Astro 402 Problem Set #3
April 5 2005; due April 15 2005

1. An observation is made of the 21 cm HI line profile in the direction $l = 30^o, b = 0^o$. Assume that the HI density is constant at 1 cm^{-3} and that the spin temperature is 150 K everywhere. Calculate the HI line profile $T_b(V)$ as a function of velocity (between -50 and +200 km s^{-1}) assuming the Galaxy to have a flat rotation curve with a speed of 220 km s^{-1} everywhere. You can calculate T_b every 10 km s^{-1}. What is the total column density of HI you are observing? Check the answer using your calculated HI profile.

2. Calculate the cooling rate (in ergs s^{-1}, for example) due to emission in the 21 cm line of HI for a cloud of radius 5 pc, temperature 200 K and HI density 1 cm^{-2}. Estimate the cooling time for the cloud. Is this cooling likely to be significant?

3. You observe an HI profile towards galactic latitude 90°, i.e. the north galactic pole. It has two distinct components; a broad line, of width 25 km/s and brightness temperature 1 K, and a narrow component, width 2 km/s and brightness temperature 10 K. There is a continuum source in this direction of brightness temperature 100 K in whose spectrum you observe a narrow absorption component of depth -20 K, while you detect no absorption from the broad component. A map of the region shows that the cloud diameter is 40 arcmin, while the broad component is very extended. What is the mass of the cloud? Are the cloud and intercloud HI in pressure equilibrium? Note that you have to make several assumptions about distances etc, just like in real life. Discuss your assumptions carefully! cloud temperature.

4.. Compute the escape probability $\beta(\tau)$ for a photon from a uniform density sphere where τ is the optical depth through the center of the sphere.

5.. A star is losing mass in a steady wind with an outflow speed of 20 km s^{-1} and a mass loss rate of 10^{-4} $M_\odot$ yr^{-1}. The hydrogen is lost in molecular form and the age of the envelope is 30,000 years. Let G (= 3×10^5 photons s^{-1} sec^{-1} sr^{-1} cm^{-2}) be the number of interstellar photons of sufficient energy to excite H_2 and f = 20% be the number of excitations which lead to dissociation of an H_2 molecule. Make a very rough calculation, ignoring the effects of dust, of the number of H atoms in the envelope. At the edge of the envelope, what is the time scale for reformation of H_2 on the surfaces of dust grains if the gas to dust ratio is normal?

6. Given that one can see quasars to the 'edge' of the Universe (i.e. z= 6 currently) what can you deduce about the relative densities of dust in the Galaxy and in intergalactic space?

7. Consider a molecular cloud of uniform density $n(H_2) = 300$ cm^{-3}, radius 1 pc, $n(CO)/n(H_2) = 10^{-4}$, temperature 10 K, and gaussian half-power line width $\Delta V = 2$ km/sec. You observe the CO J = 1-0 line at 115.27 GHz, the ^{13}CO line at 110.201 GHz, the $C^{18}O$ line at 109.78 GHz and the $^{13}C^{18}O$ line at 104.71 GHz. (**a.**). Is the H_2 density high enough to thermalize the CO(1-0) like, i.e. to populate the J = 1 and J = 0 levels in thermal equilibrium at 10 K? (**b.**) Calculate the Rayleigh-Jeans equivalent brightness temperatures of the CO(1-0), $^{13}CO(1-0$, $C^{18}O(1-0)$ and $^{13}C^{18}O(1-0)$ lines on the assumption that their relative abundances are the same as those of the isotope ratios ($^{12}C/^{13}C = 91$, $^{16}O^{18}O = 500$). (**c.**). Calculate the cooling rate time for the cloud if the only radiation is in these three lines. Ignore helium. The cooling time can be estimated by dividing the present energy content of the cloud by the cooling rate.