OOP

November 25, 2015

```
In [1]: # Just to know last time this was run:
        import time
        print time.ctime()
```

```
Mon Sep 28 15:59:03 2015
```

1 G Object Oriented Programation. Objects, classes, etc...

This is part of the Python lecture given by Christophe Morisset at IA-UNAM. More informations at: http://python-astro.blogspot.mx/

```
In [3]: %matplotlib inline
        import numpy as np
        import matplotlib.pyplot as plt
        import os # We will need this latter
        from scipy.integrate import simps
        import urllib2
```

We want here to make some plots of atmosphere models that will be downloaded from internet. We need:

- Download the file
- read it
- plot it

This can all be done in functions, and also in object.

1.0.1 Functions

Let's first see the way we can do it with functions:

The files are located there: http://astro.uni-tuebingen.de/~rauch/TMAF/flux_He+C+N+O.html

For exemple, a file is: http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/0050000_7.00_33_50_02_15.bin_0
We can download it using urllib2, putting this into a function:

```
In [4]: def dlfile(filename):
            stel_file = urllib2.urlopen('http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/' + fi
            output = open(filename,'wb') #the file where we will put the data. b stands for binary, as
            output.write(stel_file.read()) # the reading of the distant file is redirected to the writt
            output.close()
```

```
In [5]: filename = '0050000_7.00_33_50_02_15.bin_0.1.gz'
        dlfile(filename)
```

```
In [6]: ! ls -l *gz
```

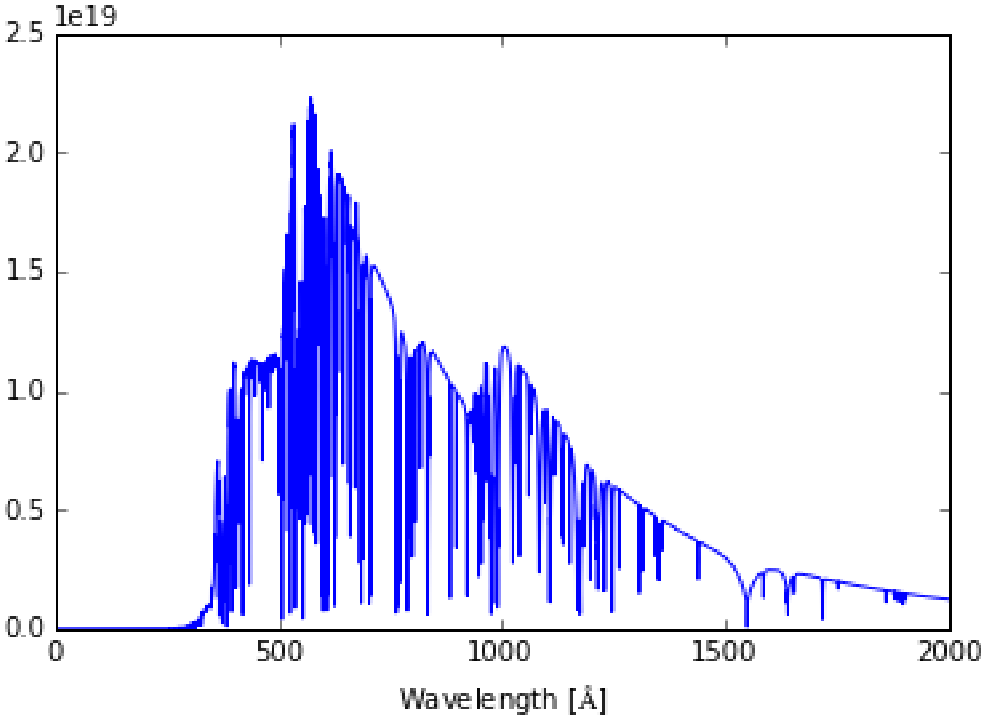
```
-rw-------  1 christophemorisset  staff    89353 Oct  1  2014 0040000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    85600 Oct  1  2014 0050000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    86018 Sep 28 16:19 0050000_7.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    86018 Sep 30  2014 0050000_7.00_33_50_02_15.bin_0.2.gz
-rw-------  1 christophemorisset  staff    86741 Oct  1  2014 0060000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    88843 Oct  1  2014 0070000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    89360 Oct  1  2014 0080000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    89971 Oct  1  2014 0090000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    89722 Oct  1  2014 0100000_5.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    90544 Oct  1  2014 0100000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    91192 Oct  1  2014 0100000_7.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    91475 Oct  1  2014 0100000_8.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    90430 Oct  1  2014 0110000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    90960 Sep 28 15:49 0110000_7.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    89525 Oct  1  2014 0120000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    89899 Oct  1  2014 0130000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    89170 Oct  1  2014 0140000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    89263 Oct  1  2014 0150000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    88929 Oct  1  2014 0160000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    88991 Oct  1  2014 0170000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    88780 Oct  1  2014 0180000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    89075 Oct  1  2014 0180000_7.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff    88591 Oct  1  2014 0190000_6.00_33_50_02_15.bin_0.1.gz
-rw-------  1 christophemorisset  staff  4229587 Sep  9 16:50 CALIFA_ah7.dat.gz
-rw-------  1 christophemorisset  staff  1270918 Sep 21 18:08 MySQL.pdf.gz
```

```
In [7]: data = np.genfromtxt(filename, comments='*', names='wl, fl') # genfromtxt can read gzip files
```

```
In [8]: data
```

