Interstellar Medium (Ay126), Spring 2011

Problem Set 8

Due: Wednesday, 2 March 2011

Reading: Chs. 9 and 10 of Tielens

1. Derive equation (9.4) from equations (9.1)–(9.3) and the density-size relation of HII regions (see Section 7.2.1).

2. Write the ionization balance for carbon photo-ionization and C^+-e^- radiative recombination. Manipulate this equation to arrive at equation (9.6).

3. Compare the photo-ionization rate of magnesium with the cosmic-ray ionization rate of H_2 and arrive at equation (9.7). Inserting a neutral Mg gas-phase abundance of 3×10^6, a primary cosmic-ray ionization rate appropriate for dense clouds ($\zeta_{CR} = 3 \times 10^{17}$), and the photo-ionization rate from Table 8.1, show that the depth in a molecular cloud where these two processes contribute equally to the ionization balance is $A_V \simeq 6$.

4. Balancing the photo-electric heating rate and the [OI] 63 μm cooling rate, derive equation (9.8).

5. Balancing the photo-electric heating rate and the [CII] 158 μm cooling rate, derive equation (9.9).
   (a) Starting from equation (9.15) arrive at equation (9.18).
   (b) Starting from equation (5.40) derive equation (9.19).
   (c) Explain (physically) why $\tau_{100\ \mu\mathrm{m}}$ is independent of G_0.

6. Derive the relationship between the [CII] line flux and the total mass of the emitting gas (equation (9.33)).

7. Discuss briefly the interrelationship, similarities and differences of PDRs and HII regions.

8. Inside a dense molecular cloud, atomic hydrogen is produced by cosmic-ray ionization of H_2. Derive equation (10.24) by balancing H formation by cosmic rays with accretion of H on grains. What could be the cause of a higher-than-calculated atomic-hydrogen abundance inside dense clouds ?

9. Accretion of ice mantles inside dense molecular clouds will increase the average grain size. All grains will acquire the same mantle thickness (cf., equation (10.25)). Adopt the MRN size distribution for interstellar grains (equation (5.97)) and calculate the increase in grain size if all the available gas phase oxygen (cf., Table 5.3) condenses out as H_2O.