

ASTR 3520, Fall 2002
Homework Set #4: Ionized Nebulae
Due, Tuesday, 25 Nov 2003

(1) Stromgren Spheres:

Consider an O star with a Lyman continuum luminosity of 10^{50} photons sec^{-1} .

[a] Assume that the star is embedded in a uniform density medium with $n(H) = 10^3 \text{ cm}^{-3}$ that has infinite extent in every direction. At this density, what is the radius of the region that can be maintained in a completely ionized state?

[b] What is the mass of the ionized nebula you computed in part [a]?

[c] Use the formula you used above to give a general expression for the mass of an HII region as a function of the mean electron density and the Lyman continuum luminosity of its central star.

(2) Dynamics of an HII region: Consider the $n(H) = 10^3 \text{ cm}^{-3}$ neutral medium of problem 1. Suppose that before the star (with a Lyman continuum luminosity of 10^{50} photons sec^{-1}) turned on, the initial temperature of the medium was $T_I = 100 \text{ K}$. When the gas becomes ionized, it heats to a uniform temperature $T_{II} = 10^4 \text{ K}$.

[a] Suppose the star turns-on its full Lyman continuum luminosity at $t=0$ and a short time later, an R-type front propagates outward rapidly until it ionized the volume you computed in problem 1. As you reach photo-ionization equilibrium, the R-type front slows down and disappears. Qualitatively, what happens to the HII region next.

[b] Eventually, the HII region reaches pressure equilibrium with its surroundings. What is the average density of the final HII region? What is the radius of the final HII region? What is the final mass of the HII region?

[c] Suppose you obtained a high resolution spectrum with $\Delta v = 1 \text{ km/s}$, how would you expect the *surface brightness* and *line width* of a line such as H-alpha to evolve from $t=0$ till the end of its evolution? (Hint: What happens to the column density and velocity field as the HII region evolves?)

(3) Ionization Equilibrium: Working backwards.

[a] Consider a spherical planetary nebula that is 0.5 pc in diameter, and has an average electron density, $n_e = 10^4 \text{ cm}^{-3}$. Assuming that all of the UV

radiation is absorbed in the nebula, what is the Lyman continuum luminosity of its central star?