## Interstellar Medium (Ay126), Spring 2011

Problem Set 1

## Due: In class, first class of week 2

1. The multiwavelength Milky Way. The web site
http://mwmw.gsfc.nasa.gov/mwpics/mwmw_8x10.jpg shows a set of images of the Milky Way at wavelengths ranging from -rays to the radio regime. More details of the surveys, and galactic longitude scales, are given at http://mwmw.gsfc.nasa.gov/mmw_images.html. You may also want to look at
http://www.its.caltech.edu/~kamion/Ay126/MultiMilkyWay.pdf, a nicer and more recent compilation assembled by Chris Hirata. These images allow for a quick comparison of the Milky Way at these different wavelengths. Perusal of these images can be very illuminating. The aim of this exercise is to gain an understanding of what objects show up at certain wavelengths. Referring to these images,
(a) Why is the galactic plane hardly visible at optical and soft X-ray wavelengths, while it is very prominent at near-infrared through farinfrared wavelengths?
(b) Explain why the X-ray emission from the mid-plane of the galaxy is dominated by relatively hard X-ray emission ( 1.5 keV ), while emission at 0.25 keV dominates at higher latitudes.
(c) Why is diffuse -ray emission an excellent tracer of interstellar gas?
(d) Describe and exlain the appearance of the Vela supernova remnant, $\left(l=265^{\circ}\right)$ at the various wavelengths.
(e) Which is more centrally concentrated in the Galaxy: molecular-gas emission or 21 cm emission from atomic hydrogen?

## 2. Interstellar light.

(a) Plot equation 1.1 ( p 14 ) of Tielens and compare to Figure 1.8 (page 12). Over what range of wavelengths is the fit useful?
(b) Then convert equation 1.1 to per Angstrom rather than per Hertz, plot, and compare to Figure 1.9 (page 13).
(c) A more useful way to plot smooth spectra isfff as $\lambda I=\nu I_{\nu}$, the flux per $\log$ frequency or wavelength interval. Use such a plot to verify the statement after equation 1.1. Many molecules are ionized or dissociated by photons with energies in the range $6-13.6 \mathrm{eV}$, while other important molecules such as $\mathrm{H}_{2}$ and CO are only affected by photons above 11 eV .
(d) Hydrogen is photoionized by photons of energy energy $E>13.6 \mathrm{eV}$. The photoionization cross section for a neutral hydrogen atom to such photons is roughly $\sigma=610^{18}(13.6 \mathrm{eV} / E)^{3} \mathrm{~cm}^{2}$. Estimating fluxes from Figure 1.9 of Tielens, approximately what will be the lifetime to ionization of a neutral hydrogen atom in the solar neighborhood?
(e) Why does the spectrum in the Figures drop by over 4 orders of magnitude from just above to just below 1000 AA $\left(10^{-5} \mathrm{~cm}\right)$ ? Try to be at least a little quantitative in discussing the magnitude of the drop.
3. Energy sources. The first 5 energy sources for the diffuse ISM given in Table 1.2 of Tielens, and discussed in sections 1.3 all have pressures and energy densities equal within an order of magnitude. Yet the heating rates differ by a factor of 50 . Discuss why, and the consequences for heating and energy balance in the ISM.
4. Densities. Taking a typical ISM pressure of $10^{12} \mathrm{dyn}_{\mathrm{cm}}{ }^{2}$ (Tielens Table 1.2) calculate the densities of static equilibrium gas clouds at
(a) 100 K
(b) 104 K
(c) 106 K
and explain what type and wavelength (crudely: something like "gammarays from iron molecules") of emission you would expect to dominate the cooling of each cloud.