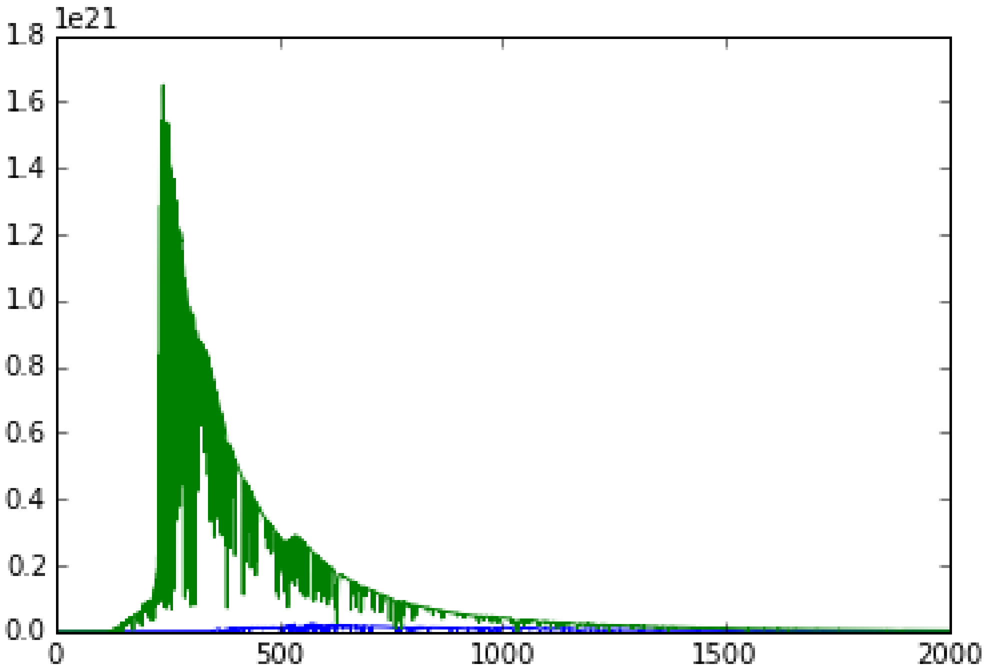
```
Out[8]: array([(5.0, 4.596e-20), (5.1, 3.524e-19), (5.2, 2.475e-18), ...,
               (1999.8, 1.242e+18), (1999.9, 1.242e+18), (2000.0, 1.241e+18)],
              dtype=[('wl', '<f8'), ('fl', '<f8')])
```

```
In [9]: plt.plot(data['wl'], data['fl']) # let's have a look at the data
        plt.xlabel(r'Wavelength [$\AA$]');
```

