Using_pyCloudy_1

June 2, 2020

[1]:
```
%matplotlib inline
import numpy as np
import matplotlib.pyplot as plt
import os
home_dir = os.environ['HOME'] + '/'
```

[2]:
```
import pyCloudy as pc
```

[3]:
```
# Define verbosity to high level (will print errors, warnings and messages)
pc.log_.level = 3
```

[4]:
```
# The directory in which we will have the model
# You may want to change this to a different place so that the current directory
# will not receive all the Cloudy files.
dir_ = '/tmp/models/'
```

[5]:
```
# Define some parameters of the model:
model_name = 'model_1'
full_model_name = '{0}{1}'.format(dir_, model_name)
dens = 2. #log cm-3
Teff = 45000. #K
qH = 47. #s-1
r_min = 5e17 #cm
dist = 1.26 #kpc
```

[6]:
```
# these are the commands common to all the models (here only one ...)
options = ('no molecules',
           'no level2 lines',
           'no fine opacities',
           'atom h-like levels small',
           'atom he-like levels small',
           'COSMIC RAY BACKGROUND',
           'element limit off -8',
           'print line optical depth',
           )
```

[7]:
```
emis_tab_c13 = ['H  1  4861',
                'H  1  6563',
                'He 1  5876',
                'N  2  6584',
                'O  1  6300',
                'O II  3726',
                'O II  3729',
                'O  3  5007',
                'TOTL  4363',
                'S II  6716',
                'S II 6731',
                'Cl 3 5518',
                'Cl 3 5538',
                'O  1 63.17m',
                'O  1 145.5m',
                'C  2 157.6m']
```

[8]:
```
emis_tab = ['H  1  4861.33A',
            'H  1  6562.81A',
            'Ca B  5875.64A',
            'N  2  6583.45A',
            'O  1  6300.30A',
            'O  2  3726.03A',
            'O  2  3728.81A',
            'O  3  5006.84A',
            'BLND  4363.00A',
            'S  2  6716.44A',
            'S  2  6730.82A',
            'Cl 3  5517.71A',
            'Cl 3  5537.87A',
            'O  1  63.1679m',
            'O  1  145.495m',
            'C  2  157.636m']
```

[9]:
```
abund = {'He' : -0.92, 'C' : 6.85 - 12, 'N' : -4.0, 'O' : -3.40, 'Ne' : -4.00,
         'S' : -5.35, 'Ar' : -5.80, 'Fe' : -7.4, 'Cl' : -7.00}
```

[10]:
```
# Defining the object that will manage the input file for Cloudy
c_input = pc.CloudyInput(full_model_name)
```

[11]:
```
# Filling the object with the parameters
# Defining the ionizing SED: Effective temperature and luminosity.
# The lumi_unit is one of the Cloudy options, like "luminosity solar", "q(H)",␣
 ↪"ionization parameter", etc...
c_input.set_BB(Teff = Teff, lumi_unit = 'q(H)', lumi_value = qH)
```

[12]:
```
# Defining the density. You may also use set_dlaw(parameters) if you have a␣
↪density law defined in dense_fabden.cpp.
c_input.set_cste_density(dens)
```

[13]:
```
# Defining the inner radius. A second parameter would be the outer radius␣
↪(matter-bounded nebula).
c_input.set_radius(r_in=np.log10(r_min))
c_input.set_abund(ab_dict = abund, nograins = True)
c_input.set_other(options)
c_input.set_iterate() # (0) for no iteration, () for one iteration, (N) for N␣
↪iterations.
c_input.set_sphere() # () or (True) : sphere, or (False): open geometry.
c_input.set_emis_tab(emis_tab) # better use read_emis_file(file) for long list␣
↪of lines, where file is an external file.
c_input.set_distance(dist=dist, unit='kpc', linear=True) # unit can be 'kpc',␣
↪'Mpc', 'parsecs', 'cm'. If linear=False, the distance is in log.
```

[14]:
```
# Writing the Cloudy inputs. to_file for writing to a file (named by␣
↪full_model_name). verbose to print on the screen.
c_input.print_input(to_file = True, verbose = False)
```

```
    CloudyInput: Input writen in /tmp/models/model_1.in
```

[15]:
```
# Printing some message to the screen
pc.log_.message('Running {0}'.format(model_name), calling = 'test1')
```

```
    test1: Running model_1
```

[16]:
```
# Tell pyCloudy where your cloudy executable is:
pc.config.cloudy_exe = '/usr/local/Cloudy/c17.02/source/cloudy.exe'
```

```
    _Config: cloudy_exe set to /usr/local/Cloudy/c17.02/source/cloudy.exe
```

