Modelling Gaseous Nebulae using Cloudy

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CLODY INSTALLATION

Useful links:

- https://gitlab.nublado.org/cloudy/cloudy/-/wikis/DownloadLinks
- https://data.nublado.org/workshop/18Thailand/docs/Cloudy_docs/QuickStart.pdf
- https://www.youtube.com/watch?v=emg4LoynLRE

To download the software and related files, In terminal
`wget https://data.nublado.org/cloudy_releases/c22/c22.01.tar.gz`

Unzip the file and change directory to "...path/ c22.01/source"
>make

cloudyconfig.h file is created

>./cloudy.exe (press enter)
test (press enter)
(press enter)

If this executes correctly, then the software works.

To use cloudy from any folder the flowing steps are followed.
In a working directory of choice, open terminal:
>gedit cloudy
add this line **/home/sagarika/belgrade/agn/c22.01/source/cloudy.exe -p $1** and save.
In terminal:
>chmod +x cloudy
then go to the bashrc file
>gedit ~/.bashrc
add the following line
export PATH=/home/sagarika/belgrade/agn/cloudy:$PATH
save and exit
open new terminal
>**echo $PATH**
/home/sagarika/belgrade/agn/cloudy:/home/sagarika/anaconda3/condabin:/home/sagarika/.local/bin:/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/usr/games:/usr/local/games:/snap/bin

THEORY

We attempt to model a Planetary Nebulae and BLR Cloud using Cloudy.
Initially we need to specify a few parameters

- Shape and Luminosity of the radiation field hitting the cloud
- Density of the cloud
- Radius of the cloud
- Composition of the cloud (whether solar or not)

Gas-phase abundances are close to solar values unless mentioned otherwise. If solar abundances are used, grains are not included in the simulation. By default the hydrogen density will be kept constant across the cloud.

SIMULATION 1

CREATING THE INPUT FILE

In the working directory, in terminal

>gedit script.in // Creating the input file

In this text file write the following:

blackbody 1.2e5 K   // The shape of the continuum and temperature in Kelvin
luminosity 38   **//** Luminosity in log(ergs/s)
radius 18   **//** Inner radius for shell of Pne in log(cm)
hden 5   **//** Hydrogen density in log(cm^{-3})
sphere
#abundance planetary nebula
iterate
print last iteration
save overview ".ovr"
save continuum ".con" units microns last

save and exit

Here we give input for spectral energy distribution of a black body. We can give either luminosity or intensity. If we specify luminosity, we must specify inner radius of the cloud. From observation we know that gas usually always covers a star fully and so we include sphere in the geometry of the code.
For the purpose of comparison this simulation has been run considering two cases. One with solar abundances and one with planetary nebula abundances.

We can also set outer radius but since that has not been set here, calculations will continue till the kinetic temperature of the gas has fallen to the lowest default, i.e., 4000 K. Other stopping criterions also could have been used.

OUTPUT

In terminal

>**cloudy script**

It will create the ".ovr" and ".con" files

The ".ovr" file helps in creating plots for visualizing data, showing the temperature and ionization structure of the ionization cloud.
The ".con" file shows the incident and total continuum.
We insert the keywork **units microns last** to express wavelengths in microns otherwise it will be expressed in terms of photon energy in Rydbergs.

PLOTTING IN GNUPLOT

```
gnuplot> set xrange [1e-1:1e3]
gnuplot> set log x
gnuplot> set log y
gnuplot> set xlabel 'Wavelength'
gnuplot> set ylabel 'Flux'
gnuplot> plot\
>'test1.con' u 1:7 t 'Solar Abundances' with lines,\
>'test11.con' u 1:7 t 'PNe Abundances' with lines
gnuplot>
```

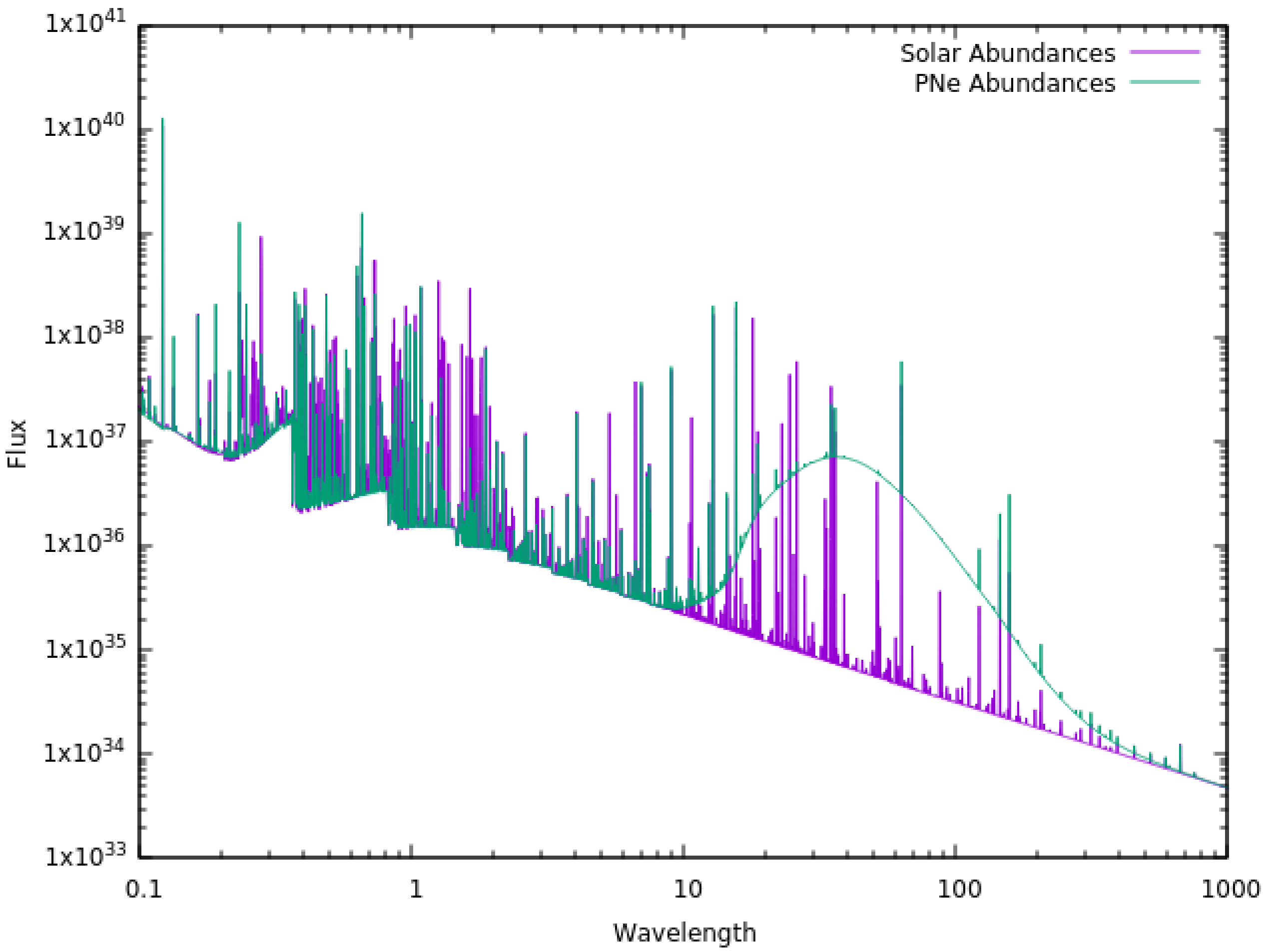


Fig 1: The above graph shows the variation of flux(ergs cm^{-2} s^{-1}) with wavelength(microns) for solar abundances and Planetary Nebula abundances. Both axes are in log scale.

