10 Nov 2008 **Ay 20** E.S. Phinney

Basic Astronomy and the Galaxy

Problem Set 5

Due **in class** *Monday* 17 November, 2008

Readings: Carroll & Ostlie Chapter 9 (complete) and Chapter 10.

Homework Problems:

1. **Photons in a blackbody spectrum**

   a) Find an expression for $n_\lambda d\lambda$, the number density (number per unit volume) of blackbody photons with a wavelength between λ and $\lambda + d\lambda$, and integrate this (numerically or otherwise) over all wavelengths to find an expression for the total number density of photons as a function of temperature. Your answer should be of the form $n = KT^3$, and you should give K numerically for n in cm^{-3} and T in Kelvin.

   b) The cosmic microwave background radiation left over from the Big Bang today fills the universe with blackbody radiation at $T = 2.726\mathrm{K}$. What is the number density n of its photons?

   c) Show that the average energy u/n of photons in a blackbody spectrum of temperature T is $2.70kT$.

   d) Evaluate that average energy (in eV units) for blackbody photons at the center of the sun ($T = 1.57 \times 10^7\mathrm{K}$) and in the solar photosphere ($T = 5777\mathrm{K}$).

2. Carroll & Ostlie problem 9.16

3. Carroll & Ostlie problem 9.20

4. Carroll & Ostlie problem 9.26

5. Carroll & Ostlie Problem 9.28

6. **Isothermal atmospheres**

   a) If the outer part of a star's atmosphere were isothermal with a temperature T_0, what would be the pressure as a function of optical depth $p(\tau)$ within the atmosphere? Assume that that gas pressure $\rho kT/\mu$ is much larger than the radiation pressure. Assume opacity $\kappa = \rho f(T)$. You will need the equation of hydrostatic equilibrium as well as radiative transfer for this.

   b) What would be the limb darkening law $I_\nu(\mu, \tau = 0)/I_\nu(\mu = 1, \tau = 0)$ for an isothermal atmosphere with very high optical depth?