Luminosity, relative intensity

- **Species ID and line wavelength**
- **Intensity (erg cm^{-2} s^{-1}) or luminosity (erg s^{-1}) of line**
  - depending on case
- **Intensity relative to normalization line, default Hβ**
  - Change with *normalize* command

O	3	88.3323m	-5.577	1.5126
O	3	51.8004m	-5.106	4.4704
O	3	4931.23A	-8.339	0.0026
O	3	4958.91A	-4.876	7.5973
O	3	5006.84A	-4.401	22.6702
O	3	2320.95A	-7.193	0.0366
O	3	4363.21A	-6.593	0.1456
O	3	1660.81A	-7.187	0.0371
O	3	1666.15A	-6.720	0.1087

Two level atom AGN3 Sec 3.5

- **Excitation, deexcitation rates**
- **Transition probabilities**
- **Critical density**
- **Two limits**
  - Low densities, every excitation leads to emission of a photon
  - high densities, levels are n LTE, photon emission proportional to $n_u A_{ul}$

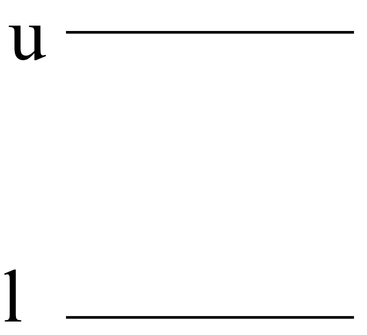
Emissivity of two-level atom

$4\pi j = n_u A_{ul} h\nu$ [erg cm^{-3} s^{-1}]

$$n_l q_{lu} n_e = n_u (A_{ul} + q_{ul} n_e)$$

$$\frac{n_u}{n_l} = \frac{q_{lu} n_e}{A_{ul} + q_{ul} n_e}$$

$$n_l + n_u = n_{total}$$



Critical density n_{crit}

- $A_{ul} = q_{ul} n_{crit}$, so $n_{crit} = {}^{A_{ul}}/_{q_{ul}}$

- Low density limit, $n_e \ll n_{crit}$
- $4\pi j = n_e n_l q_{ul} h\nu \propto n^2$

- High density limit, $n_e \gg n_{crit}$
- $4\pi j = n_l \frac{q_{lu}}{q_{ul}} A_{ul} h\nu \propto n$

Table 3.15

Critical densities for collisional deexcitation

Ion	Level	n_e (cm^{-3})	Ion	Level	n_e (cm^{-3})
C II	$^2P^o_{3/2}$	5.0×10^1	O III	$^1D_2$	6.8×10^5
C III	$^3P^o_2$	5.1×10^5	O III	$^3P_2$	3.6×10^3
N II	$^1D_2$	6.6×10^4	O III	$^3P_1$	5.1×10^2
N II	$^3P_2$	3.1×10^2	Ne II	$^2P^o_{1/2}$	7.1×10^5
N II	$^3P_1$	8.0×10^1	Ne III	$^1D_2$	9.5×10^6
N III	$^2P^o_{3/2}$	1.5×10^3	Ne III	$^3P_0$	3.1×10^4
N IV	$^3P^o_2$	1.1×10^6	Ne III	$^3P_1$	2.1×10^5
O II	$^2D^o_{3/2}$	1.5×10^4	Ne V	$^1D_2$	1.3×10^7
O II	$^2D^o_{5/2}$	3.4×10^3	Ne V	$^3P_2$	3.5×10^4
S II	$^2D^o_{3/2}$	5.4×10^4	Ne V	$^3P_1$	6.2×10^3
S II	$^2D^o_{5/2}$	1.6×10^4			

NOTE: All values are calculated for $T = 10{,}000$ K.