We see the spectrum from Near UltrViolet to Far InfraRed part of the EM spectrum. The bump around 30 micrometers when PNe abundances are considered is due to thermal dust emission. The heating of dust from the central source as well as dust grain interaction can cause this feature. This feature is not seeing while using solar abundances because, when using solar abundances, dust grains are not considered for the simulation. The features seen below 1 micron are due to the recombination continuum. We also see a lot of emission lines and they can be due to recombination and collisional excitation.

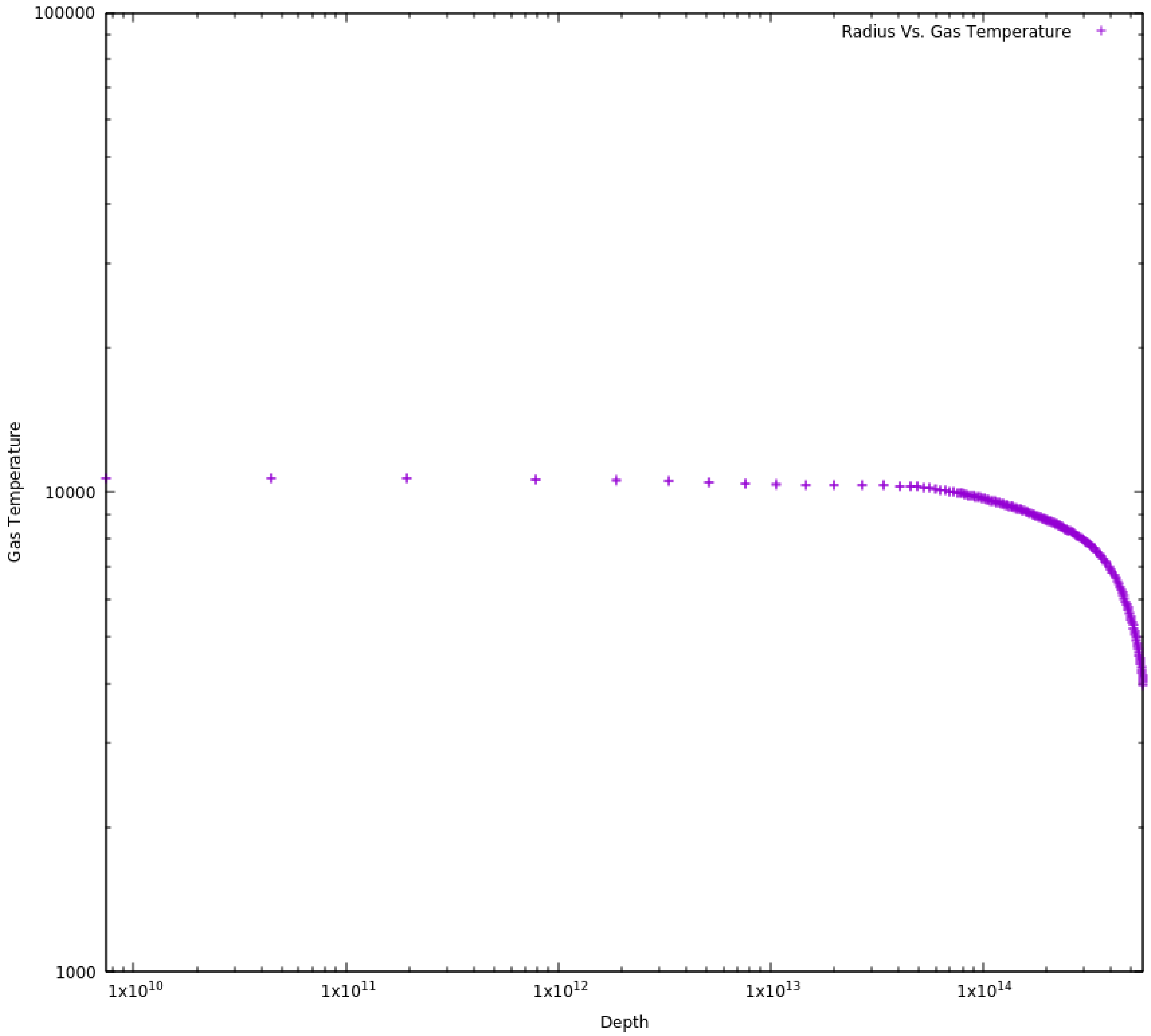


Fig 2: Shows the variation of gas temperature (K) with distance from the center of the cloud (units of cm). Both axes are in log scale.

The plot of distance from the central source vs the temperature is shown in Fig2 . A very simple understanding would be that as the distance from the central source increases, the radiation falling on successive layers of gas cloud decreases and temperature decreases. This is a very crude model of understanding because there might be a lot of other factors affecting the gas temperature. But it is seen that for the simulation we have created here, the temperature falls, first gradually and then rapidly.

