Finding lines in Cloudy

- ◆ **Run smoke test with command**
- ◆ **Save line labels**

- ◆ **Spectral label, wavelength, identifies a line**

- ◆ **Save file has label, wavelength, comment about line**

- ◆ **Pick lines from this save file**

Luminosity, relative intensity

- ◆ **Intensity or luminosity 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

Emissivity vs density, temperature

- ◆ **Recombination line, O III forbidden lines**

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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}

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

$$n_l q_{lu} n_e = n_u [A_{ue} + q_{ue} n_e]$$

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

$$n_u + n_l = n$$

critical density
$$A_{ue} = q_{ue} n_{crit}$$

$$n_e \ll n_{crit}$$
$$4\pi j = n_l n_e q_{lu} h\nu$$

$$n_e \gg n_{crit}$$
$$4\pi j = n_l \frac{q_{lu}}{q_{ue}} A_{ue} h\nu$$

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 LDL
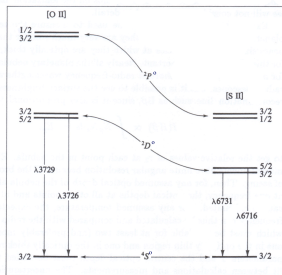- Emissivity goes as n^2

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Forbidden lines

- [O III]
- $O^{++} + e \rightarrow O^{++*} \rightarrow O^{++} + $ photons
- Critical densities of many forbidden lines $n \sim 1e3$ cm^{-3}, so they can be in LDL or HDH
- Emissivity goes as n^2 or n

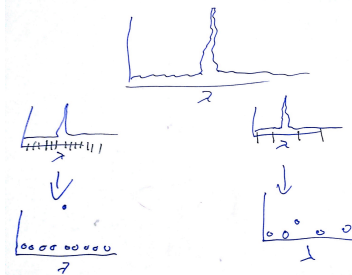2014 Cloudy workshop

Density indicators

AGN3 Fig 5.7

Inward vs total emission

- ◆ "Inwd" label for line
- ◆ Inward/outward emission computed on second and later iterations
  - – Iterate to convergence
  - – Print last
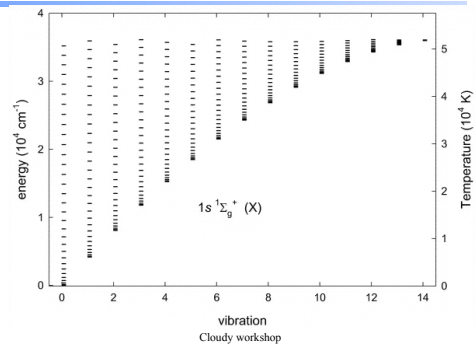
Line to continuum contrast

- ◆ Hazy 1, sec 19.14.44
  - – Line to continuum contrast in save continuum

Databases in Cloudy

- ◆ Stout (atoms & low ionization)
- ◆ Chianti (higher ionization)
- ◆ LAMDA (heavy-element molecules)

H$_2$ (Shaw+05) "species H2"

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Controlling model atoms

- ◆ **Series of SPECIES XXX commands**
- ◆ **Compare exec time species limit vs small**

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