[17]:
```
# Running Cloudy with a timer. Here we reset it to 0.
pc.log_.timer('Starting Cloudy', quiet = True, calling = 'test1')
c_input.run_cloudy()
pc.log_.timer('Cloudy ended after seconds:', calling = 'test1')
```

```
    run_cloudy: running: cd /tmp/models ;
/usr/local/Cloudy/c17.02/source/cloudy.exe
    run_cloudy: ending: cd /tmp/models ;
/usr/local/Cloudy/c17.02/source/cloudy.exe
  test1: Cloudy ended after seconds: in 21.469310998916626
```

[18]:
```
# Reading the Cloudy outputs in the Mod CloudyModel object
Mod = pc.CloudyModel(full_model_name)
```

```
     CloudyModel /tmp/models/model_1: Creating CloudyModel for
/tmp/models/model_1
     CloudyModel /tmp/models/model_1: Li abundance not defined
     CloudyModel /tmp/models/model_1: Be abundance not defined
     CloudyModel /tmp/models/model_1: B abundance not defined
     CloudyModel /tmp/models/model_1: Sc abundance not defined
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.rad read
     CloudyModel /tmp/models/model_1: Number of zones: 125
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.phy read
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_H read
     CloudyModel /tmp/models/model_1: filling H with 3 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_He read
     CloudyModel /tmp/models/model_1: filling He with 3 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_C read
     CloudyModel /tmp/models/model_1: filling C with 13 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_N read
     CloudyModel /tmp/models/model_1: filling N with 8 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_O read
     CloudyModel /tmp/models/model_1: filling O with 12 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_Ne read
     CloudyModel /tmp/models/model_1: filling Ne with 11 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_Ar read
     CloudyModel /tmp/models/model_1: filling Ar with 19 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_S read
     CloudyModel /tmp/models/model_1: filling S with 17 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_Cl read
     CloudyModel /tmp/models/model_1: filling Cl with 18 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_Fe read
     CloudyModel /tmp/models/model_1: filling Fe with 27 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.ele_Si read
     CloudyModel /tmp/models/model_1: filling Si with 15 columns
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.emis read
     CloudyModel /tmp/models/model_1: Number of emissivities: 16
     CloudyModel /tmp/models/model_1: /tmp/models/model_1.cont read
```

[19]:
```
# Use TAB to know all the methods and variables for CloudyModel class
# Mod.TAB
dir(Mod) # This is the online answering way
# Description of this class is available here: http://pythonhosted.org//
 ↪pyCloudy/classpy_cloudy_1_1c1d_1_1cloudy__model_1_1_cloudy_model.html
```

