Interstellar Medium (Ay126), Spring 2011

Problem Set 9

Due: Wednesday, 9 March 2011

Reading: Class notes and Ch. 40 of Draine's book.

1. The 511 keV positronium annihilation line from the central regions of the Galaxy has an observed photon flux $F_{511} = 7.3 \times 10^{-4}$ cm^{-2} sec^{-1} from a "disk" component (Weidenspointer et al. 2008, New. Astr. Rev. **52**, 454).

   (a) Estimate the total positronium formation rate $\dot{N}_{Ps}$, and the positronium annihilation luminosity, assuming that all of the interstellar material is at the 8.5 kpc distance of the Galactic center.

   (b) Compare the total positronium formation rate $\dot{N}_{Ps}$ with the rate $\dot{N}_{Ps} \simeq 4 \times 10^{42}$ sec^{-1} of creation of positrons from the decay ^{26}Al.

   (c) If the Ps forms by radiative recombination, the radiative-recombination process will be analogous to that for hydrogen. What will be the wavelength of the analogs to Hα and Lyα?

   (d) The positronium recombinations will be "case A." Suppose that a fraction $f(3-2) \simeq 0.2$ of the case-A recombinations produce a $3 \rightarrow 2$ photon. Estimate the Galactic luminosity in this line.

2. As discussed in class, people now believe that dust grains are probably sped up by absorption of light from an anisotropic interstellar radiation field. In this problem you will get a feel for how anisotropic the stellar radiation field might be.

   (a) Estimate the anisotropy of the radiation field in an interstellar cloud by pretending that it consists of an isotropic component with energy density 0.4 eV cm^{-3} plus radiation from an imaginary source of luminosity $L \simeq 10^{10}\ L_\odot$ located at the Galactic center at a distance 8.5 kpc. What is the energy density (eV cm^{-3}) of the radiation associated with this anisotropic component?

   (b) Obviously one should worry about the contribution from the single apparently brightest star to the anisotropy of the local radiation field. Suppose that the brightest star in the sky is an A1V star with a luminosity $L = 50\ L_\odot$ at a distance $d = 2.7$ pc (e.g., Sirius on our sky). Calculate the ratio of the energy density contributed by this star to the energy density contributed by the "galactic center" pseudosource considered above.

3. Consider a dust grain with internal density $\rho \simeq 2$ g cm^{-3} (appropriate for carbonaceous material). Suppose the grain to be spherical with radius $a = 10^{-7}\, a_{-7}$ cm.

   (a) If the gas kinetic temperature is $T = 100\, T_2$ K, what is the rms translational velocity of the dust grain due to thermal excitation alone?

   (b) If the grain rotation is in thermal equilibrium with the gas, what will be the rms rotation state?

   (c) If the grain is neutral and is located in an HI region with density $n_H = 10^2\, n_2$ cm^{-3}, what is the timescale τ_M for the grain to collide with its own mass of gas? (If the only process acting to change the linear and angular momentum of the grain is direct collisions with neutral atoms, the translational and rotational motion of the grain will "thermalize" on this timescale).