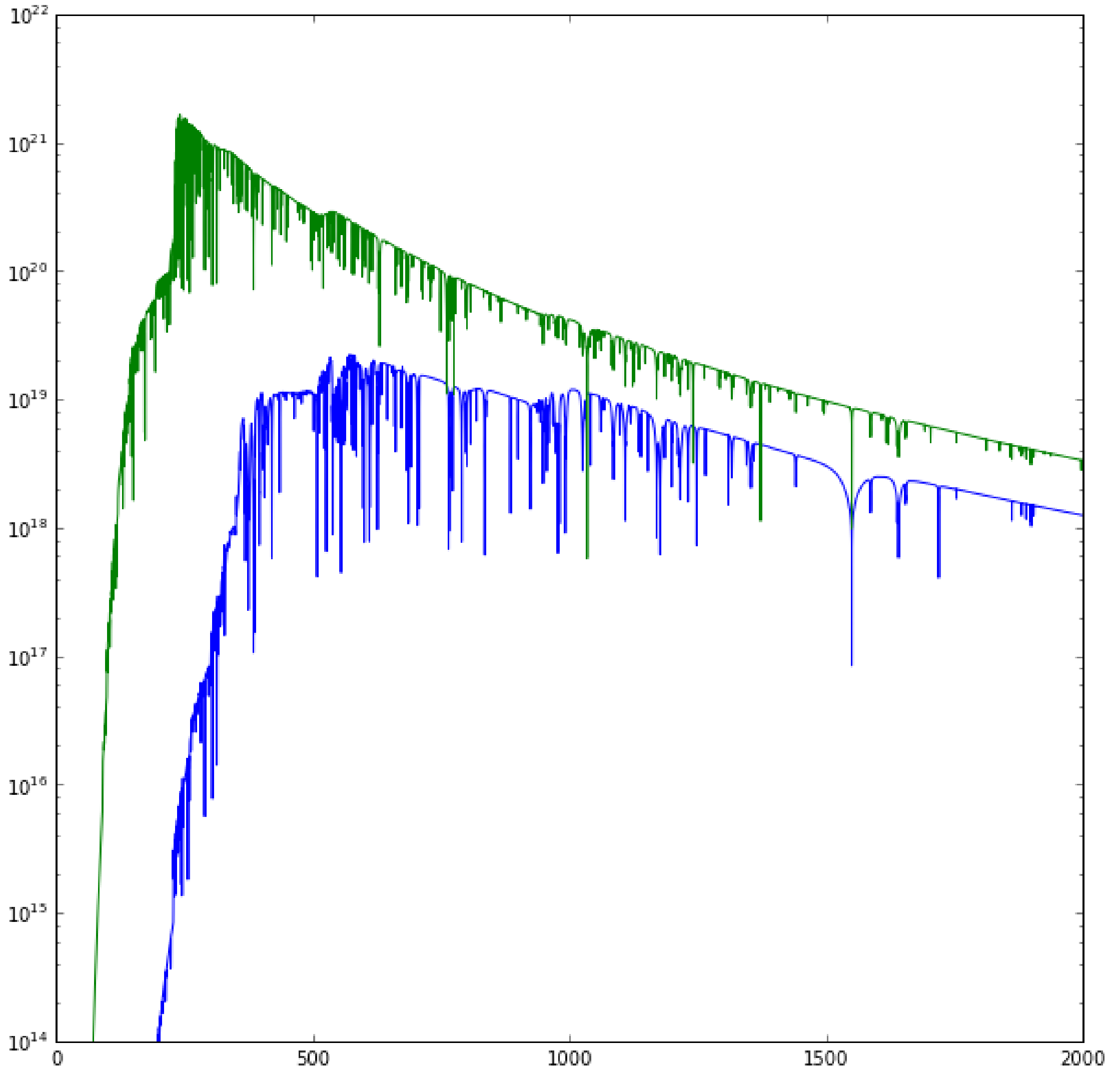


If we want to overplot another file, we only have to download it and follow the same process:

```
In [10]: filename2 = '0110000_7.00_33_50_02_15.bin_0.1.gz'
         dlfile(filename2)

In [11]: data2 = np.genfromtxt(filename2, comments='*', names='wl, fl') # data and data2 contains the 2

In [12]: plt.plot(data['wl'], data['fl'])
         plt.plot(data2['wl'], data2['fl']);
```

