Thoughts from yesterday

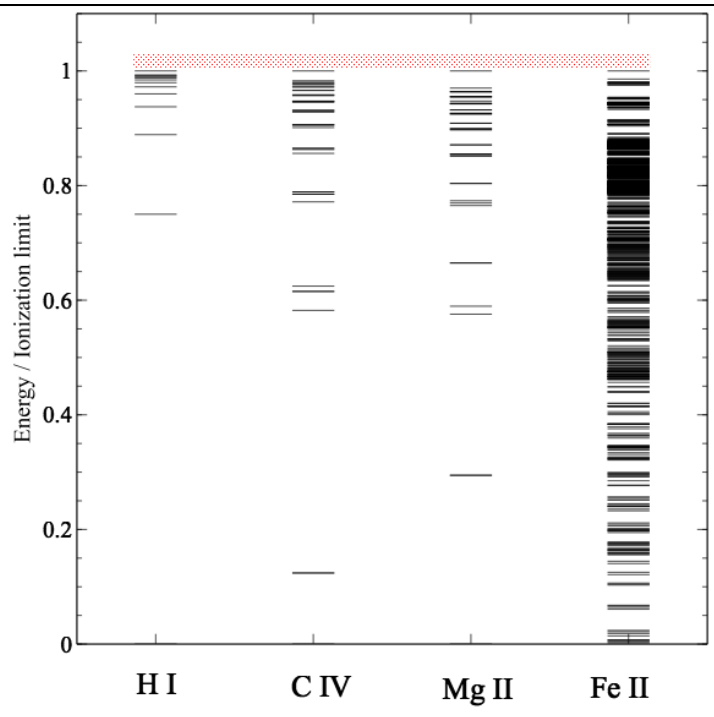
- **The CMB**
  - Radio telescopes automatically subtract off the CMB when the observation is made
  - So faint lines, much fainter than the CMB in the total Cloudy prediction, are easily observed
- **Beam switching, frequency switching**

What happened with the laser?

- **The sum of the cooling lines matches the heating**
- **So that sum can't change (energy balance)**
- **The [O III] lines are normally the strongest single coolants for an H II region, so they can't change unless the heading (set by the SED) changes**
- **The [O III] lines were not the strongest coolant's with the laser. They were with the star.**

Why use the laser at all?

- Cloudy has lots of lines and does many levels for many ions
- A single zone (which we do for speed) is optically thin
- So continuum fluorescent excitation can be important.
- But would not be with a finite column density