Luminosity of a line

- **Below critical density**
  - emissivity (emission per unit volume) is proportional to the electron-ion collision rate $j \propto n_{ion} n_e \propto n^2$,
  - Luminosity proportional to emission measure, $n^2 V$; AG3 eqn 5.12
- **Above critical density**
  - Atom is in LTE so emissivity is proportional to ion density n_{ion}
  - Luminosity proportional to mass, $n_{ion} V$

Rutten text

- Radiative Transfer in Stellar Atmospheres
- Rutten, R. J.
- http://adsabs.harvard.edu/abs/2003rtsa.book.....R
-

Vary density over extreme range

- Plot emissivity vs density over wide range to see how emissivity changes
- Recombination line, [O III] forbidden lines
- varyn.in

Recombination lines

- $H^+ + e \rightarrow H^{0*} \rightarrow H^0$ + photons
- Critical densities of H I, He I, and He II optical lines are very high, $n > 1e15\ cm^{-3}$, so they are usually in low density limit
- Emissivity goes as n^2 for $n < 10^{20}\ cm^{-3}$
- Case B predictions

- H I, He I, He II are the strongest in UV/ Opt/ IR
- Second row (C,N, O, Ne) & Fe in X-ray

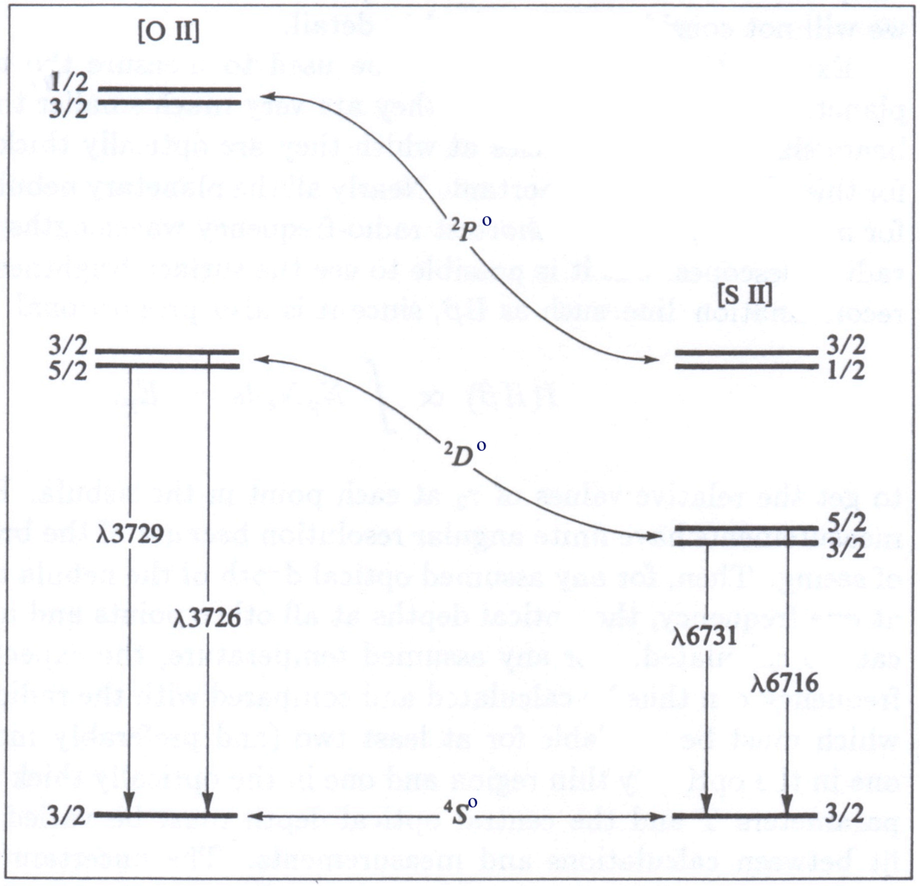
Forbidden lines

- **[O III]**
- **$O^{++} + e \rightarrow O^{++*} + e \rightarrow O^{++} + e$ + photons**
  - $n_e\, n(O^{++})\, q_{ul}$
- **Critical densities of many forbidden lines $n \sim$ 1e3 - 1e5 cm^{-3}, so they can be in low density limit or high density limit**
- **Emissivity goes as n^2 or n**

Compute spectrum of clouds with two very different densities

- **Hden = 4**
- **Hden = 14**
  - How will emissivity (emission per unit volume) from these cloud compare?
  - How can we “trick” the model into having roughly the same emission?

