# Assignment 15

## Distributed: Monday, Nov. 4 Due: Wednesday, Nov. 6

**Problem 1:**

In this problem, you will use *Cloudy* to explore line ratios as a function of metallicity, i.e., do the lines scale with metallicity as expected?

We will do this in the context of the quasar broad line region. So the setup is different from the star or planetary nebula. Find the sample input file for $Z = 2$ below:

```
set save prefix ‘‘kirk_2_"
AGN kirk
ionization parameter = -1.0
HDEN = 9.0
stop column density 23.5
metals 2.0
element scale factor helium 1.07
element scale factor nitrogen 4.0
print last
COVERING FACTOR 0.1
save last line, sort intensity, column, file=’’line’’
```

Create input files for all six of the metallicities given in the table in the notes. Don't forget to appropriately alter the helium and nitrogen metallicity.

The line file produced by each run includes entries for more than 100,000 lines. An easy way to find the line that you want is by using the unix command `grep`. For example, the command:

```
grep ‘‘He 2        1640.43A’’ kirk_2_line
```

yields

```
He 2        1640.43A        2.583e+05
```

Then you can parse the line intensity (the last number). Note that you will have to be careful with spacing and tabs, which *Cloudy* uses with abandon.

You will want to look at several line ratios from isoelectronic species: N V/C IV, N V/O VI, N IV/C III, N IV/O V. Also, look at N V/He II, C IV/He II, and O VI/He II (7 ratios altogether).

Which lines should you look at? Quasars were most prevalent in the Universe at $z \sim 2.5$. At that redshift, the rest-UV appears in the optical band, i.e., around 1000Å to 2000Å, so use lines within that bandpass. I will leave it up to you to pick the lines you use, since

you have enough knowledge at this point to be able to do that. I emphasize that you will want the brightest lines, which will therefore be collisionally-excited lines from relatively low upper levels. (I.e., there is a right answer.) Some of the lines will be doublets; add the contribution from both lines. Also, for He II, use the 1640Å line mentioned above.

Make a plot of the ratio of all the lines as a function of metallicity. Log-log is going to work best for you. Discuss the results. Do they match expectations?