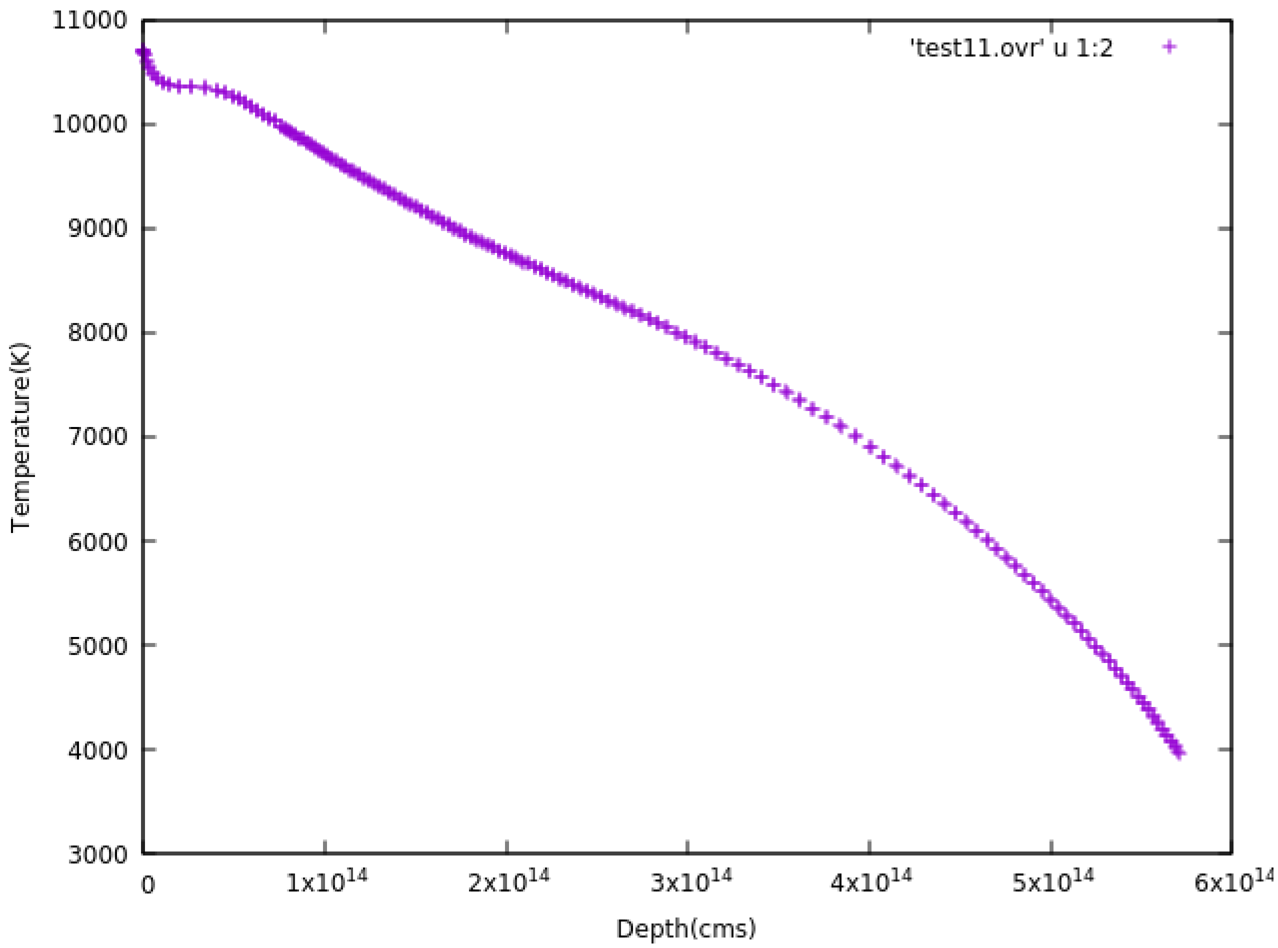
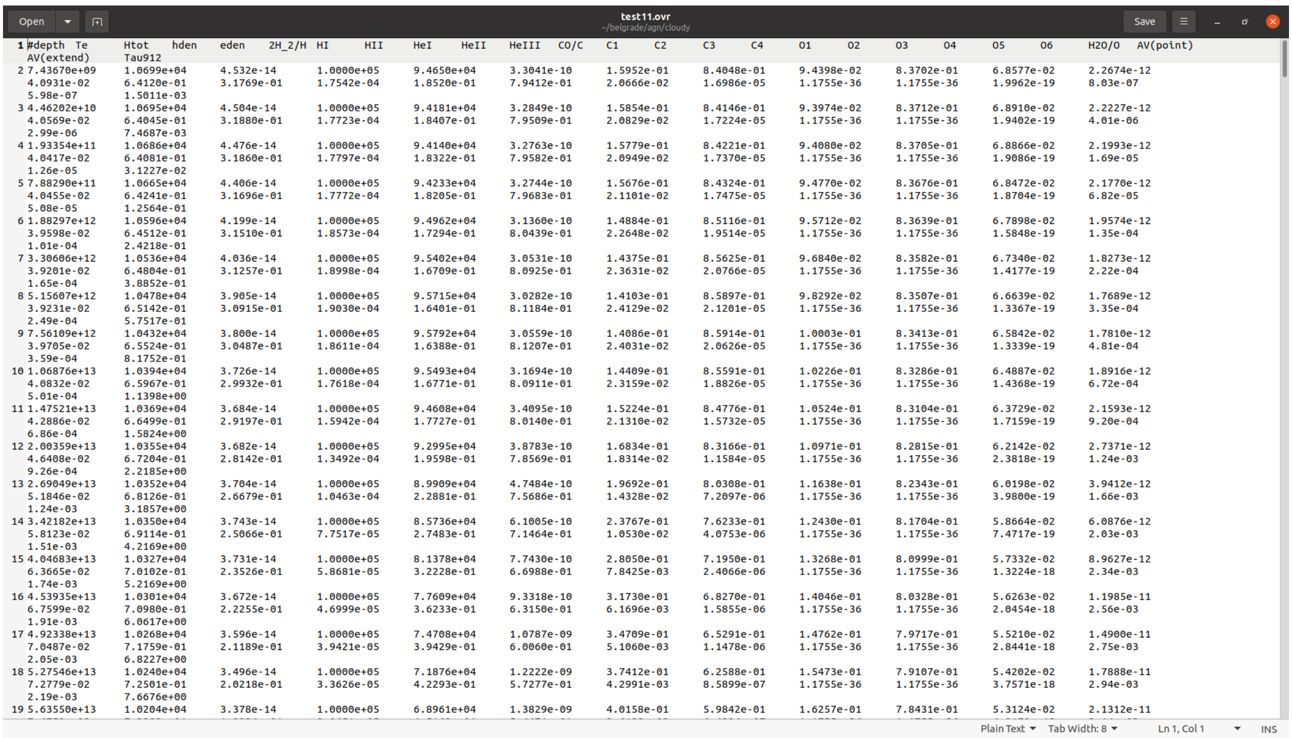


Fig 3: Shows the variation of gas temperature (K) with distance from the center of the cloud (units of cm). These are neither log values nor has log scales been used here.



