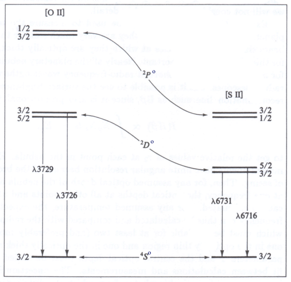
## Density indicators




AGN3 Fig 5.7

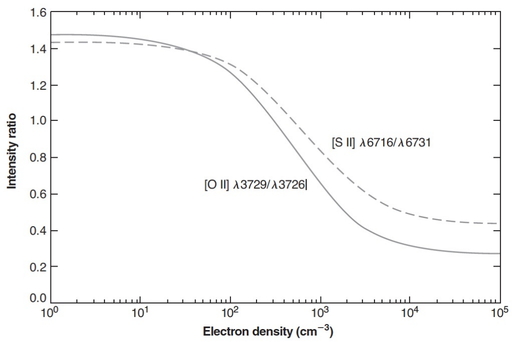
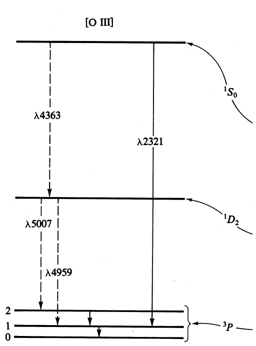



**Figure 5.8**
Calculated variation of [O II] (*solid line*) and [S II] (*dashed line*) intensity ratios as functions of $n_e$ at $T$ = 10,000 K. At other temperatures the plotted curves are very nearly correct if the horizontal scale is taken to be $n_e(10^4/T)^{1/2}$.

## Temperature indicators



## Temperature indicators

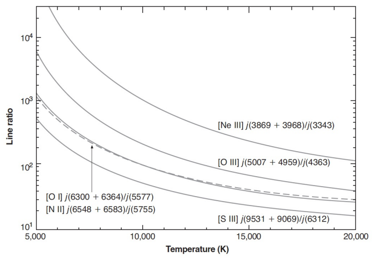
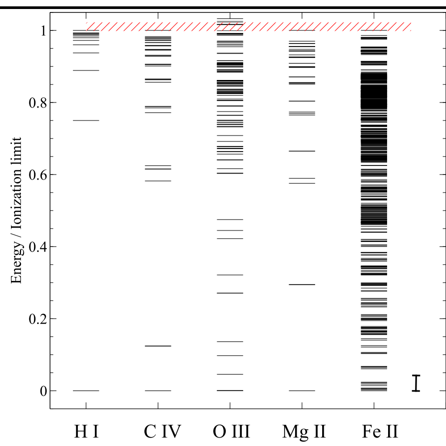



**Figure 5.1**

Four temperature sensitive forbidden line ratios are shown as a function of the electron temperature. The [O I] (solid line) and [N II] (dashed) ratios are nearly coincident, partially because of their similar excitation potentials. The ratios are shown in the low density limit ($n_e = 1\ \mathrm{cm}^{-3}$).

## Why we used the laser

- Cloudy is a complete simulation with many physical process
- A single zone (we do for speed) is optically thin
- So continuum fluorescent excitation can be important
- But would not happen with a finite column density
- The laser avoids pumping EUV lines



## The ionization parameter

The narrow emission-line spectra of BLRGs, Seyfert 1, and Seyfert 1.5 galaxies are quite similar to the spectra of NLRGs and Seyfert 2s. It seems likely that the narrow-line regions (NLRs) in which the narrow lines arise in all these types of AGNs are photoionized by high-energy photons. The only known systematic difference is that on the average the ionization goes up to a high level of ionization (strong [Fe VII] and [Fe X]) in a greater proportion of the NLRs in Seyfert 1 galaxies than in Seyfert 2s. This may indicate a difference in the shape of the ionizing spectrum at high energies, or more probably, in the fluxes of ionizing photons incident on the NLR. This can be expressed in terms of the ionization parameter,

$$U = \frac{1}{4\pi r^2 c n_{\mathrm{H}}} \int_{\nu_0}^{\infty} \frac{L_\nu}{h\nu} d\nu \qquad (13.6)$$

where $L_\nu$ is the luminosity of the source per unit frequency interval, and $r$ is the distance from the source. Physically, $U$ represents the dimensionless ratio of the ionizing photon density to the electron density.

## The ionization parameter

- **U, the ratio of ionizing photon to hydrogen densities, Davidson & Netzer 1979**

### 5.8 ionization parameter $= -1.984$

The ionization parameter is the dimensionless ratio of hydrogen-ionizing photon to total-hydrogen densities. It is defined as

$$U \equiv \frac{Q(\mathrm{H})}{4\pi r_0^2 n(\mathrm{H})\, c} \equiv \frac{\Phi(\mathrm{H})}{n(\mathrm{H})\, c} \qquad (5.4)$$

(AGN3, equation 14.7, page 357). Here $r_o$ is the separation [cm] between the center of the source of ionizing radiation and the illuminated face of the cloud, $n$(H) [cm$^{-3}$] is the total[1] hydrogen density (ionized, neutral, and molecular), $c$ is the speed of light, $Q$(H) [s$^{-1}$] is the number of hydrogen-ionizing photons emitted by the central object, and $\Phi$(H) [cm$^{-2}$ s$^{-1}$] is the surface flux of ionizing photons. The number is interpreted as the log of $U$ unless the keyword **linear** appears. The ionization parameter is a useful quantity in plane-parallel, low-density, constant-density, models, because of homology relations between models with different photon and gas densities but the same ionization parameter (see Davidson, 1977).

This is an intensity command.

## varyU – vary the ionization parameter

- **Ionization parameter changes the ionization of the gas**
- **To measure it, find lines from the same element, but different ions**
- **Vary U and look at line ratios**

## U and T(star) determine ionization

- **No matter how intense the radiation field, how large the U, ions with ionization potentials higher than the highest energy in the SED cannot be produced**