

## AY230 – Homework Set #1

Due October 14, 2008

- (1) Ionization state in a plane-parallel geometry: The goal of this problem is to use the 'on-the-spot' approximation to estimate the physical width of the boundary region for an HII region.

Consider an infinite slab of Hydrogen gas with constant density  $n_H$ . Consider an ionizing radiation field with ionizing photon flux

$$\mathcal{J} = \frac{\phi}{4\pi r^2} \quad (\text{photons/s/cm}^2) \quad (1)$$

- (a) Introduce

$$\bar{\sigma} = \frac{\int \mathcal{J} \sigma_\nu^{ph} d\nu}{\int \mathcal{J} d\nu} \quad (2)$$

Derive an expression for the transfer equation of the incident radiation field  $d\mathcal{J}/ds$ . (Note: for our geometry  $ds = dr$ )

- (b) Using the on-the-spot approximation, derive an expression for the ionization fraction  $x$
- (c) Define a dimensionless path  $\xi$ , where

$$d\xi = n_H \bar{\sigma} ds \quad (3)$$

Find an expression for  $d\xi/dx$  in terms of  $x$ .

- (d) Solve (numerically) for  $\xi(x)$  assuming  $\xi = 0$  when  $x = 0.5$  and plot.
- Estimate the width of the boundary region  $\Delta\xi$  and  $\Delta r$  taking  $n_H = 10 \text{ cm}^{-3}$ .
  - Evaluate  $R_S$  for  $\phi = 10^{48.8}$  and  $n_H = 10 \text{ cm}^{-3}$ . Discuss

- (2) First Cloudy calculation: The goal of this problem is to gain familiarity with the Cloudy software package and use it to investigate the structure of HII regions.

- (a) Download, compile and install Cloudy: <http://www.nublado.org/>
- (b) Use Cloudy to generate an idealized HII region ( $n_H = 10 \text{ cm}^{-3}$ , H gas only, no metals, no dust) with our canonical O7 star ( $T_* = 3.5 \times 10^4 \text{ K}$ ,  $\log \phi = 48.84$ ). Plot the ionization fraction  $x$  as a function of distance from the star (pc).
- (c) Use your calculations to estimate the width of the boundary region for your HII region. How does this compare with your estimate from Problem 1? Discuss.
- (d) Repeat steps (b,c) for a more realistic HII region, e.g. allow for He, a solar abundance of metals and dust.