Astro 402 Problem Set #1
Feb 8 2005. Due Feb 25 2005

1. This is a very simpleminded "numbers" problem to get you familiar with orders of magnitude.

a) The total mass of gas in the galaxy is $\sim 5 \times 10^9 \mathrm{M}_\odot$. Assume that it is uniformly distributed in a disk of radius 15 kpc and thickness 200 pc, and that it is all HI (atomic hydrogen). What is the average number density of H atoms?

b) The gas is mixed with dust. What is the extinction between the Sun and the galactic center? Assume a distance to the galactic center of 10 kpc. Use the following gas to extinction ratio:

$$\mathrm{N(HI)/A_V} \quad = \quad 2 \times 10^{21} \ \ \mathrm{atoms\ cm^{-2}\ mag^{-1}}$$

c) If the dust is in spherical particles of radius 5000 Å and material density 2 gm cm^{-3}, what is the gas-to-dust ratio by mass in the galaxy? Here, assume that the dust absorption cross section is the same at all wavelengths and is the geometric cross section.

d) Now assume that some of the gas is in molecular clouds of radius 10 pc and mean density $\mathrm{n(H_2)} = 300\ \mathrm{cm}^{-3}$. What is the extinction through one molecular cloud?

2. The energy density u of starlight in the solar neighbourhood is about 0.45 eV cm^{-3}. It is sometimes convenient to approximate the density of the background starlight as a "diluted blackbody" of "dilution factor" W and "color temperature" $\mathrm{T_c}$. The dilution factor is defined to be the ratio of the actual energy density u to the energy density of (undiluted) blackbody radiation of temperature $\mathrm{T_c}$. Take $\mathrm{T_c} = 5000$ K as characteristic of the starlight background.

a) Estimate W for the starlight background. (And what is W for the CMB?)

b) The cosmic background has a temperature of 2.7 K. Estimate the ratio of the number density of microwave background photons to the number density of starlight photons in the solar neighborhood.

c) What is the ratio of starlight energy density to microwave background energy density?

3. Assuming the same properties of the interstellar gas and dust as in Problem 1 (same total mass of gas, same dust grain properties etc.) estimate the total luminosity of the interstellar dust (i.e. the total amount of radiation per second emitted by the dust). What fraction is this of the luminosity of a $10^{10}\ \mathrm{L}_\odot$ galaxy?

4. The one-dimensional velocity dispersion of HI clouds is about 9 km/sec. At what height (z) above the Galactic plane does the HI density have half the value in the plane? If the midplane HI density is 1 atom cm^{-3} and its temperature is 100 K, what is the thermal pressure of the HI gas? What is the "turbulent pressure" of the HI gas?

5. Consider a pure hydrogen HII region surrounding a hot star, $T_\star = 30,000K$, $L_\star = 10^4\ L_\odot$. Estimate the temperature of the HII region (assume that the star is a black body. You can assume that the density is $10^3\ cm^{-3}$ but I don't think you need this. Ionization potential of H is 13.6 eV).

6. Suppose a star emits 5×10^{49} photons s^{-1} capable of ionizing hydrogen. Assume it's embedded in an infinite cloud of pure H. Make a graph or table of the mass and radius of the HII region as a function of its density (take a density range of $10^{-3}\ cm^{-3}$ to $10^5\ cm^{-3}$).