A311, 2005-10-21

1. Estimate how long it takes an O6 star to establish a 10pc raidius Strömgren sphere in gas of number density $n = 10\,\mathrm{cm}^{-3}$. Make a simple "lower-limit" estimation by ignoring recombination while the HII region is being established. Use numbers given in class in previous lectures as necessary.

How does this length of time compare to the main-sequence lifetime of an O6 star (about 4 million years)?

2. Our analysis of the size and structure of an HII region assumed that all of the neutral Hydrogen is sitting in the ground state. Show that this is a good assumption by estimating each of the following:

- The mean time between collisional excitations from the n=1 to the n=2 state;
- The typical time it takes an excited H atom (in an excited state due to recombination) to decay;
- The mean time between photoionizations.

Assume that the nebula has $n = 10\,\mathrm{cm}^{-3}$, neutral fraction $\xi = 10^{-3}$, and $T = 10^4\,\mathrm{K}$. The ionization cross-section for photons of 13.6 eV is $6 \times 10^{-18}\,\mathrm{cm}^2$. Assume that $\Omega(1, 2)$ from the n=1 to n=2 level of Hydrogen is (like all Ω's) within a factor of a few of 1. (See Osterbrock Table 3.12 for more detail.) The transition of an electron from the $2s$ to the $1s$ state in Hydrogen is forbidden, so should provide a nice estimate of an upperish limit on how long Hydrogen will stay excited, should the electron in a H atom one way or another make its way into the $2s$ state. (Why is it that we want an upper limit?) A *two-photon* emission process from the $2s$ to the $1s$ state has a probability of $A_{21} = 8.2\,\mathrm{s}^{-1}$, and is more probable than emission of a Lyα photon.

Explain how the three times estimates you've given above justify the assumption that the neutral Hydrogen is entirely in the ground state.

3. Look at the diagram below (Figure 12.1 from Osterbrock). In class, we discussed how the fact that AGN tend to have higher [OIII]/Hβ ratios results from the fact that the ionizing source in an AGN (an accretion disk around a black hole) tends to have a harder spectrum than the blackbody of a young star. Thus, the fraction of ionizing photons capable of producing HeII and OIII is larger in an AGN.

Why would an AGN tend to have a larger [NII]/Hα ratio? (This is the question I didn't know the answer to on my own graduate school oral exam.) Refer to the table of ionization potentials I gave you in class on Wednesday.