(1)

$$\frac{\Delta N}{\Delta t} = Q = 5\times10^{48}\ \text{sec}^{-1}$$ RATE OF IONIZING PHOTON PRODUCTION BY STAR

$$N = \frac{4}{3}\pi r^3 n$$ # OF H'S TO IONIZE

$$\frac{N}{\Delta N/\Delta t} = \Delta t = \frac{\frac{4}{3}\pi r^3 n}{Q} = \frac{4\pi\,(10\,pc)^3\left(\frac{3.086\times10^{18}\,cm}{pc}\right)^3(10\,cm^{-3})}{3(5\times10^{48}\,s^{-1})}$$

$$= 2.5\times10^{11}\,s = \underline{8{,}000\ years}$$

$$\ll \tau_{OB}$$

SEE ALSO CLASS NOTES 2005/10/26

(2)

$$\frac{\#\ \text{COLLISIONAL EXCITATIONS}}{\text{TIME}} = n_e\, q_{12}$$

PER H ATOM

$$= n_e\sqrt{\frac{2\pi}{kT}}\ \frac{\hbar^2}{m_e^{3/2}}\ \frac{\Omega(1,2)}{\omega_1}\ e^{-\Delta E/kT}$$

$$\Delta E = \frac{hc}{1220\,\text{Å}} = 1.63\times10^{-11}\,erg$$

$T = 10^4\,K \rightarrow kT = 1.38\times10^{-12}\,erg$

$\omega_1 = 1$

$\Omega(1,2) \approx 1$ WE ASSUME

$n_e = 10\ cm^{-3}$

PLUG IN:

$$\frac{\#\ \text{COLLISIONAL EXCITATIONS}}{\text{TIME}} = 6.4\times10^{-12}\ s^{-1}$$

TIME BETWEEN COLLISIONAL EXCITATIONS $= 1.6\times10^{11}\,s = 5000\,yr$

TIME FOR $n=2$ TO RADIATIVELY DROP TO $n=1$: $\frac{1}{8.2}\,s = 0.12\,s$

$$\frac{\#\ \text{PHOTOIONIZATIONS}}{\text{TIME}\cdot\text{VOL}} = n_{H^0}\underbrace{\int \frac{4\pi J_\nu}{h\nu}\, a_\nu(H^0)\, d\nu}_{\approx\,10^{-8}\,sec^{-1}}$$

$\approx 10^{-8}\ sec^{-1}$ (OSTERBROCK p. 13)

↳ @ 5pc

$$\frac{\text{\# PHOTOIONIZATIONS}}{\text{TIME}} = 10^{-8}\ s^{-1} \Rightarrow \text{TIME BETWEEN PHOTOIONIZATIONS} = 10^{8}\ s$$

↖ PER H ATOM

COLLISIONAL EXCITATION TIME >>> RADIATIVE DE-EXCITATION TIME

↳ DOESN'T SIT IN UPPER STATE

PHOTOIONIZATION TIME >>> RADIATIVE DE-EXCITATION TIME

↳ DOESN'T EVEN SIT UP THERE LONG ENOUGH TO MATTER FOR PHOTOIONIZATION

COLLISIONAL EXCITATION TIME >> PHOTOIONIZATION TIME

↳ TYPICAL ATOM WILL BE PHOTOIONIZED BEFORE IT EVEN COLLIDES UP AT ALL!

(3)

χ (NI - NII) = 14.5 eV ⇐ CLOSE TO HI → HII

χ (NII - NIII) = 29.6 eV ⇐ CLOSE TO HeI - HeII & OII → OIII

SO WHY MORE [NII] WHEN MORE [OIII]? YOU'D EXPECT HOTTER STARS TO DEPLETE NII IN FAVOR OF NIII

BUT IF YOU HAVE A RANGE OF IONIZATION STATES, YOU WILL GET MORE "LOW" IONIZATION LINES LIKE [NII]. IN AGN, THE HARD NON-THERMAL SPECTRUM PRODUCES BIG PARTIALLY IONIZED REGIONS WITH BIGGER NII, OI, etc.