[19]:
```
['C3D_comments',
 'H0_mass',
 'H_mass',
 'H_mass_cut',
 'H_mass_full',
 'Hbeta',
```

```
'Hbeta_cut',
'Hbeta_full',
'Hbeta_label',
'Hp_mass',
'Phi',
'Phi0',
'Q',
'Q0',
'T0',
'Teff',
'_CloudyModel__H_mass_cut',
'_CloudyModel__Hbeta_cut',
'_CloudyModel__r_in_cut',
'_CloudyModel__r_out_cut',
'_CloudyModel__r_range',
'__class__',
'__delattr__',
'__dict__',
'__dir__',
'__doc__',
'__eq__',
'__format__',
'__ge__',
'__getattribute__',
'__gt__',
'__hash__',
'__init__',
'__init_subclass__',
'__le__',
'__lt__',
'__module__',
'__ne__',
'__new__',
'__reduce__',
'__reduce_ex__',
'__repr__',
'__setattr__',
'__sizeof__',
'__str__',
'__subclasshook__',
'__weakref__',
'_get_H_mass_cut',
'_get_Hbeta_cut',
'_get_over_range',
'_get_r_in_cut',
'_get_r_out_cut',
'_i_emis',
```

```
'_i_line',
'_init_abunds',
'_init_all2zero',
'_init_cont',
'_init_emis',
'_init_grains',
'_init_heatcool',
'_init_ionic',
'_init_lin',
'_init_opd',
'_init_phy',
'_init_pressure',
'_init_rad',
'_l_emis',
'_quiet_div',
'_r_out_cut_doc',
'_read_stout',
'_res',
'_set_H_mass_cut',
'_set_Hbeta_cut',
'_set_r_in_cut',
'_set_r_out_cut',
'aborted',
'abund',
'abunds',
'abunds_full',
'add_emis_from_pyneb',
'calling',
'cautions',
'cloudy_version',
'cloudy_version_major',
'comments',
'cool',
'cool_full',
'date_model',
'depth',
'depth_full',
'distance',
'dr',
'dr_full',
'drff',
'dv',
'dv_full',
'dvff',
'emis_from_pyneb',
'emis_full',
'emis_is_log',
```

```
'emis_labels',
'emis_labels_13',
'emis_labels_17',
'empty_model',
'ff',
'ff_full',
'gabund',
'gabund_full',
'gabund_labels',
'gas_mass_per_H',
'gasize',
'gdgrat',
'gdgrat_full',
'gdgrat_labels',
'gdsize',
'get_EW',
'get_EW2',
'get_G0',
'get_Ha_EW',
'get_Hb_EW',
'get_Hb_SB',
'get_T0_emis',
'get_T0_emis_rad',
'get_T0_ion_rad',
'get_T0_ion_rad_ne',
'get_T0_ion_vol',
'get_T0_ion_vol_ne',
'get_ab_ion_rad',
'get_ab_ion_rad_ne',
'get_ab_ion_vol',
'get_ab_ion_vol_ne',
'get_cont_x',
'get_cont_y',
'get_emis',
'get_emis_rad',
'get_emis_vol',
'get_integ_spec',
'get_interp_cont',
'get_ionic',
'get_line',
'get_ne_emis',
'get_ne_ion_rad_ne',
'get_ne_ion_vol_ne',
'get_t2_emis',
'get_t2_ion_rad_ne',
'get_t2_ion_vol_ne',
'gmass',
```

```
'gsize',
'gtemp',
'gtemp_full',
'gtemp_labels',
'heat',
'heat_full',
'info',
'intens',
'ionic_full',
'ionic_names',
'is_valid_ion',
'line_is_log',
'lines',
'liste_elem',
'log_',
'log_U',
'log_U_mean',
'log_U_mean_ne',
'model_name',
'model_name_s',
'nH',
'nH_full',
'nH_mean',
'nHff_full',
'n_elements',
'n_emis',
'n_gabund',
'n_gdgrat',
'n_gtemp',
'n_ions',
'n_lines',
'n_zones',
'n_zones_full',
'ne',
'ne_full',
'nenH',
'nenH_full',
'nenHff2_full',
'opd_absorp',
'opd_energy',
'opd_scat',
'opd_total',
'out',
'out_exists',
'phi',
'plan_par',
'plot_spectrum',
```

```
 'pressure_full',
 'print_lines',
 'print_stats',
 'r_in',
 'r_in_cut',
 'r_out',
 'r_out_cut',
 'r_range',
 'rad_integ',
 'rad_mean',
 'radius',
 'radius_full',
 'read_outputs',
 'rlines',
 'slines',
 't2',
 'te',
 'te_full',
 'tenenH',
 'tenenH_full',
 'theta',
 'thickness',
 'thickness_full',
 'vol_integ',
 'vol_mean',
 'warnings',
 'zones',
 'zones_full']
```

[20]:
```
Mod.print_stats()
```

```
 Name of the model: /tmp/models/model_1
 R_in (cut) = 5.000e+17 (5.000e+17), R_out (cut) = 1.939e+18 (1.939e+18)
 H+ mass = 2.37e+00, H mass = 2.52e+00 N zones: 125
 <H+/H> = 0.97, <He++/He> = 0.00, <He+/He> = 0.86
 <O+++/O> = 0.00, <O++/O> = 0.29, <O+/O> = 0.67
 <N+++/O> = 0.00, <N++/O> = 0.40, <N+/O> = 0.58
 T(O+++) = 7764, T(O++) = 7577, T(O+) = 7844
 <ne> = 104,  <nH> = 100, T0 = 7766, t2=0.0016
 <log U> = -2.80
```

[21]:
```
Mod.print_lines()
```

```
H__1_486133A 4.637019e+34
H__1_656281A 1.267532e+35
CA_B_587564A 7.136729e+33
N__2_658345A 6.660257e+34
O__1_630030A 1.359615e+33
```

```
O__2_372603A 4.641195e+34
O__2_372881A 6.246388e+34
O__3_500684A 5.514793e+34
BLND_436300A 1.262825e+32
S__2_671644A 7.944240e+33
S__2_673082A 6.105032e+33
CL_3_551771A 1.305241e+32
CL_3_553787A 9.322326e+31
O__1_631679M 8.776794e+32
O__1_145495M 8.560449e+31
C__2_157636M 1.709964e+32
```

[22]:
```
Mod.get_ab_ion_vol_ne('O',2)
```

[22]:
```
0.29396603831570584
```

[23]:
```
Mod.get_T0_ion_vol_ne('O', 2)
```

[23]:
```
7577.428427622063
```

[24]:
```
Mod.log_U_mean
```

[24]:
```
-2.7960141432706367
```

[25]:
```
Mod.log_U_mean_ne
```

[25]:
```
-2.778477750233511
```

[26]:
```
print('T0 = {0:7.1f}K, t2 = {1:6.4f}'.format(Mod.T0, Mod.t2))
```

```
T0 =  7766.5K, t2 = 0.0016
```