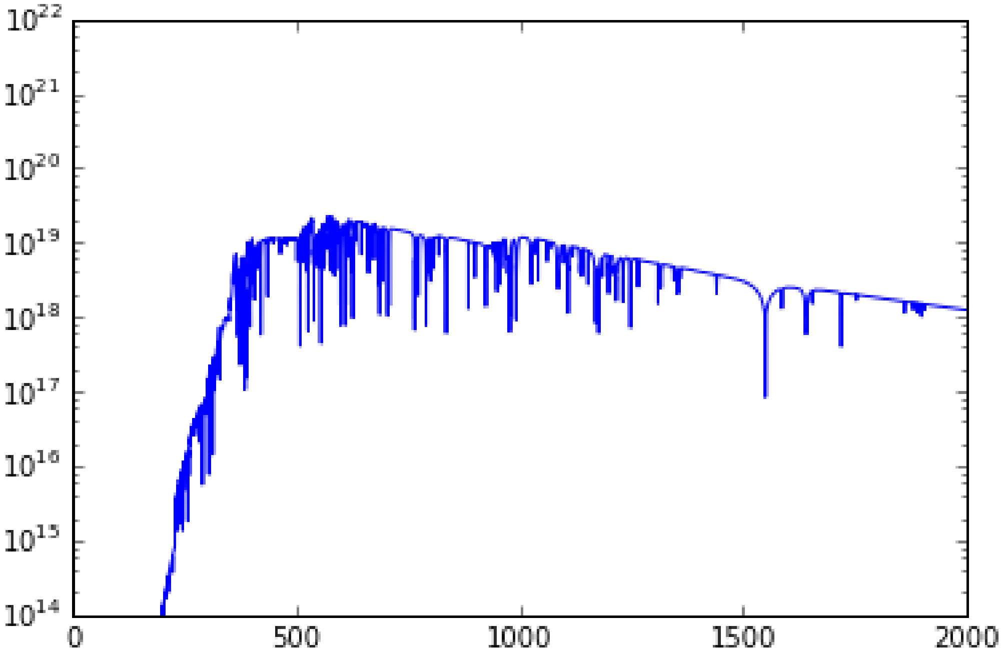


```
In [15]: fig, ax = plt.subplots(figsize=(10,10))
         ax.plot(data['wl'], data['fl'])
         ax.plot(data2['wl'], data2['fl'])
         ax.set_yscale('log')
         ax.set_ylim(1e14, 1e22);
```



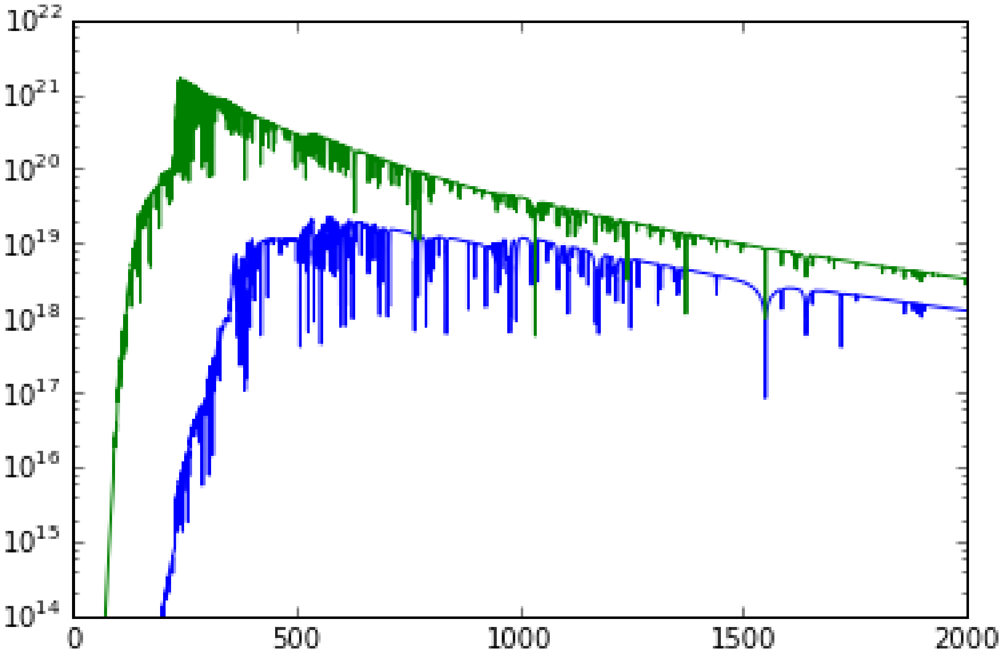
Great, but it would be better if everything were in the same place. Making a function more complete that deal with everything:

```
In [17]: def plot_spr(filename):
             dlfile(filename) # download the file
             data = np.genfromtxt(filename, comments='*', names='wl, fl') # read it
             fig, ax = plt.subplots()
             ax.plot(data['wl'], data['fl']) # plot it
             ax.set_yscale('log') # use log axes
             ax.set_ylim(1e14, 1e22)
         plot_spr(filename)
```

