AST383D (Fall 2007)

STELLAR STRUCTURE AND EVOLUTION

Problem Set 1

Due Wednesday, September 19, 2007

(worth 10/100)

1. Mean molecular weight

a. Calculate the mean molecular weight (μ) for a fully ionized, pure He gas!

b. Calculate μ for a completely neutral gas that consists of 50% (by mass) H and 50% He!

2. Validity of Newtonian Gravity

Assume that the interior of a star can be described by the equation of state for an ideal gas ($P = nk_{\rm B}T$). In Einstein's theory of General Relativity (GR), pressure acts as a source of gravity, because it is just another form of energy. Assuming the ideal gas law, estimate the temperature where Newtonian gravity would break down, and would need to be replaced by GR! A simple order-of-magnitude estimate is sufficient here.

3. Internal Stellar Energy

Consider a simple homogeneous (i.e., constant density) star of mass $M = 3M_{\odot}$ and radius $R = 2R_{\odot}$. Assume that this star is in complete (dynamical and thermal) equilibrium. Also assume that the stellar interior is an ideal gas ($P = nk_{\rm B}T$).

a. What is the total internal (kinetic) energy ($E_{\rm int}$) of this star (in ergs)?

b. Calculate the mass-averaged temperature!

4. Kelvin-Helmholtz Contraction

Assume that the present-day Sun had no internal nuclear energy source, and would thus need to supply its luminosity by gravitational (Kelvin-Helmholtz) contraction. Calculate the rate ($\dot{R}$) at which the radius would have to shrink (in cm s^{-1})!

5. Radiative Diffusion

Assume that energy transport in the Sun were entirely due to radiative diffusion. Calculate the number of scatterings ($N_{\rm sc}$) a photon would experience on average on its way from the center to the surface! How much energy (in units of eV) would a photon lose on average per single scattering?

6. Convection near the Hayashi-line

Very briefly explain why stars in the red (cold) part of the HRD, close to the Hayashi-line, have deep surface convection zones!