[27]:
```
print('Hbeta Equivalent width = {0:6.1f}, Hbeta Surface Brightness = {1:4.2e}'.
 ↪format(Mod.get_Hb_EW(), Mod.get_Hb_SB()))
```

```
Hbeta Equivalent width = -709.5, Hbeta Surface Brightness = 9.23e-14
```

[28]:
```
Mod.emis_labels
```

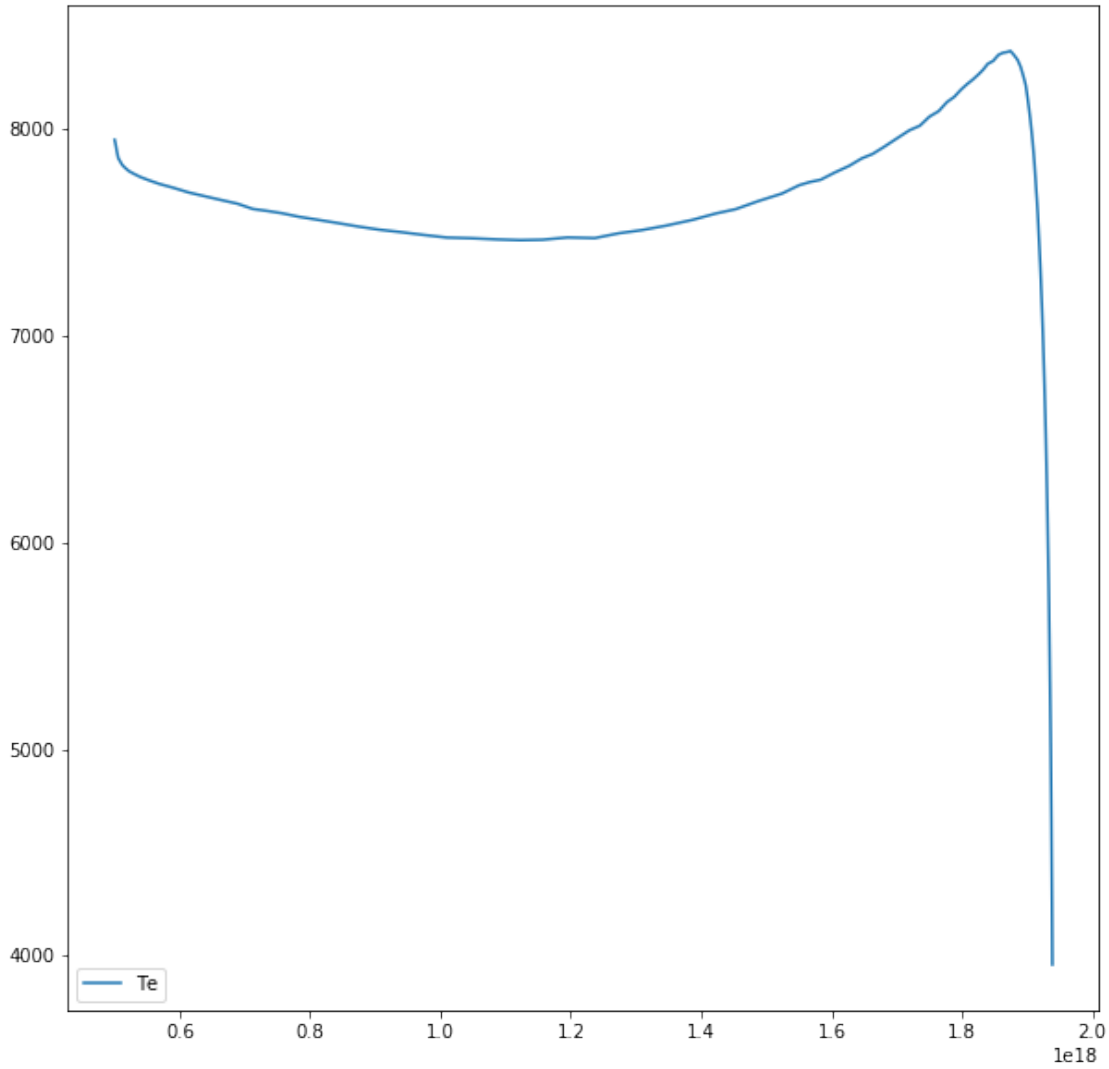
[28]:
```
array(['H__1_486133A', 'H__1_656281A', 'CA_B_587564A', 'N__2_658345A',
       'O__1_630030A', 'O__2_372603A', 'O__2_372881A', 'O__3_500684A',
       'BLND_436300A', 'S__2_671644A', 'S__2_673082A', 'CL_3_551771A',
       'CL_3_553787A', 'O__1_631679M', 'O__1_145495M', 'C__2_157636M'],
      dtype='<U12')
```