Open

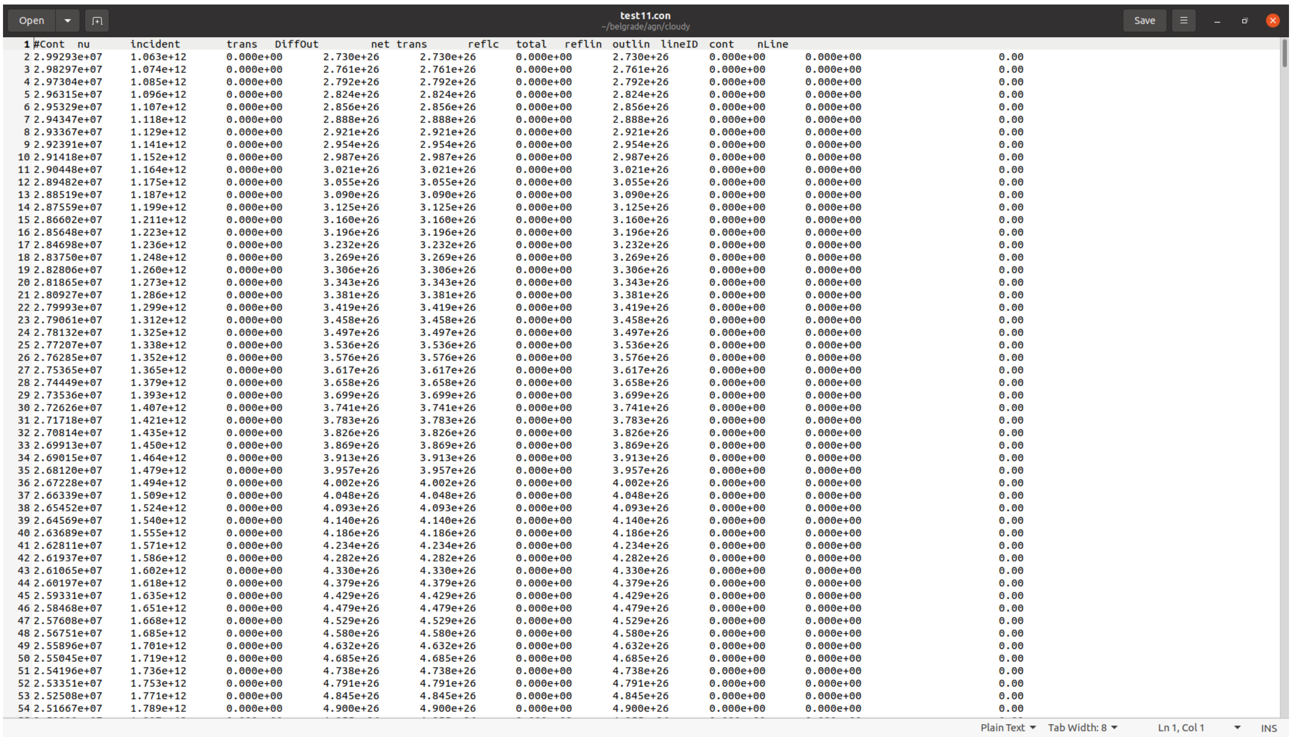
test11.ovr
~/belgrade/agn/cloudy

Save

```
 1 #depth  Te        Htot     hden      eden     2H_2/H  HI        HII       HeI       HeII      HeIII     CO/C      C1        C2        C3        C4        O1        O2        O3        O4        O5        O6        H2O/O     AV(point)
   AV(extend)        Tau912
 2 7.43670e+09       1.0699e+04         4.532e-14          1.0000e+05          9.4650e+04          3.3041e-10          1.5952e-01          8.4048e-01          9.4398e-02          8.3702e-01          6.8577e-02          2.2674e-12
   4.0931e-02        6.4120e-01         3.1769e-01          1.7542e-04          1.8520e-01          7.9412e-01          2.0666e-02          1.6986e-05          1.1755e-36          1.1755e-36          1.9962e-19          8.03e-07
   5.98e-07          1.5011e-03
 3 4.46202e+10       1.0695e+04         4.504e-14          1.0000e+05          9.4181e+04          3.2849e-10          1.5854e-01          8.4146e-01          9.3974e-02          8.3712e-01          6.8910e-02          2.2227e-12
   4.0569e-02        6.4045e-01         3.1880e-01          1.7723e-04          1.8407e-01          7.9509e-01          2.0829e-02          1.7224e-05          1.1755e-36          1.1755e-36          1.9402e-19          4.01e-06
   2.99e-06          7.4687e-03
 4 1.93354e+11       1.0686e+04         4.476e-14          1.0000e+05          9.4140e+04          3.2763e-10          1.5779e-01          8.4221e-01          9.4080e-02          8.3705e-01          6.8866e-02          2.1993e-12
   4.0417e-02        6.4081e-01         3.1860e-01          1.7797e-04          1.8322e-01          7.9582e-01          2.0949e-02          1.7370e-05          1.1755e-36          1.1755e-36          1.9086e-19          1.69e-05
   1.26e-05          3.1227e-02
 5 7.88290e+11       1.0665e+04         4.406e-14          1.0000e+05          9.4233e+04          3.2744e-10          1.5676e-01          8.4324e-01          9.4770e-02          8.3676e-01          6.8472e-02          2.1770e-12
   4.0455e-02        6.4241e-01         3.1696e-01          1.7772e-04          1.8205e-01          7.9683e-01          2.1101e-02          1.7475e-05          1.1755e-36          1.1755e-36          1.8704e-19          6.82e-05
   5.08e-05          1.2564e-01
 6 1.88297e+12       1.0596e+04         4.199e-14          1.0000e+05          9.4962e+04          3.1360e-10          1.4884e-01          8.5116e-01          9.5712e-02          8.3639e-01          6.7898e-02          1.9574e-12
   3.9598e-02        6.4512e-01         3.1510e-01          1.8573e-04          1.7294e-01          8.0439e-01          2.2648e-02          1.9514e-05          1.1755e-36          1.1755e-36          1.5848e-19          1.35e-04
   1.01e-04          2.4218e-01
 7 3.30606e+12       1.0536e+04         4.036e-14          1.0000e+05          9.5402e+04          3.0531e-10          1.4375e-01          8.5625e-01          9.6840e-02          8.3582e-01          6.7340e-02          1.8273e-12
   3.9201e-02        6.4804e-01         3.1257e-01          1.8998e-04          1.6709e-01          8.0925e-01          2.3631e-02          2.0766e-05          1.1755e-36          1.1755e-36          1.4177e-19          2.22e-04
   1.65e-04          3.8852e-01
 8 5.15607e+12       1.0478e+04         3.905e-14          1.0000e+05          9.5715e+04          3.0282e-10          1.4103e-01          8.5897e-01          9.8292e-02          8.3507e-01          6.6639e-02          1.7689e-12
   3.9231e-02        6.5142e-01         3.0915e-01          1.9030e-04          1.6401e-01          8.1184e-01          2.4129e-02          2.1201e-05          1.1755e-36          1.1755e-36          1.3367e-19          3.35e-04
   2.49e-04          5.7517e-01
 9 7.56109e+12       1.0432e+04         3.800e-14          1.0000e+05          9.5792e+04          3.0559e-10          1.4086e-01          8.5914e-01          1.0003e-01          8.3413e-01          6.5842e-02          1.7810e-12
   3.9705e-02        6.5524e-01         3.0487e-01          1.8611e-04          1.6388e-01          8.1207e-01          2.4031e-02          2.0626e-05          1.1755e-36          1.1755e-36          1.3339e-19          4.81e-04
   3.59e-04          8.1752e-01
10 1.06876e+13       1.0394e+04         3.726e-14          1.0000e+05          9.5493e+04          3.1694e-10          1.4409e-01          8.5591e-01          1.0226e-01          8.3286e-01          6.4887e-02          1.8916e-12
