Astro 402 Problem Set #2
March 8 2005; due March 25 2005

1. Suppose there is a cluster of galaxies containing pure hydrogen gas at a temperature of 10^8 K and with density 3×10^{-3} cm^{-3}. If the cluster diameter is 1 Mpc, calculate the bremmstrahlung spectrum of the cluster and the total luminosity. Estimate the cooling time. Comments?

2. An HII region forms in an infinite cloud of hydrogen and dust of (gas) density 10^3 cm^{-3}. Suppose the dust and gas are well mixed and have the interstellar value of $N_H/A_V = 2 \times 10^{21}$cm^{-2}mag^{-1} and that the central star has a Lyman luminosity of 5×10^{49} photons s^{-1}. Estimate the radius of the HII region. (Assume that the dust absorbs only; neglect scattering. The recombination coefficient at $T_e = 10^4$ K is 2×10^{-13} cm^{3}s^{-1}).

3. Derive the equation of radiative transfer through a slab of optical depth τ and temperature T (include 'background' radiation of temperature T_o and intensity I_o).

4. Give one or two-sentence (and/or one or two formula) definitions of:
albedo
specific intensity
optical depth
HII region
PAH
forbidden line

5. Why is hydrogen atomic in the diffuse interstellar medium?

6. Describe the physical properties of the phases of the ISM with approximate numerical values for the temperature, density and volume filling factor. Describe how each phase is observed.

7. Why is interstellar dust warmer than the equilibrium temperature of interstellar space?

8. What is the electron-scattering optical depth of an HII region of density $n_e = 10^5$ cm^{-3} and radius 2 pc?

9. The ionization threshold of H, E_o, is 13.6 eV, and the ionization cross section is $6 \times 10^{-18}(E/E_o)^{-3}$ cm^2. Consider a cloud of H of density 1 cm^{-3} at temperature 10 K at a distance of 10 pc from an X-ray source emitting photons of energy 300 eV at a rate of $N_x = 3 \times 10^{49}$ photons s^{-1}. Estimate the fractional ionization n_e/n_H of the cloud. The recombination coefficient is $\alpha = 2 \times 10^{-11} T_e^{-0.5}$ cm^3 s^{-1}. If the electrons have sufficient kinetic energy they can collisionally ionize further H atoms. Taking this into account, what is the fractional ionization of the cloud?