[29]:
```
# printing line intensities
for line in Mod.emis_labels:
```

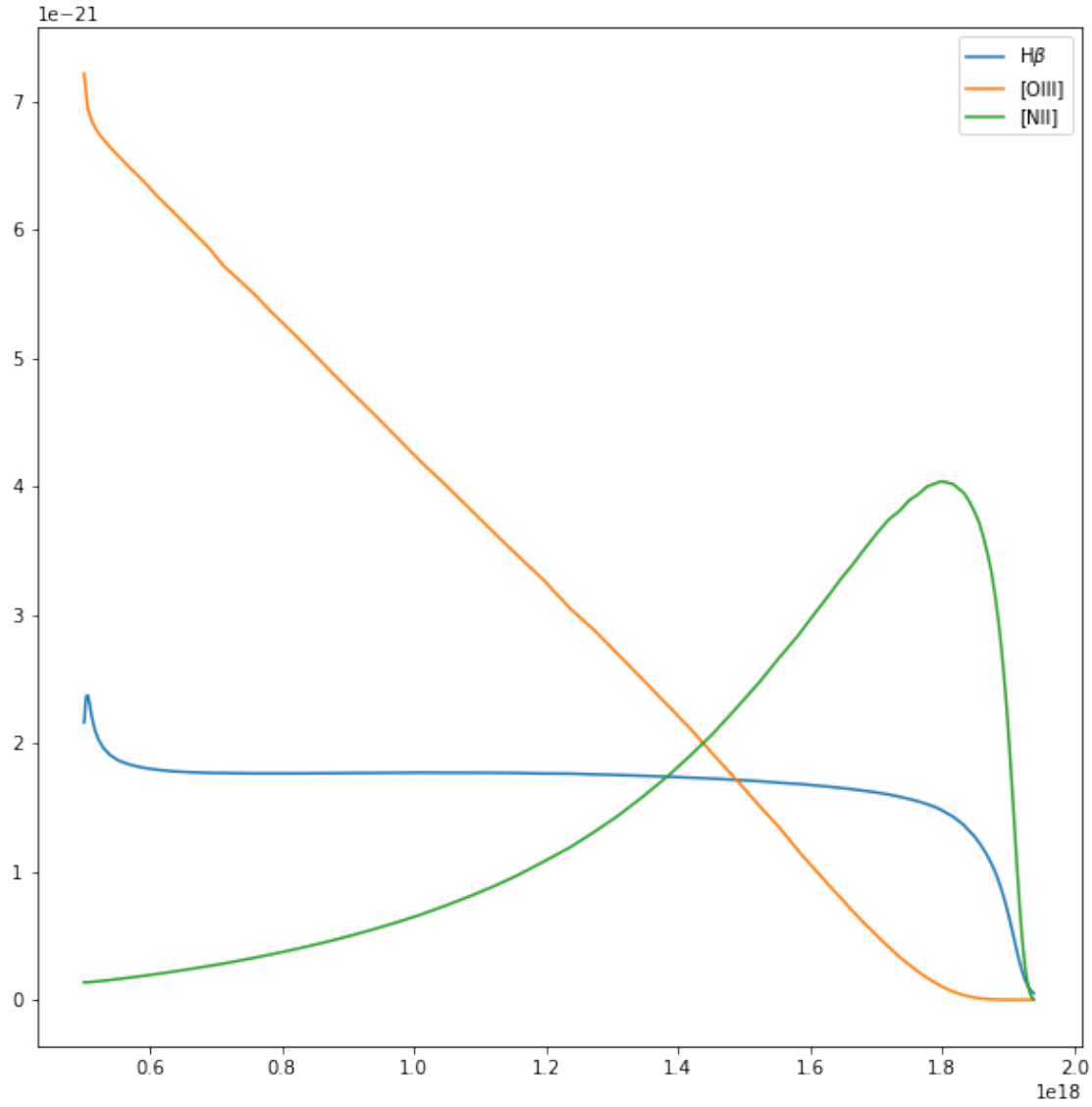
```
    print('{0} {1:10.3e} {2:7.2f}'.format(line, Mod.get_emis_vol(line), Mod.
↪get_emis_vol(line) / Mod.get_emis_vol('H__1_486133A') * 100.))
```

```
H__1_486133A  4.637e+34  100.00
H__1_656281A  1.268e+35  273.35
CA_B_587564A  7.137e+33   15.39
N__2_658345A  6.660e+34  143.63
O__1_630030A  1.360e+33    2.93
O__2_372603A  4.641e+34  100.09
O__2_372881A  6.246e+34  134.71
O__3_500684A  5.515e+34  118.93
BLND_436300A  1.263e+32    0.27
S__2_671644A  7.944e+33   17.13
S__2_673082A  6.105e+33   13.17
CL_3_551771A  1.305e+32    0.28
CL_3_553787A  9.322e+31    0.20
O__1_631679M  8.777e+32    1.89
O__1_145495M  8.560e+31    0.18
C__2_157636M  1.710e+32    0.37
```

