Astro 403 Problem Set #1
Feb 3 2011. Due Feb 10 2011

These are very simple-minded numbers problems to get familiar with the units and orders of magnitude

1. 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 $\mathrm{A_V}$ in magnitudes 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 $\mathrm{cm^{-3}}$, 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.

2. The energy density u of starlight in the solar neighbourhood is about 0.45 eV $\mathrm{cm^{-3}}$. 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 Problems 1 and 2 (same total mass of gas, same dust grain properties, dust temperature = 5 K) 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 $5 \times 10^{10}\ \mathrm{L}_\odot$ galaxy?

4. A *red giant* star has an effective temperature of 2500 K and a luminosity of $10^4\ \mathrm{L}_\odot$. Estimate its radius. If its mass is 1 $\mathrm{M}_\odot$, estimate its mean density. The star pulsates. Estimate its pulsation period.

5. Suppose you have a white dwarf of mass 1 $M_\odot$, radius the same as the Earth's, and composed of pure hydrogen. If its initial temperature is 100,000 K, calculate the time it takes for the star to cool to a temperature of 5,000 K. (Assume: 1. the star stays isothermal: 2. the star is composed of a perfect gas: 3. its radius stays constant: and 4. the star radiates like a perfect black body).