Temperature indicators

- **Lines from same species which have different excitation potentials**

[O III]

$\lambda 4363$

$\lambda 2321$

$^1S_0$

$\lambda 5007$

$^1D_2$

$\lambda 4959$

2
1
0

^3P
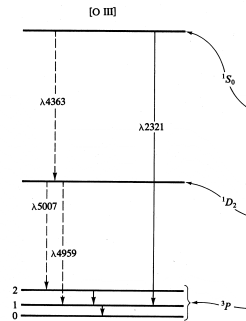
Ionization parameter indicators

- **Lines from different ionization stages of the same element**

Databases in Cloudy

- ◆ Iso sequences (H and He like)
- ◆ H_2
- ◆ Stout (atoms & low ionization)
- ◆ Chianti (higher ionization)
- ◆ LAMDA (heavy-element molecules)

- ◆ Database print command
  - Reports all databases in us
  - The number of levels used

- ◆ Species "C+2" levels 40

H_2 (Shaw+05) "species H2"

$1s\ ^1\Sigma_g^+$ (X)

energy (10^4 cm^{-1})

Temperature (10^4 K)

vibration
Cloudy workshop
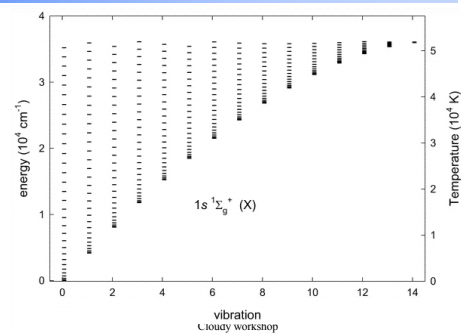
Controlling model atoms

- ◆ **Series of SPECIES XXX commands**
- ◆ **Compare exec time species limit vs small**
- ◆ **C17 review**

Converging the optical depths

- ◆ **Iterate command, hazy 10.7**
- ◆ **Iterate to convergence**
- ◆ **Hazy 10.7.3 Convergence problems**
  - Trouble if outer edge of cloud is "fuzzy"
  - For instance, by lowest temperature
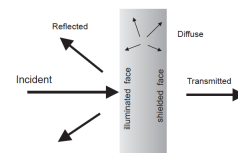 - Set outer radius or column density

Reflected

Diffuse

Incident

Transmitted

illuminated face

shielded face

Figure 2.1: Several of the radiation fields that enter in the calculations.

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 16.43.2, 19.14.44**
  - – Line to continuum contrast in save continuum
  - – Command SET SAVE LINE WIDTH
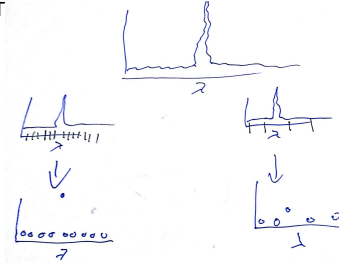
Resolution of continuum mesh

- ◆ **Default resolution set by data/continuum**
- ◆ **Will trip our checksum monitor**

The optimizer

Hazy 1 Chap 17

Downhill simplex

- ◆ **Evaluate sum of differences between predictions and observations at every set of parameter**
- ◆ **Vary the parameters to minimize this sum of errors**

$$\chi_i^2 = \left(\frac{F_i^m - F_i^0}{\min\left(F_i^m, F^0\right)\sigma} \right)^2 \qquad (17.1)$$

Specify observed quantities

- **Series of "optimize" commands**
- **Column density**
  - optimize column densities
  - hydrogen 1 < 17
  - carbon 4 17.4 error =.001
  - silicon 3 14.6 // The Si+2 column density
  - end of column densities

Luminosity or intensity of normalization line

- optimize intensity -0.3

- normalize to "O 3" 5007
- // we want a 5007 luminosity of 10ˆ34.8 erg/s
- optimize luminosity 34.8

Line spectrum

- optimize lines
- O 3 5007 intensity =13.8 error =0.1
- Blnd 3727 < 2.1 (only upper limit)
- O 3 88.33m 1.2
- O 1 145.5m 1.6
- end of lines

Temperatures

- optimize temperature
- Hydrogen 1 36200K volume
- H2 0 150K radius
- end of temperatures

Controlling the optimizer

- **Hazy 1 Sect 17.7**
  - Optimize increment = 0.4 dex
  - Optimize iteration = 1000
  - Optimize range -2.3 to 3.9
  - Optimize tolerance 0.01