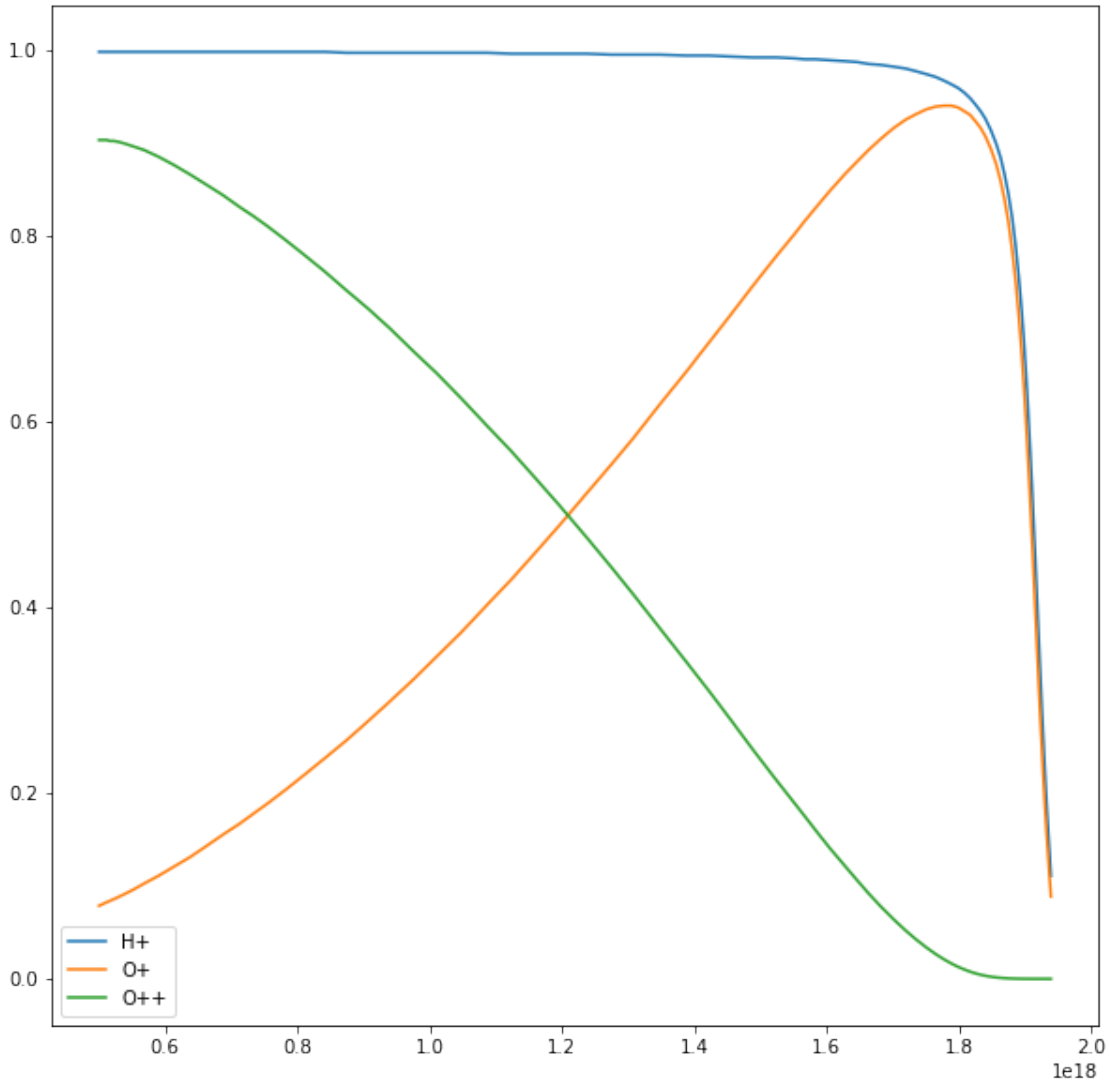
[35]:
```
plt.figure(figsize=(10,10))
plt.plot(Mod.radius, Mod.te, label = 'Te')
plt.legend(loc=3);
```