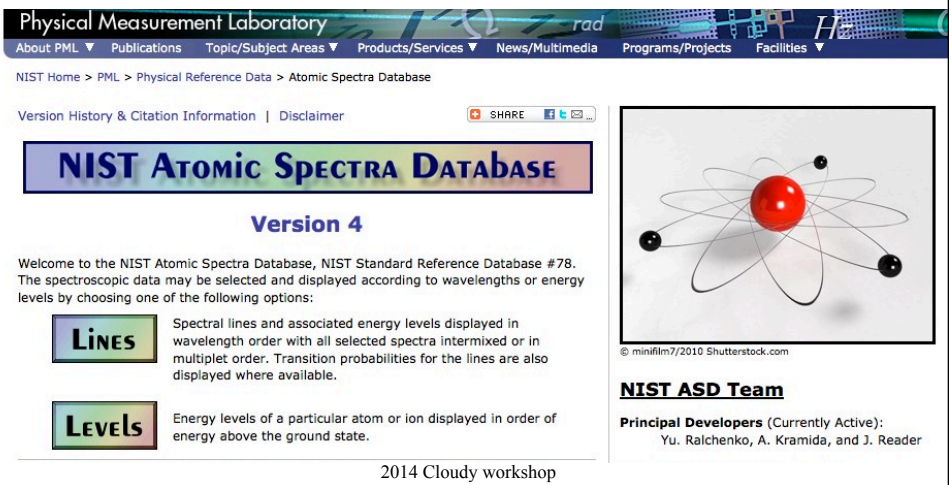


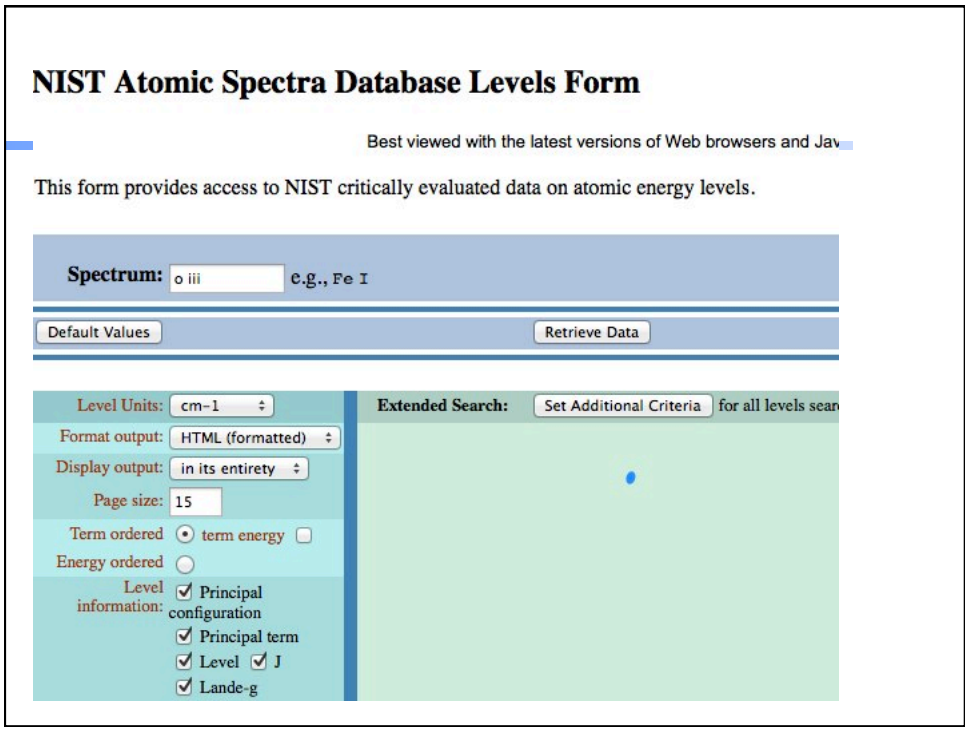
Peter's atomic line list

- http://www.pa.uky.edu/~peter/atomic/
- **Search wavelength range to find what lines are present**

NIST

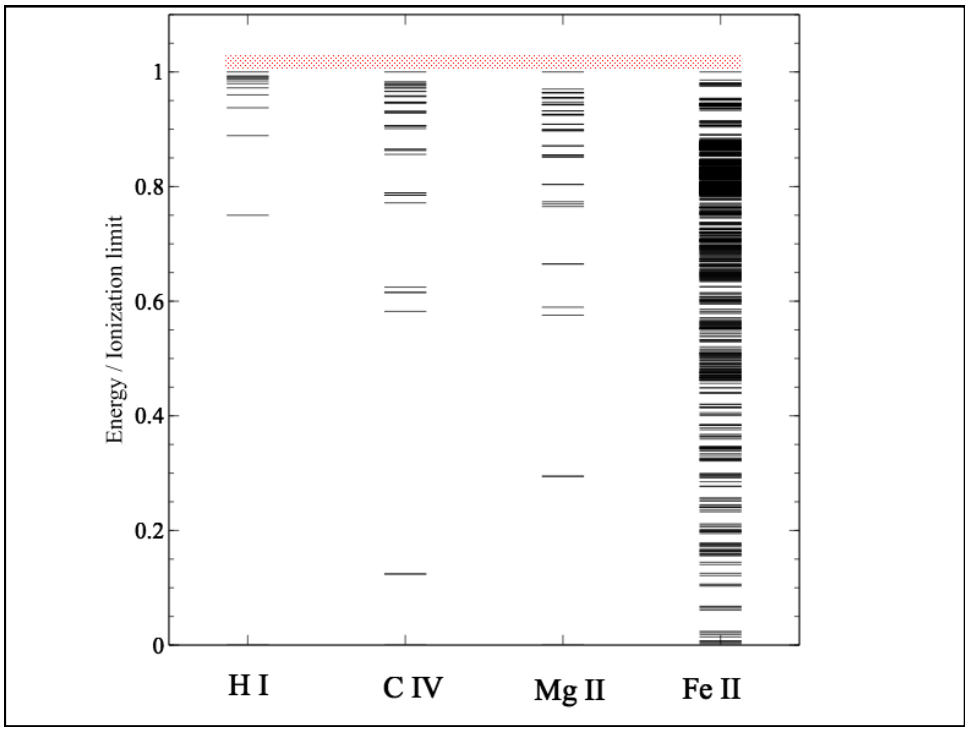
- http://www.nist.gov/pml/data/asd.cfm





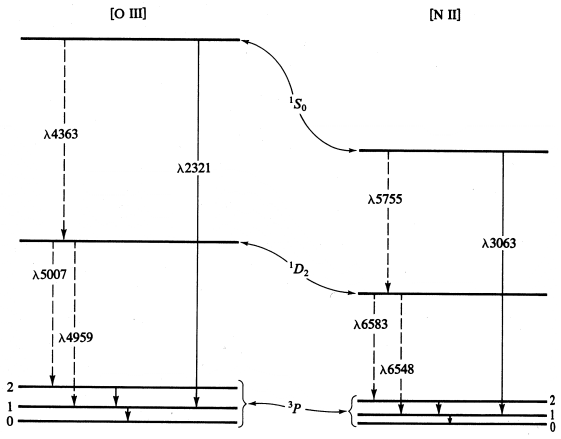
Two types of lines

- **Recombination AGN3 sec 4.2**
  - e + p radiative recombination
  - q~10^{-13} cm^3 s^{-1}
  - Mainly H, He
- **Collisionally excited AGN3 3.5**
  - Inelastic e + ion collision
  - q~10^{-9} cm^3 s^{-1}
  - Heavy elements