   4.0832e-02        6.5967e-01         2.9932e-01          1.7618e-04          1.6771e-01          8.0911e-01          2.3159e-02          1.8826e-05          1.1755e-36          1.1755e-36          1.4368e-19          6.72e-04
   5.01e-04          1.1398e+00
11 1.47521e+13       1.0369e+04         3.684e-14          1.0000e+05          9.4608e+04          3.4095e-10          1.5224e-01          8.4776e-01          1.0524e-01          8.3104e-01          6.3729e-02          2.1593e-12
   4.2886e-02        6.6499e-01         2.9197e-01          1.5942e-04          1.7727e-01          8.0140e-01          2.1310e-02          1.5732e-05          1.1755e-36          1.1755e-36          1.7159e-19          9.20e-04
   6.86e-04          1.5824e+00
12 2.00359e+13       1.0355e+04         3.682e-14          1.0000e+05          9.2995e+04          3.8783e-10          1.6834e-01          8.3166e-01          1.0971e-01          8.2815e-01          6.2142e-02          2.7371e-12
   4.6408e-02        6.7204e-01         2.8142e-01          1.3492e-04          1.9598e-01          7.8569e-01          1.8314e-02          1.1584e-05          1.1755e-36          1.1755e-36          2.3818e-19          1.24e-03
   9.26e-04          2.2185e+00
13 2.69049e+13       1.0352e+04         3.704e-14          1.0000e+05          8.9909e+04          4.7484e-10          1.9692e-01          8.0308e-01          1.1638e-01          8.2343e-01          6.0198e-02          3.9412e-12
   5.1846e-02        6.8126e-01         2.6679e-01          1.0463e-04          2.2881e-01          7.5686e-01          1.4328e-02          7.2097e-06          1.1755e-36          1.1755e-36          3.9800e-19          1.66e-03
   1.24e-03          3.1857e+00
14 3.42182e+13       1.0350e+04         3.743e-14          1.0000e+05          8.5736e+04          6.1005e-10          2.3767e-01          7.6233e-01          1.2430e-01          8.1704e-01          5.8664e-02          6.0876e-12
   5.8123e-02        6.9114e-01         2.5066e-01          7.7517e-05          2.7483e-01          7.1464e-01          1.0530e-02          4.0753e-06          1.1755e-36          1.1755e-36          7.4717e-19          2.03e-03
   1.51e-03          4.2169e+00
15 4.04683e+13       1.0327e+04         3.731e-14          1.0000e+05          8.1378e+04          7.7430e-10          2.8050e-01          7.1950e-01          1.3268e-01          8.0999e-01          5.7332e-02          8.9627e-12
   6.3665e-02        7.0102e-01         2.3526e-01          5.8681e-05          3.2228e-01          6.6988e-01          7.8425e-03          2.4066e-06          1.1755e-36          1.1755e-36          1.3224e-18          2.34e-03
   1.74e-03          5.2169e+00
16 4.53935e+13       1.0301e+04         3.672e-14          1.0000e+05          7.7609e+04          9.3318e-10          3.1730e-01          6.8270e-01          1.4046e-01          8.0328e-01          5.6263e-02          1.1985e-11
   6.7599e-02        7.0980e-01         2.2255e-01          4.6999e-05          3.6233e-01          6.3150e-01          6.1696e-03          1.5855e-06          1.1755e-36          1.1755e-36          2.0454e-18          2.56e-03
   1.91e-03          6.0617e+00
17 4.92338e+13       1.0268e+04         3.596e-14          1.0000e+05          7.4708e+04          1.0787e-09          3.4709e-01          6.5291e-01          1.4762e-01          7.9717e-01          5.5210e-02          1.4900e-11
   7.0487e-02        7.1759e-01         2.1189e-01          3.9421e-05          3.9429e-01          6.0060e-01          5.1060e-03          1.1478e-06          1.1755e-36          1.1755e-36          2.8441e-18          2.75e-03
   2.05e-03          6.8227e+00
18 5.27546e+13       1.0240e+04         3.496e-14          1.0000e+05          7.1876e+04          1.2222e-09          3.7412e-01          6.2588e-01          1.5473e-01          7.9107e-01          5.4202e-02          1.7888e-11
   7.2779e-02        7.2501e-01         2.0218e-01          3.3626e-05          4.2293e-01          5.7277e-01          4.2991e-03          8.5899e-07          1.1755e-36          1.1755e-36          3.7571e-18          2.94e-03
   2.19e-03          7.6676e+00
19 5.63550e+13       1.0204e+04         3.378e-14          1.0000e+05          6.8961e+04          1.3829e-09          4.0158e-01          5.9842e-01          1.6257e-01          7.8431e-01          5.3124e-02          2.1312e-11
```