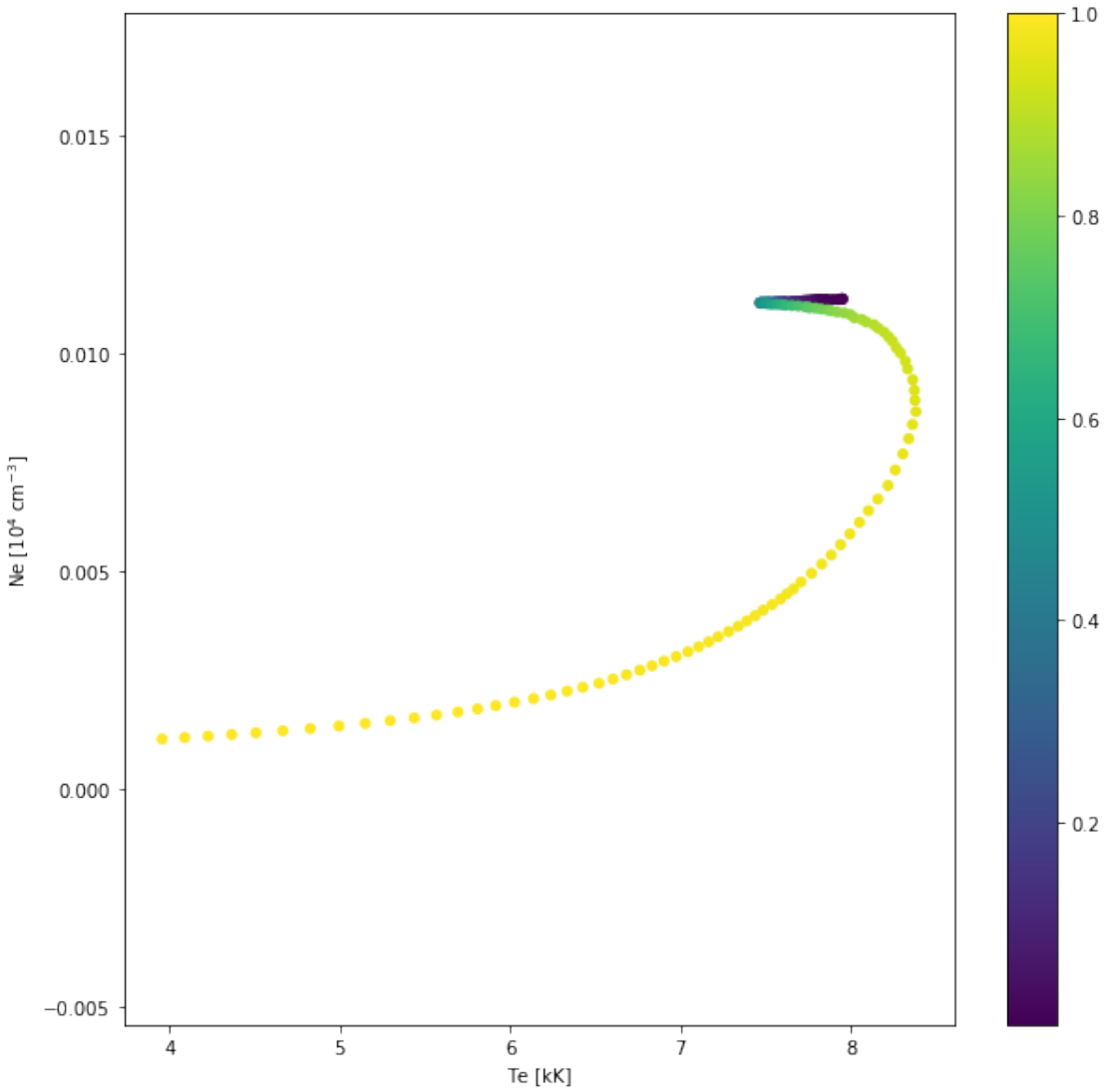
[36]:
```
plt.figure(figsize=(10,10))
plt.plot(Mod.radius, Mod.get_emis('H__1_486133A'), label = r'H$\beta$')
plt.plot(Mod.radius, Mod.get_emis('O__3_500684A'), label = '[OIII]')
plt.plot(Mod.radius, Mod.get_emis('N__2_658345A'), label = '[NII]')
plt.legend();
```



