ASTR 592
M/W/F 3:00 - 3:50 PM
Due March 4

Problem Set #3

1. Stellar Winds

An empirical formula to describe the average observed mass loss from massive stars (stars with $L \gtrsim 10^3$ L$_\odot$) was derived by de Jager et al. (1988):

$$\log(-\dot{M}) \approx -8.16 + 1.77 \log\left(\frac{L}{L_\odot}\right) - 1.68 \log\left(\frac{T_{eff}}{\mathrm{K}}\right) \qquad (\text{in } \mathrm{M}_\odot\,\mathrm{yr}^{-1}) \qquad (1)$$

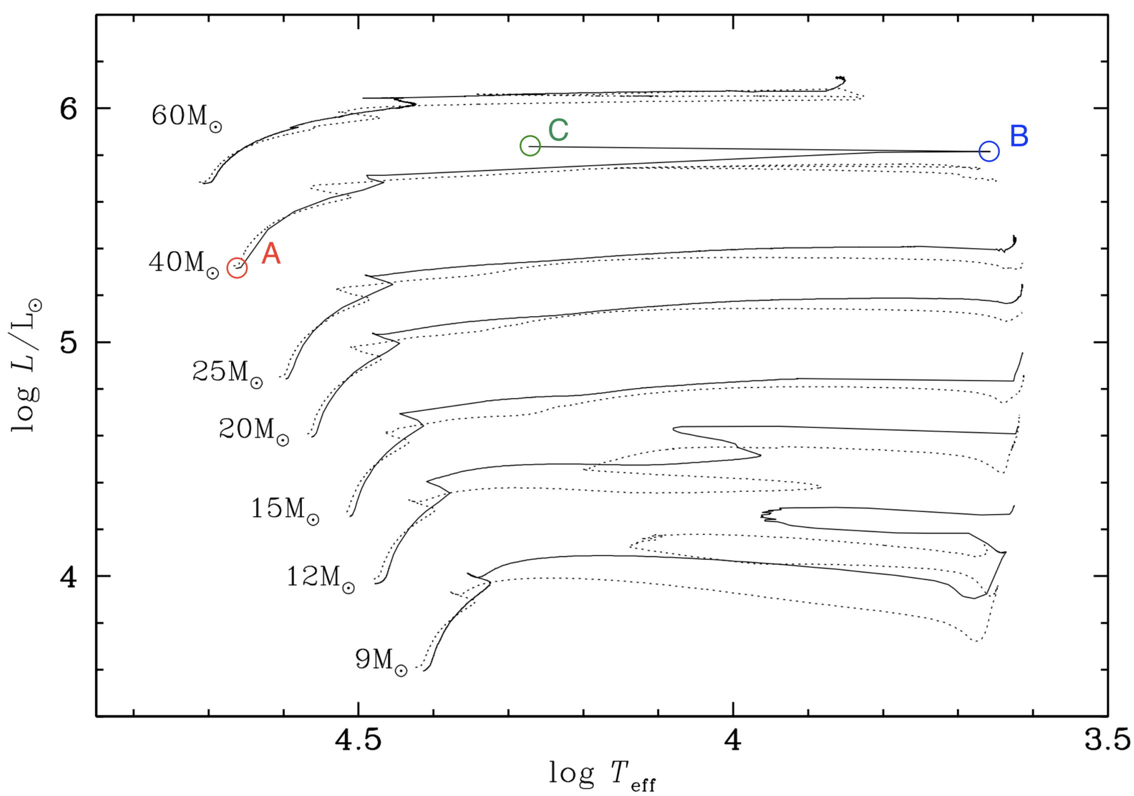

Figure 1: Stellar evolution models from Maeder & Meynet (2001).

(a) Use this formula to calculate the mass loss rate for a 40 $M_\odot$ star at points A, B, and C using the models in the figure on the previous page.

(b) Assume that a 40 solar mass star evolves through the following stages:

	Stage	v_{wind} (km/s)	Duration (yrs)
A	core H fusion	2000	9×10^5
B	core He fusion	30	9×10^4
C	core C fusion	2000	6×10^2

Table 1: Stellar Lifetime Estimates

During which stage does it lose the most mass? How much mass does it lose in total?

(c) Assume that the star spends the majority of its lifetime exactly at points A, B, and C, as shown on the HR diagram. Estimate the total kinetic energy released from the winds of the star over its lifetime and compare this to the energy that the star radiates away over this same period. How do these compare to the energy released in a type II supernova?

2. HII Regions

(a) Estimate the cooling time (due to the O^+ line) for an HII region around the star in Problem 1 during stage A. Assume n $\sim 10^8$ m^{-3} and use Table 5.2 to estimate T_e for the nebula from the effective temperature of the star. (Note, if you use the cooling time equation from lecture, you will want to assume an oxygen abundance of 1.6×10^{-4}.)

(b) Estimate the adiabatic sound-crossing time for this HII region. Assume that $S_* = 2\times10^{49}$ s^{-1}. Which will this nebula reach faster: pressure equilibrium with its surroundings, or thermal equilibrium with its surroundings? Based on this, would you generally expect HII regions to be in pressure equilibrium (isobaric) or thermal equilibrium (isothermal)?