Plain Text   Tab Width: 8   Ln 1, Col 1   INS

Fig 4: “.ovr” output file structure.



1	#Cont nu	incident	trans	DiffOut	net trans	reflc	total	reflin	outlin	lineID	cont	nLine
2	2.99293e+07	1.063e+12	0.000e+00	2.730e+26	2.730e+26	0.000e+00	2.730e+26	0.000e+00	0.000e+00			0.00
3	2.98297e+07	1.074e+12	0.000e+00	2.761e+26	2.761e+26	0.000e+00	2.761e+26	0.000e+00	0.000e+00			0.00
4	2.97304e+07	1.085e+12	0.000e+00	2.792e+26	2.792e+26	0.000e+00	2.792e+26	0.000e+00	0.000e+00			0.00
5	2.96315e+07	1.096e+12	0.000e+00	2.824e+26	2.824e+26	0.000e+00	2.824e+26	0.000e+00	0.000e+00			0.00
6	2.95329e+07	1.107e+12	0.000e+00	2.856e+26	2.856e+26	0.000e+00	2.856e+26	0.000e+00	0.000e+00			0.00
7	2.94347e+07	1.118e+12	0.000e+00	2.888e+26	2.888e+26	0.000e+00	2.888e+26	0.000e+00	0.000e+00			0.00
8	2.93367e+07	1.129e+12	0.000e+00	2.921e+26	2.921e+26	0.000e+00	2.921e+26	0.000e+00	0.000e+00			0.00
9	2.92391e+07	1.141e+12	0.000e+00	2.954e+26	2.954e+26	0.000e+00	2.954e+26	0.000e+00	0.000e+00			0.00
10	2.91418e+07	1.152e+12	0.000e+00	2.987e+26	2.987e+26	0.000e+00	2.987e+26	0.000e+00	0.000e+00			0.00
11	2.90448e+07	1.164e+12	0.000e+00	3.021e+26	3.021e+26	0.000e+00	3.021e+26	0.000e+00	0.000e+00			0.00
12	2.89482e+07	1.175e+12	0.000e+00	3.055e+26	3.055e+26	0.000e+00	3.055e+26	0.000e+00	0.000e+00			0.00
13	2.88519e+07	1.187e+12	0.000e+00	3.090e+26	3.090e+26	0.000e+00	3.090e+26	0.000e+00	0.000e+00			0.00
14	2.87559e+07	1.199e+12	0.000e+00	3.125e+26	3.125e+26	0.000e+00	3.125e+26	0.000e+00	0.000e+00			0.00
15	2.86602e+07	1.211e+12	0.000e+00	3.160e+26	3.160e+26	0.000e+00	3.160e+26	0.000e+00	0.000e+00			0.00
16	2.85648e+07	1.223e+12	0.000e+00	3.196e+26	3.196e+26	0.000e+00	3.196e+26	0.000e+00	0.000e+00			0.00
17	2.84698e+07	1.236e+12	0.000e+00	3.232e+26	3.232e+26	0.000e+00	3.232e+26	0.000e+00	0.000e+00			0.00
18	2.83750e+07	1.248e+12	0.000e+00	3.269e+26	3.269e+26	0.000e+00	3.269e+26	0.000e+00	0.000e+00			0.00
19	2.82806e+07	1.260e+12	0.000e+00	3.306e+26	3.306e+26	0.000e+00	3.306e+26	0.000e+00	0.000e+00			0.00
20	2.81865e+07	1.273e+12	0.000e+00	3.343e+26	3.343e+26	0.000e+00	3.343e+26	0.000e+00	0.000e+00			0.00
21	2.80927e+07	1.286e+12	0.000e+00	3.381e+26	3.381e+26	0.000e+00	3.381e+26	0.000e+00	0.000e+00			0.00
22	2.79993e+07	1.299e+12	0.000e+00	3.419e+26	3.419e+26	0.000e+00	3.419e+26	0.000e+00	0.000e+00			0.00
23	2.79061e+07	1.312e+12	0.000e+00	3.458e+26	3.458e+26	0.000e+00	3.458e+26	0.000e+00	0.000e+00			0.00
24	2.78132e+07	1.325e+12	0.000e+00	3.497e+26	3.497e+26	0.000e+00	3.497e+26	0.000e+00	0.000e+00			0.00
25	2.77207e+07	1.338e+12	0.000e+00	3.536e+26	3.536e+26	0.000e+00	3.536e+26	0.000e+00	0.000e+00			0.00
26	2.76285e+07	1.352e+12	0.000e+00	3.576e+26	3.576e+26	0.000e+00	3.576e+26	0.000e+00	0.000e+00			0.00
27	2.75365e+07	1.365e+12	0.000e+00	3.617e+26	3.617e+26	0.000e+00	3.617e+26	0.000e+00	0.000e+00			0.00
28	2.74449e+07	1.379e+12	0.000e+00	3.658e+26	3.658e+26	0.000e+00	3.658e+26	0.000e+00	0.000e+00			0.00
29	2.73536e+07	1.393e+12	0.000e+00	3.699e+26	3.699e+26	0.000e+00	3.699e+26	0.000e+00	0.000e+00			0.00
30	2.72626e+07	1.407e+12	0.000e+00	3.741e+26	3.741e+26	0.000e+00	3.741e+26	0.000e+00	0.000e+00			0.00
31	2.71718e+07	1.421e+12	0.000e+00	3.783e+26	3.783e+26	0.000e+00	3.783e+26	0.000e+00	0.000e+00			0.00
32	2.70814e+07	1.435e+12	0.000e+00	3.826e+26	3.826e+26	0.000e+00	3.826e+26	0.000e+00	0.000e+00			0.00
33	2.69913e+07	1.450e+12	0.000e+00	3.869e+26	3.869e+26	0.000e+00	3.869e+26	0.000e+00	0.000e+00			0.00
34	2.69015e+07	1.464e+12	0.000e+00	3.913e+26	3.913e+26	0.000e+00	3.913e+26	0.000e+00	0.000e+00			0.00
35	2.68120e+07	1.479e+12	0.000e+00	3.957e+26	3.957e+26	0.000e+00	3.957e+26	0.000e+00	0.000e+00			0.00
36	2.67228e+07	1.494e+12	0.000e+00	4.002e+26	4.002e+26	0.000e+00	4.002e+26	0.000e+00	0.000e+00			0.00
37	2.66339e+07	1.509e+12	0.000e+00	4.048e+26	4.048e+26	0.000e+00	4.048e+26	0.000e+00	0.000e+00			0.00
38	2.65452e+07	1.524e+12	0.000e+00	4.093e+26	4.093e+26	0.000e+00	4.093e+26	0.000e+00	0.000e+00			0.00
39	2.64569e+07	1.540e+12	0.000e+00	4.140e+26	4.140e+26	0.000e+00	4.140e+26	0.000e+00	0.000e+00			0.00
40	2.63689e+07	1.555e+12	0.000e+00	4.186e+26	4.186e+26	0.000e+00	4.186e+26	0.000e+00	0.000e+00			0.00
41	2.62811e+07	1.571e+12	0.000e+00	4.234e+26	4.234e+26	0.000e+00	4.234e+26	0.000e+00	0.000e+00			0.00
42	2.61937e+07	1.586e+12	0.000e+00	4.282e+26	4.282e+26	0.000e+00	4.282e+26	0.000e+00	0.000e+00			0.00
43	2.61065e+07	1.602e+12	0.000e+00	4.330e+26	4.330e+26	0.000e+00	4.330e+26	0.000e+00	0.000e+00			0.00
44	2.60197e+07	1.618e+12	0.000e+00	4.379e+26	4.379e+26	0.000e+00	4.379e+26	0.000e+00	0.000e+00			0.00
45	2.59331e+07	1.635e+12	0.000e+00	4.429e+26	4.429e+26	0.000e+00	4.429e+26	0.000e+00	0.000e+00			0.00
46	2.58468e+07	1.651e+12	0.000e+00	4.479e+26	4.479e+26	0.000e+00	4.479e+26	0.000e+00	0.000e+00			0.00
47	2.57608e+07	1.668e+12	0.000e+00	4.529e+26	4.529e+26	0.000e+00	4.529e+26	0.000e+00	0.000e+00			0.00
48	2.56751e+07	1.685e+12	0.000e+00	4.580e+26	4.580e+26	0.000e+00	4.580e+26	0.000e+00	0.000e+00			0.00
49	2.55896e+07	1.701e+12	0.000e+00	4.632e+26	4.632e+26	0.000e+00	4.632e+26	0.000e+00	0.000e+00			0.00
50	2.55045e+07	1.719e+12	0.000e+00	4.685e+26	4.685e+26	0.000e+00	4.685e+26	0.000e+00	0.000e+00			0.00
51	2.54196e+07	1.736e+12	0.000e+00	4.738e+26	4.738e+26	0.000e+00	4.738e+26	0.000e+00	0.000e+00			0.00
52	2.53351e+07	1.753e+12	0.000e+00	4.791e+26	4.791e+26	0.000e+00	4.791e+26	0.000e+00	0.000e+00			0.00
53	2.52508e+07	1.771e+12	0.000e+00	4.845e+26	4.845e+26	0.000e+00	4.845e+26	0.000e+00	0.000e+00			0.00
54	2.51667e+07	1.789e+12	0.000e+00	4.900e+26	4.900e+26	0.000e+00	4.900e+26	0.000e+00	0.000e+00			0.00

Fig 5: “.con” output file structure.

The data structure of the overview and continuum files are show in Fig 4 and Fig 5. The first lines gives the description of the columns of the tables.

SIMULATION 2

THEORY

Here we model a cloud in a quaser broad emission line region. The shape of a quaser continuum is usually fitted with a set of power laws. Here we use the intensity of the incident radiation field given as flux of photons that are capable of ionizing hydrogen. So, here we don't need to mention the starting radius.

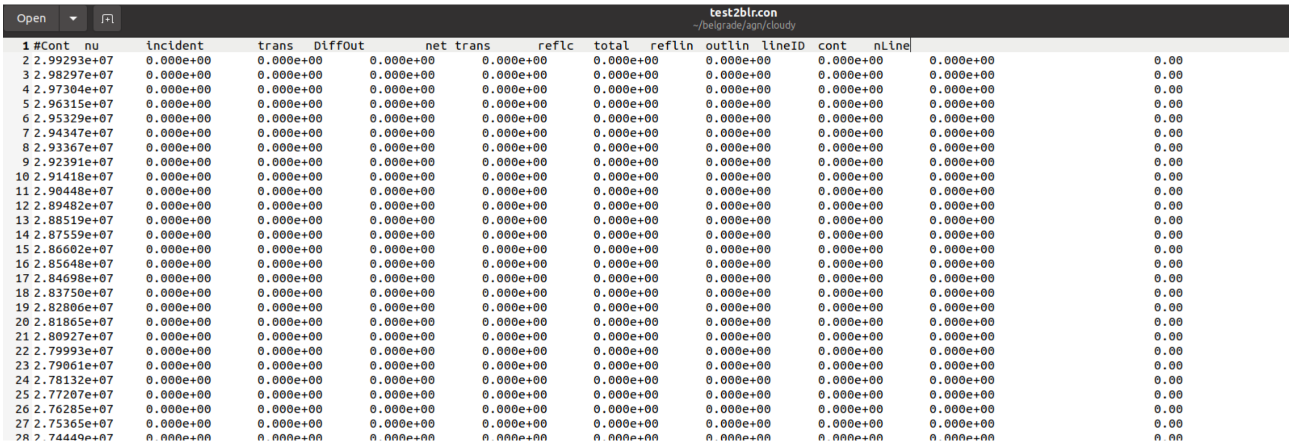
We specify the hydrogen density and stopping criteria in terms of hydrogen column density. Studies of ratio of emission lines show a density of 10^{10} cm^{-3}. We use 10^{22} cm^{-3} so that H^+-H^0 ionization fonts can be present within the cloud.