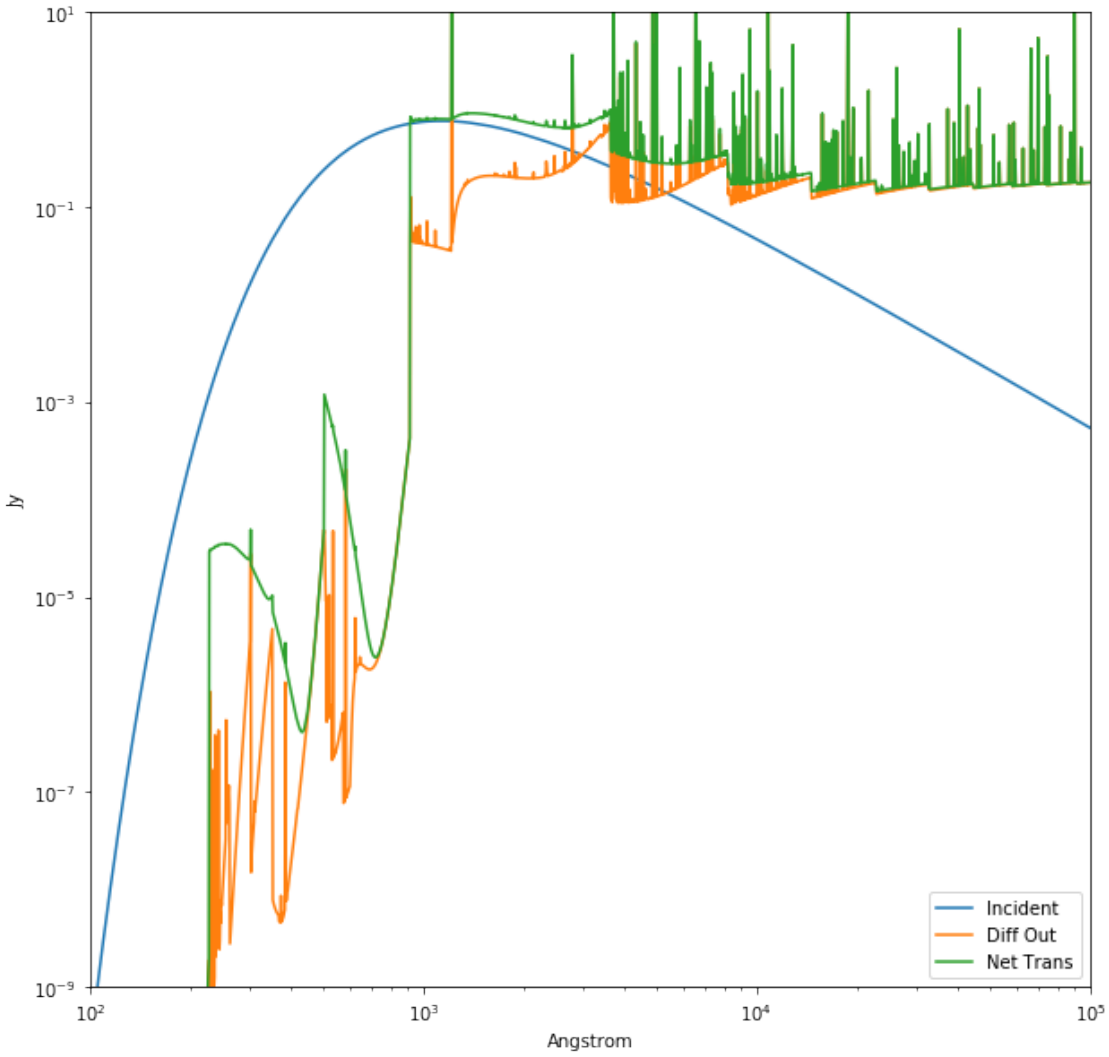
[37]:
```
plt.figure(figsize=(10,10))
plt.plot(Mod.radius, Mod.get_ionic('H', 1), label = 'H+')
plt.plot(Mod.radius, Mod.get_ionic('O', 1), label = 'O+')
plt.plot(Mod.radius, Mod.get_ionic('O', 2), label = 'O++')
plt.legend(loc=3);
```



[38]:
```
plt.figure(figsize=(10,10))
plt.scatter(Mod.te/1e3, Mod.ne/1e4, c = Mod.depth/np.max(Mod.depth), edgecolors␣
 ↪= 'none')
plt.colorbar()
plt.xlabel('Te [kK]')
plt.ylabel(r'Ne [$10^4$ cm$^{-3}$]');
```



[39]:
```
plt.figure(figsize=(10,10))
plt.loglog(Mod.get_cont_x(unit='Ang'), Mod.get_cont_y(cont = 'incid', unit =␣
 ↪'Jy'), label = 'Incident')
plt.loglog(Mod.get_cont_x(unit='Ang'), Mod.get_cont_y(cont = 'diffout', unit =␣
 ↪'Jy'), label = 'Diff Out')
plt.loglog(Mod.get_cont_x(unit='Ang'), Mod.get_cont_y(cont = 'ntrans', unit =␣
 ↪'Jy'), label = 'Net Trans')
plt.xlim((100, 100000))
plt.ylim((1e-9, 1e1))
plt.xlabel('Angstrom')
plt.ylabel('Jy')
plt.legend(loc=4);
```


10^{1}
10^{-1}
10^{-3}
10^{-5}
10^{-7}
10^{-9}
Jy
10^{2}
10^{3}
10^{4}
10^{5}
Angstrom
Incident
Diff Out
Net Trans