Density indicators



AGN3 Fig 5.7

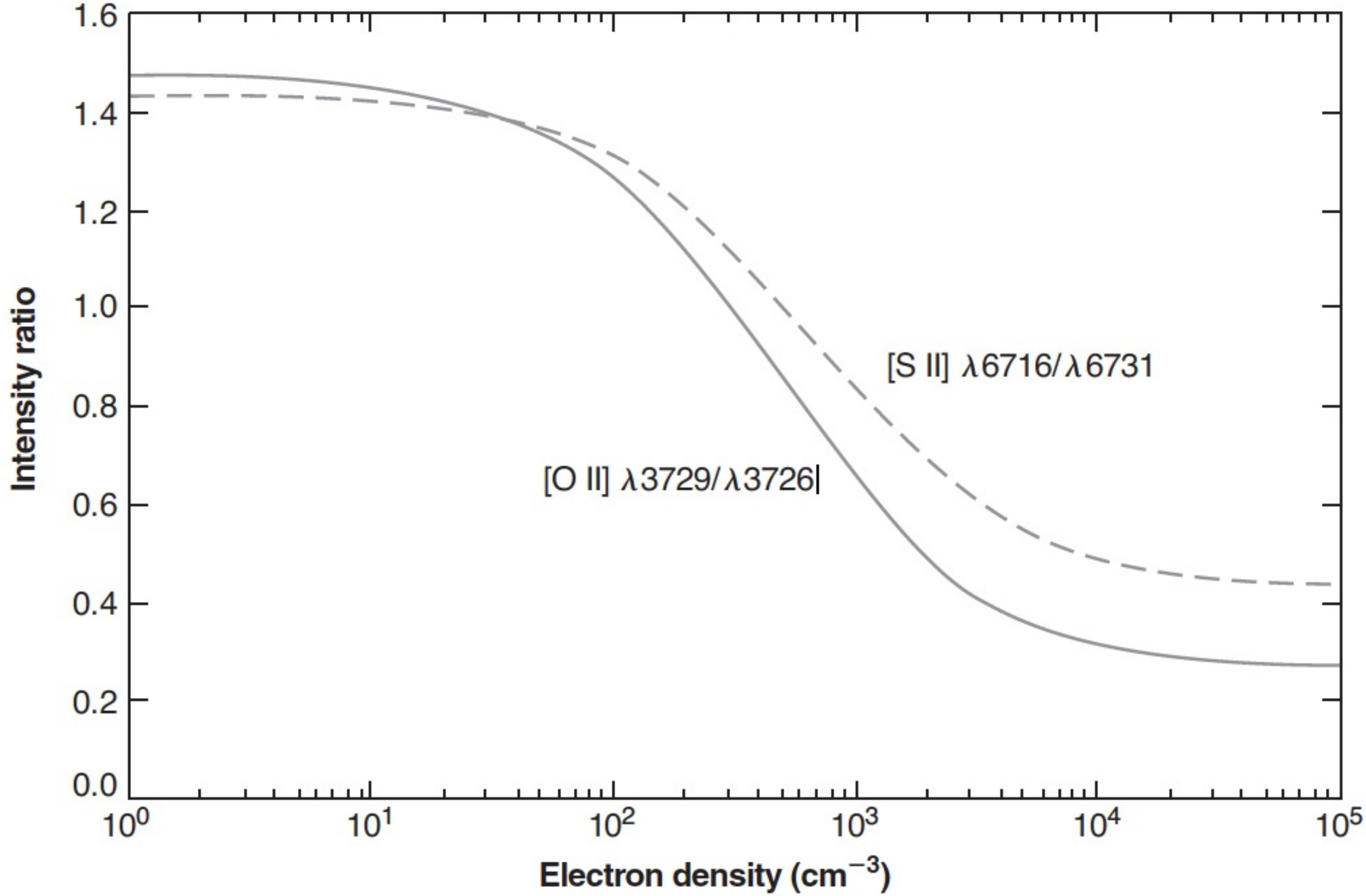


Figure 5.8

Calculated variation of [O II] (*solid line*) and [S II] (*dashed line*) intensity ratios as functions of n_e at T = 10,000 K. At other temperatures the plotted curves are very nearly correct if the horizontal scale is taken to be $n_e(10^4/T)^{1/2}$.