We use solar abundances here. The covering factor is very small and so the sphere command is not included here.

Line transfer effects are important in BLR. It is also necessary to iterate on the solution to converge the optical depths and we save the last iteration.

INPUT FILE

table power law // To specify a built in power-law spectrum
phi(H) 18.5 // Flux of H-ionizing photons in log(cm^{-2} s^{-1}). This is not luminosity but intensity.
hden 10 // Hydrogen density in log(cm^{-3})
stop column density 22 // Hydrogen density in log(cm^{-3})
iterate to convergence
save overview "blr.ovr" last
save continuum "blr.con" units microns last //Saves result to last iteration



#Cont nu	incident	trans	DiffOut	net trans	reflc	total	reflin	outlin	lineID	cont	nLine
2.99293e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.98297e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.97304e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.96315e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.95329e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.94347e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.93367e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.92391e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.91418e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.90448e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.89482e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.88519e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.87559e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.86602e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.85648e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.84698e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.83750e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.82806e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.81865e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.80927e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.79993e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.79061e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.78132e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.77207e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.76285e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.75365e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00
2.74449e+07	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00	0.000e+00		0.00

Fig 6.1: “.con” file for BLR simulation

Open test2blr.con ~/belgrade/agn/cloudy

4300	1.79796e+01	8.834e+06	8.751e+06	4.607e+05	9.212e+06	4.986e+05	9.710e+06	1.428e-05	1.347e-05	Ca 6		600.07
4301	1.79198e+01	8.937e+06	8.854e+06	4.636e+05	9.318e+06	5.020e+05	9.820e+06	1.745e+03	1.736e+03	Fe 2		300.03
4302	1.78602e+01	9.042e+06	8.958e+06	4.650e+05	9.423e+06	5.039e+05	9.927e+06	6.982e+00	6.931e+00	H 1	H 1	600.07
4303	1.78007e+01	9.148e+06	9.063e+06	4.672e+05	9.531e+06	5.066e+05	1.004e+07	0.000e+00	0.000e+00			0.00
4304	1.77415e+01	9.256e+06	9.170e+06	4.685e+05	9.639e+06	5.083e+05	1.015e+07	0.000e+00	0.000e+00	H2O		300.03
4305	1.76825e+01	9.364e+06	9.278e+06	4.697e+05	9.748e+06	5.101e+05	1.026e+07	0.000e+00	0.000e+00			0.00
4306	1.76236e+01	9.474e+06	9.335e+06	5.597e+05	9.895e+06	6.115e+05	1.051e+07	9.962e+04	8.878e+04	H 1		900.10
4307	1.75650e+01	9.585e+06	9.497e+06	4.722e+05	9.969e+06	5.137e+05	1.048e+07	0.000e+00	0.000e+00			0.00
4308	1.75065e+01	9.698e+06	9.598e+06	5.090e+05	1.011e+07	5.525e+05	1.066e+07	3.704e+04	3.556e+04	He 1		900.10
4309	1.74483e+01	9.812e+06	9.722e+06	4.747e+05	1.020e+07	5.173e+05	1.071e+07	1.399e-06	1.393e-06	S 1		300.03
4310	1.73902e+01	9.927e+06	9.837e+06	4.760e+05	1.031e+07	5.191e+05	1.083e+07	0.000e+00	0.000e+00			0.00
4311	1.73324e+01	1.004e+07	9.953e+06	4.772e+05	1.043e+07	5.209e+05	1.095e+07	7.205e+00	6.765e+00	Mn 5		600.07
4312	1.72747e+01	1.016e+07	1.008e+07	5.335e+05	1.061e+07	5.821e+05	1.119e+07	5.934e+04	5.501e+04	He 2		600.07
4313	1.72172e+01	1.028e+07	1.019e+07	4.798e+05	1.067e+07	5.246e+05	1.119e+07	0.000e+00	0.000e+00			0.00
4314	1.71599e+01	1.040e+07	1.031e+07	4.810e+05	1.079e+07	5.264e+05	1.132e+07	9.608e-07	9.503e-07	Ne 3		600.07
4315	1.71028e+01	1.052e+07	1.042e+07	4.823e+05	1.090e+07	5.283e+05	1.143e+07	1.243e-04	1.228e-04	P 9		600.07
4316	1.70459e+01	1.065e+07	1.055e+07	5.155e+05	1.107e+07	5.633e+05	1.163e+07	3.311e+04	3.195e+04	He 1		600.07
4317	1.69892e+01	1.077e+07	1.068e+07	4.849e+05	1.116e+07	5.320e+05	1.169e+07	0.000e+00	0.000e+00			0.00
4318	1.69327e+01	1.090e+07	1.045e+07	4.862e+05	1.094e+07	5.339e+05	1.147e+07	0.000e+00	0.000e+00			0.00
4319	1.68763e+01	1.103e+07	1.093e+07	6.653e+05	1.160e+07	8.563e+05	1.245e+07	3.205e+05	1.778e+05	H 1		3900.43
4320	1.68202e+01	1.115e+07	1.106e+07	4.887e+05	1.155e+07	5.377e+05	1.209e+07	0.000e+00	0.000e+00			0.00
4321	1.67642e+01	1.129e+07	1.119e+07	5.018e+05	1.169e+07	5.520e+05	1.224e+07	1.234e+04	1.182e+04	He 2		300.03
4322	1.67084e+01	1.142e+07	1.132e+07	4.913e+05	1.181e+07	5.416e+05	1.235e+07	2.735e+01	2.724e+01	Fe 2		600.07
4323	1.66528e+01	1.155e+07	1.145e+07	4.933e+05	1.195e+07	5.442e+05	1.249e+07	6.969e+02	6.902e+02	He 1		900.10
4324	1.65974e+01	1.169e+07	1.154e+07	5.753e+05	1.212e+07	6.344e+05	1.275e+07	8.892e+04	8.135e+04	H 1		900.10
4325	1.65422e+01	1.182e+07	1.172e+07	4.952e+05	1.222e+07	5.475e+05	1.277e+07	0.000e+00	0.000e+00			0.00
4326	1.64871e+01	1.196e+07	1.186e+07	4.965e+05	1.236e+07	5.494e+05	1.291e+07	0.000e+00	0.000e+00			0.00
4327	1.64323e+01	1.210e+07	1.184e+07	6.479e+05	1.249e+07	7.412e+05	1.323e+07	1.898e+05	1.501e+05	H 1		3600.39
4328	1.63776e+01	1.225e+07	1.214e+07	4.992e+05	1.264e+07	5.534e+05	1.320e+07	3.008e-01	2.984e-01	He 1		300.03
4329	1.63231e+01	1.239e+07	1.228e+07	5.058e+05	1.279e+07	5.609e+05	1.335e+07	5.474e+03	5.346e+03	He 2		1500.16
4330	1.62688e+01	1.254e+07	1.243e+07	5.018e+05	1.293e+07	5.574e+05	1.349e+07	4.782e-08	4.726e-08	Co 2		300.03
4331	1.62147e+01	1.268e+07	1.202e+07	7.098e+05	1.273e+07	1.106e+06	1.384e+07	5.469e+05	2.067e+05	H 1		5700.62
4332	1.61607e+01	1.283e+07	1.272e+07	5.044e+05	1.323e+07	5.615e+05	1.379e+07	1.341e-12	1.324e-12	Cl 7		600.07
4333	1.61069e+01	1.298e+07	1.287e+07	5.058e+05	1.338e+07	5.636e+05	1.394e+07	2.419e-15	1.507e-15	Na 2		300.03
4334	1.60533e+01	1.313e+07	1.302e+07	5.071e+05	1.353e+07	5.656e+05	1.410e+07	0.000e+00	0.000e+00	Na 2		0.00
4335	1.59999e+01	1.329e+07	1.318e+07	5.084e+05	1.369e+07	5.677e+05	1.425e+07	0.000e+00	0.000e+00	S 15		300.03
4336	1.59467e+01	1.344e+07	1.333e+07	5.098e+05	1.384e+07	5.698e+05	1.441e+07	2.023e-07	2.009e-07	Fe 3		300.03
4337	1.58936e+01	1.360e+07	1.349e+07	5.111e+05	1.400e+07	5.719e+05	1.457e+07	0.000e+00	0.000e+00	H2O		300.03
4338	1.58407e+01	1.376e+07	1.361e+07	5.838e+05	1.419e+07	6.507e+05	1.484e+07	7.669e+04	7.133e+04	Cl 6		600.07
4339	1.57880e+01	1.392e+07	1.381e+07	5.158e+05	1.432e+07	5.781e+05	1.490e+07	1.996e+03	1.977e+03	H 1		900.10
4340	1.57355e+01	1.409e+07	1.397e+07	5.152e+05	1.449e+07	5.782e+05	1.506e+07	0.000e+00	0.000e+00			0.00
4341	1.56831e+01	1.425e+07	1.413e+07	5.165e+05	1.465e+07	5.804e+05	1.523e+07	0.000e+00	0.000e+00	H2O		600.07