[O III]

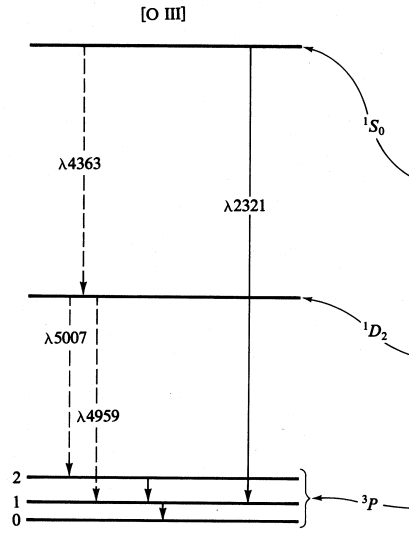
- **AGN3 Fig 3.1**



Cloudy workshop

O III

Configuration	Term	J	Level (cm^{-1})
$2s^2 2p^2$	^3P	0	0
		1	113.178
		2	306.174
$2s^2 2p^2$	^1D	2	20 273.27
$2s^2 2p^2$	^1S	0	43 185.74
$2s2p^3$	$^5S°$	2	60 324.79
$2s2p^3$	$^3D°$	3	120 025.2
		2	120 053.4
		1	120 058.2



Species vs spectra

- H^0, C^{3+}, O^{2+}, H_2, CO are baryons
- H I, C IV, O III, H_2, and CO are the spectra they emit / absorb
- O III is a permitted line produced by O^{2+}, while [O III] is forbidden

Species vs spectra

- **H I Lya *emission* can be produced by**
  - Recombination of H^+
  - Impact excitation of H^0
- **H I absorption can only be produced by H^0**
- **H I is not the same as H^0**
  - Ambiguous for emission lines

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

0	3	88.3323m	-5.577	1.5126
0	3	51.8004m	-5.106	4.4704
0	3	4931.23A	-8.339	0.0026
0	3	4958.91A	-4.876	7.5973
0	3	5006.84A	-4.401	22.6702
0	3	2320.95A	-7.193	0.0366
0	3	4363.21A	-6.593	0.1456
0	3	1660.81A	-7.187	0.0371
0	3	1666.15A	-6.720	0.1087

Emissivity vs density, temperature

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

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 $n_u A_{ul}$

Recombination lines

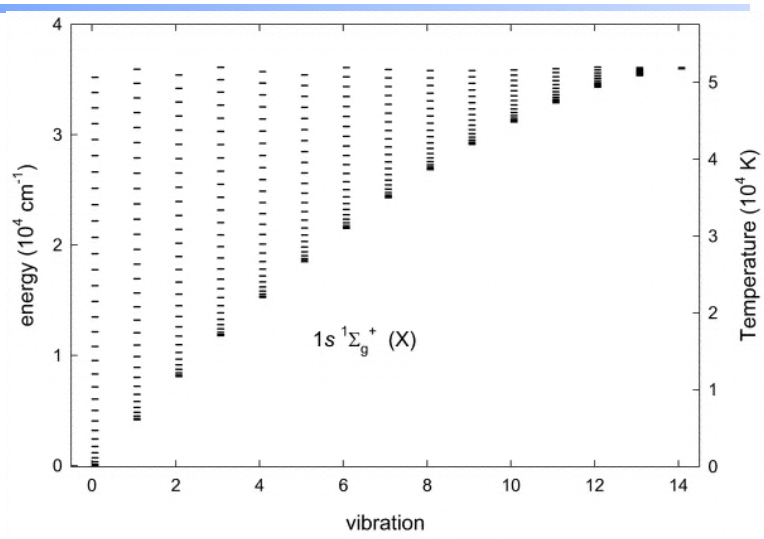
- **$H^+ + e \rightarrow H^{0*} \rightarrow H^0 +$ photons**
- **Critical densities of H I, He I, and He II optical lines are very high, n > 1e15 cm^{-3}, so they are usually in LDL**
- **Emissivity goes as n^2**

Forbidden lines

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

Inward vs total emission

H_2 (Shaw+05) "species H2"



Controlling model atoms

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