Astronomy 405: Solar System and the Interstellar Medium (Spring 2013)

Homework 8, due on April 1

1. Helium atom has two electrons. At the ground state, both electrons are in the 1s orbit. At the lowest excited states, one electron can be in the 2s or 2p orbit.

   (a) Show that the notations for the ground state is 1^1S_0 and the lowest excited states are 2^1S_0 and 2^1P_1, if the two electrons have opposite spins.

   (b) Show that the notations for the ground state is 2^3S_1 and the lowest excited states are 2^3P_0, 2^3P_1, and 2^3P_2, if the two electrons have parallel spins.

2. The cooling time t_c is approximated as $n(\mathrm{H})kT/\Lambda$, where Λ is the cooling rate. Consider a cloud in which $n(\mathrm{H}) = 100$ cm^{-3}, $n(\mathrm{e}) = 0.1$ cm^{-3}, and $n(\mathrm{C}^+) = 0.04$ cm^{-3}, at a temperature of 200 K. Suppose that cooling occurs solely by the excitation of transitions in C^+ by collisions with electrons, and the cooling rate Λ_{C^+} is $8\times10^{-20}n(\mathrm{e})n(\mathrm{C}^+)T^{-1/2}\exp(-92\mathrm{K}/T)$ erg cm^{-3} s^{-1}. Calculate the cooling time, t_c, in years.

3. In equilibrium, each photoionization is balanced by a recombination. The heating rate due to photoionization of atom X is thus $\alpha n(\mathrm{e})n(\mathrm{X}^+)E$, where α is the recombination rate coefficient for $\mathrm{X}^+ + \mathrm{e} \rightarrow \mathrm{X} + h\nu$, and E is the excess energy released in the photoionization. What is the heating due to C atoms in the cloud of Problem 2? (Use $\alpha = 10^{-11}$ cm^3 s^{-1}, and assume that $E = 2.1$ eV.) Show that at $T \sim 15$ K, the heating due to C^+ is roughly balanced by the cooling due to C^+ *in any cloud*.

4. When the light of supernova SN1987A faded away, images taken by the Hubble Space Telescope showed beautiful rings around SN1987A (see figure). These rings were believed to be ionized by the UV flash from the supernova. Consider the inner ring, which has a density of 10^4 H cm^{-3} and a radius of 0.2 pc. The UV flash of the supernova emitted 10^{57} ionizing photons. Assume that the UV flash lasted only 1 sec of time.

   (a) How long does it take this radiation to ionize the inner edge of the inner ring? (This is basically the ionization timescale.)

   (b) What is the recombination timescale? How does this timescale compare to the age of SN1987A (26 years)?