Fig 6.2: “.con” file for BLR simulation

OUTPUT FILES

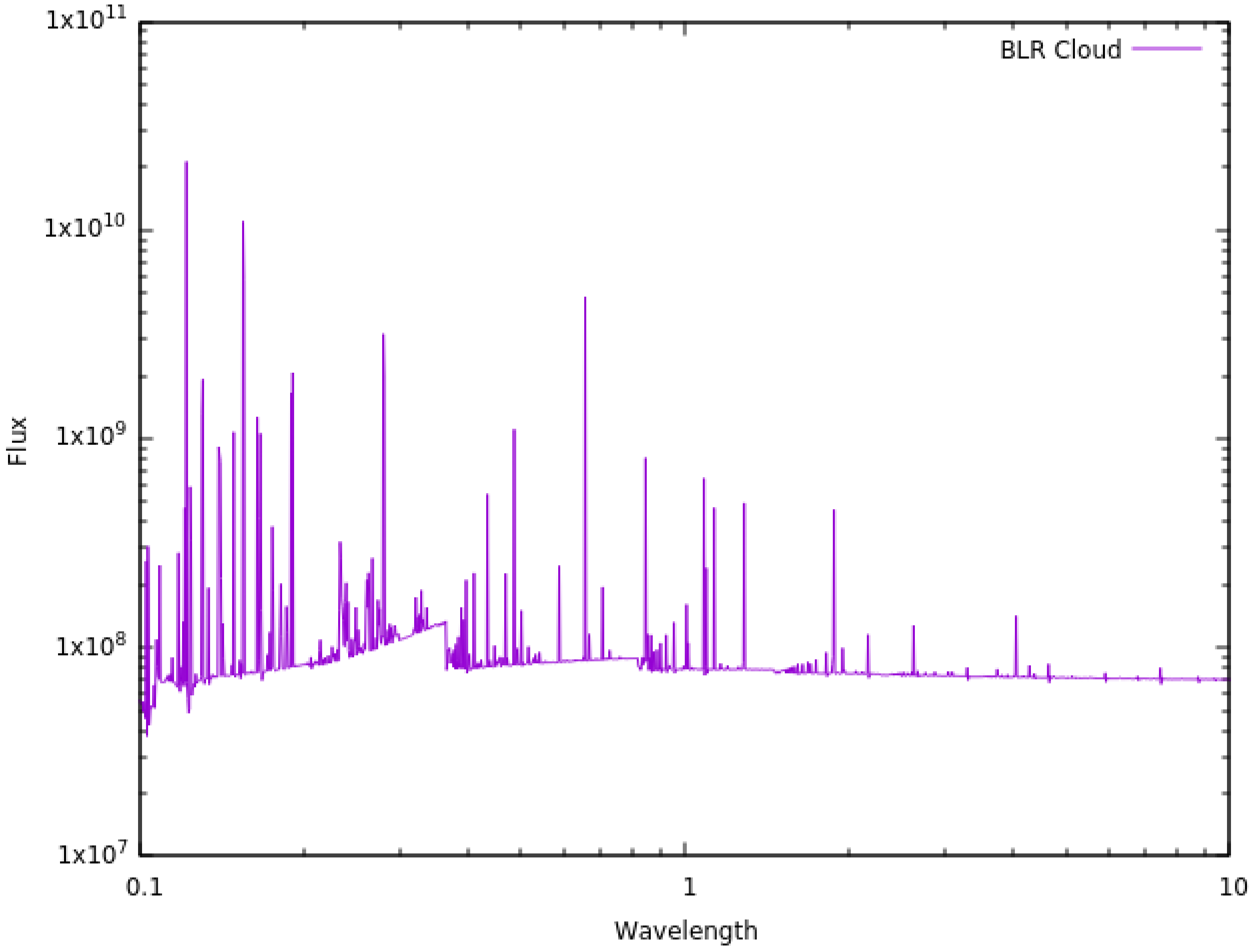


Fig 5. The above graph shows the variation of flux, νf_ν (ergs cm^{-2} s^{-1}) with wavelength(microns) for a single broad emission-line cloud in an active nucleus.

[1]There is a huge energy difference between the central ionizing source in a Pne and radiation striking BLR clouds. In PNe, the gass temperatures fall to 100 K on the neutral H^+-H^0 ionization font as little radiation can pass through it.
But in BLR cloud there is a warm partially ionized zone that extends beyond the font and is heated by X-Rays. So we need to put a stopping criteria and iterate to convergence.
This is a major difference between a cloud ionized by a central source like a star and a cloud ionized by non-thermal ionization.

We can see a lot of emission lines in the spectrum. When simulated carefully and correctly these line profiles can give us an understanding of kinematics and structure of the gas cloud.

1 test1.in is the input file for Pne sumulation using solar abundances
test11.in is the input file for Pne simutaion using planetary nebula abundances
test2.in is the input file for BLR cloud simulation