-5} R_\odot$ (neutron star). **d)** Under what physical conditions might the Eddington limit be exceded?

5) Problem 4.3 of Choudhuri