[I] THE [OIII] LINE IS COLLISIONALLY EXCITED, SO

(a) LUMINOSITY → $L_{OIII} = (Vol)\, n_e n_{O^{++}} \, q_{12}$ ← EACH COLLISION UP TO ^1D LEADS TO RADIATIVE DE-EXCITATION, SINCE $n_e < n_{CRIT}$

(IGNORE CASCADE FROM ^1S)

$$= (Vol)\, n_e \,(7\times10^{-4} n_H) \sqrt{\frac{2\pi}{kT}} \frac{\hbar^2}{m_e^{3/2}} \frac{\Omega(1,2)}{\omega_1} e^{-\Delta E/kT} h\nu$$

↑ ASSUME ALL O IS O^{++}

$n_p = n_H$ FOR FULLY IONIZED

$$L_{H\beta} = (0.12)\, n_e n_p \alpha_B(H^0, T)\, h\nu_{H\beta}\, (Vol)$$

(0.12) ↑ 12% OF RECOMBINATIONS TO $n\geq2$ GO THROUGH 4–2 IN CASCADE

$n_e n_p \alpha_B(H^0,T)$ = # RECOMBINATIONS TO $n\geq2$ / VOL · TIME

$h\nu_{H\beta}$ = $E_{H\beta}$

$$\frac{F_{OIII}}{F_{H\beta}} = \frac{L_{OIII}}{L_{H\beta}} = \frac{(7\times10^{-4})\sqrt{\frac{2\pi}{kT}} \frac{\hbar^2}{m_e^{3/2}} \frac{\Omega(1,2)}{\omega_1} e^{-\Delta E/kT} h\nu}{(0.12)\, \alpha_B(H^0, T)\, h\nu_{H\beta}}$$

PLUG IN:

$$\boxed{\frac{F_{OIII}}{F_{H\beta}} = 26}$$

(b) NOT AT ALL! <u>UNLESS</u> $n_H \rightarrow n_{CRIT}([OIII])$, IN WHICH CASE THE RATIO WILL BE SUPPRESSED AS [OIII] IS COLLISIONALLY DE-EXCITED

(c) THE RATIO WILL ↑ WITH T. RECOMBINATION RATES ↓ WITH T, BUT MORE IMPORTANTLY, THE $\exp(-\Delta E/kT)$ SUPPRESSION OF OIII COLLISIONAL EXCITATION WILL CHANGE WITH T, ENHANCING [O III]

⟹

[1] (d) NOT AT ALL; IT ONLY DEPENDS ON THE SHAPE OF THE SPECTRUM

(e) OUR 25 RATIO IS LARGER THAN WHAT IS GENERALLY OBSERVED. REASON: OIII IS MAINLY ONLY IN THE He^+ REGION, AND THE He^+ REGION IS SMALLER THAN THE H^+ REGION.

AS $T_* \uparrow$, A GREATER FRACTION OF THE PHOTONS CAN IONIZE He, SO THE He^+ SIZE APPROACHES THE H^+ SIZE. THUS, YOU EXPECT:

$$\frac{[OIV]}{H\beta} \uparrow \quad \text{AS } T_* \uparrow$$

[2] $\frac{\#\ \text{RECOMBINATIONS}}{\text{SEC}} = \frac{4}{3}\pi r^3\, n_e n_p \alpha_B(H^0, T) = Q$

(a) (r ↑ RADIUS OF SPHERE; Q ↑ # IONIZING PHOTONS/SEC)

OSTERBROCK TABLE 2.3: $Q = 10^{49.23}$ PHOTONS/SEC

2.1: $\alpha_B = 2.59\times10^{-13}\ cm^3/s$ ← @ $T_{GAS} = 10^4 K$

FOR $n_e = n_p = 1\ cm^{-3}$, GET:

$$r = 2.5\times10^{20}\ cm = 81\ pc$$

$$M_H = \frac{4}{3}\pi r^3 m_p = m_p \frac{Q}{n_e n_p \alpha_B(H^0, T)}$$

↓ $m_p = 1.67\times10^{-24}\ g$

$$\boxed{M_H = 1.1\times10^{38}\ g \text{ OF H}}$$ ← WAY BIGGER THAN STAR MASS

STAR MASS $\approx 20 M_\odot \approx 10^{34}\ g$

↑ OR SOMETHING LIKE THAT

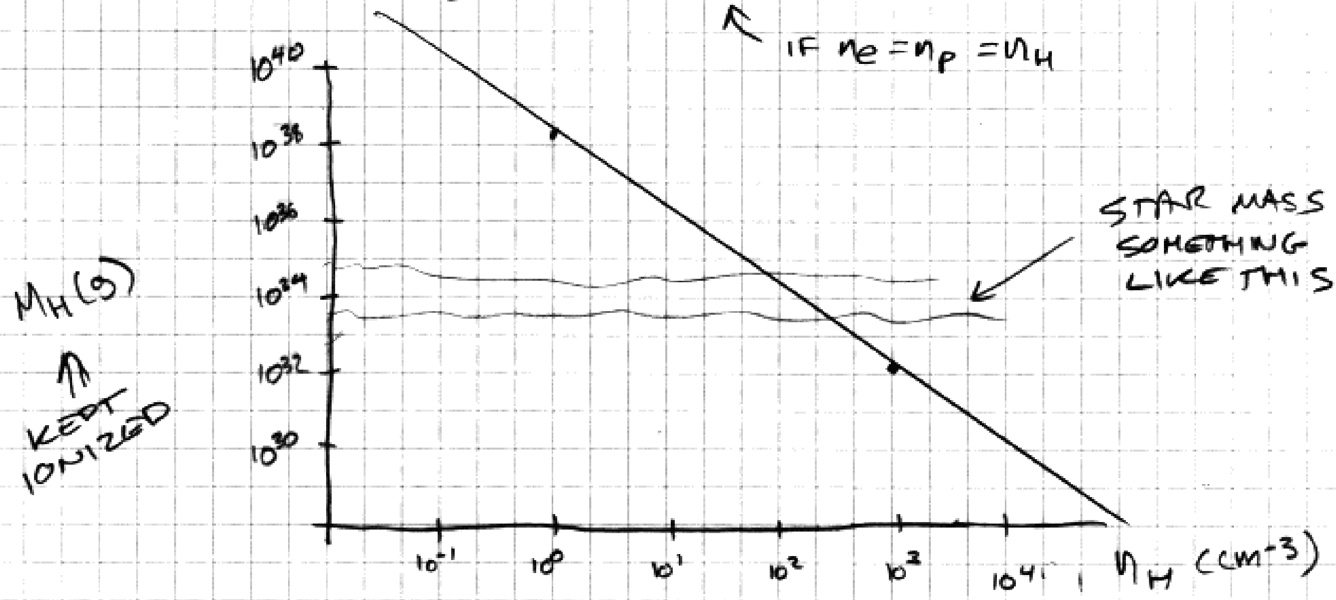
(b) PUT IN $n_e = n_p = 10^3\ cm^{-3}$,

$$\boxed{M_H = 1.1\times10^{32}\ g}$$ < STAR MASS

[2] (c)

$$\log M_H = \log \frac{Q}{\alpha_B} - 6 \log n_H$$

↑ IF $n_e = n_p = n_H$



[3] (a) $P = nkT$

P BALANCE:

$$n_{HII} k T_{HII} = n_{HI} k T_{HI}$$

$$n_{HII} = n_{HI} \frac{T_{HI}}{T_{HII}} = (10^3 \text{ cm}^{-3})\left(\frac{10^2 \text{ K}}{10^4 \text{ K}}\right)$$

$$\boxed{n_{HII} = 10 \text{ cm}^{-3}}$$

(b) FROM [2]: $r_S = \left(\frac{3Q}{4\pi n_e n_p \alpha_B}\right)^{1/3} = \boxed{5.4 \times 10^{19} \text{ cm} = 17 \text{ pc}}$

FOR $Q = 10^{49.23} \text{ s}^{-1}$, $\alpha_B = 2.59 \times 10^{-13} \text{ cm}^3 \text{ s}^{-1}$

(c) $\left(\frac{5.4 \times 10^{19} \text{ cm}}{10 \text{ km s}^{-1}}\right)\left(\frac{\text{km}}{10^5 \text{ cm}}\right)\left(\frac{1 \text{ yr}}{3.16 \times 10^7 \text{ s}}\right) = \underline{1.7 \text{ MILLION YEARS}}$

COMPARABLE TO LIFETIME OF O6 STAR,

SO IF 10 km s^{-1} IS RIGHT, THEN THAT ESTIMATE WAS MISSING SOMETHING! ⟹ MUCH LONGER THAN OUR EXPANSION TIME ESTIMATE ON 2005/10/21