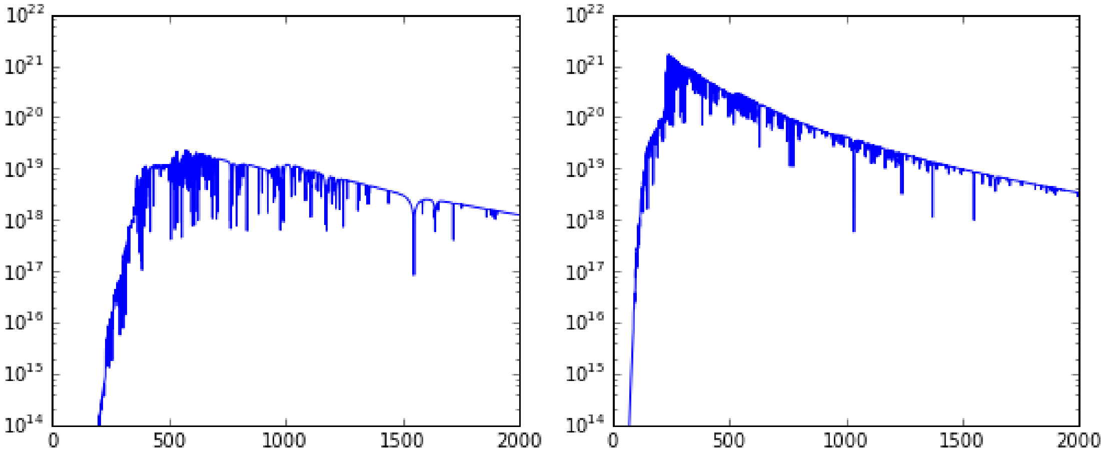


The main problem here is to superimpose the 2 plots. We can define the axis object outside and send it to the function:

```
In [18]: def plot_spr(filename, ax=None): # default is no axis sent to the function
             dlfile(filename)
             data = np.genfromtxt(filename, comments='*', names='wl, fl')
             if ax is None: # make a figue if no axis is passed to the function
                 fig, ax = plt.subplots()
             else:
                 fig = plt.gcf()
             ax.plot(data['wl'], data['fl'])
             ax.set_yscale('log')
             ax.set_ylim(1e14, 1e22)

         fig, ax = plt.subplots() # the figure and axis is buildt before calling the plotting function
         plot_spr(filename, ax=ax) # sending axis let the plots appear on the same figure
         plot_spr(filename2, ax=ax)
```



```
In [21]: fig, (ax1, ax2) = plt.subplots(1, 2, figsize=(10, 4)) # the figure and axis is buildt before c
         plot_spr(filename, ax=ax1) # sending axis let the plots appear on the same figure
         plot_spr(filename2, ax=ax2)
```



But now that everything is compact, we don't have access to the data, they are INSIDE the function…

1.0.2 Classes and Objects

It's time to make a class and to instantiate objects. Classes are intelligent containers. The can hold variables and functions (called methods). The following terminology is from http://www.tutorialspoint.com/python/python_classes_objects.htm:

- *Class*: A user-defined prototype for an object that defines a set of attributes that characterize any object of the class. The attributes are data members (class variables and instance variables) and methods, accessed via dot notation.
- *Class variable or attribute*: A variable that is shared by all instances of a class. Class variables are defined within a class but outside any of the class's methods. Class variables aren't used as frequently as instance variables are.
- *Data member*: A class variable or instance variable that holds data associated with a class and its objects.
- *Function overloading*: The assignment of more than one behavior to a particular function. The operation performed varies by the types of objects (arguments) involved.
- *Instance variable or attribute*: A variable that is defined inside a method and belongs only to the current instance of a class.
- *Inheritance* : The transfer of the characteristics of a class to other classes that are derived from it.
- *Instance*: An individual object of a certain class. An object obj that belongs to a class Circle, for example, is an instance of the class Circle.
- *Instantiation* : The creation of an instance of a class.
- *Method* : A special kind of function that is defined in a class definition.
- *Object* : A unique instance of a data structure that's defined by its class. An object comprises both data members (class variables and instance variables) and methods.
- *Operator overloading*: The assignment of more than one function to a particular operator.

```
In [22]: class Stel_Spectrum(object):
             """
             This object downloads a file from http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/
             and is able to make some plots.
             """
             def __init__(self, filename): # This function will be called at the instantiation of any o
                 self.filename = filename # we put the file name value into an instance variable. That
                 self.dlfile() # calling a method (defined below). No need for argument, as filename is
                 self.data = np.genfromtxt(self.filename, comments=’*’, names=’wl, fl’) # reading the d

             def dlfile(self): # method.
                 if not os.path.exists(self.filename): # only donwload if not yet on the disk
                     stel_file = urllib2.urlopen(’http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N
                                                 self.filename)
                     output = open(self.filename,’wb’)
                     output.write(stel_file.read())
                     output.close()

             def plot_spr(self, ax=None): # another method. Used to plot
                 if ax is None:
                     fig, ax = plt.subplots()
                 else:
                     fig = plt.gcf()
                 ax.plot(self.data[’wl’], self.data[’fl’])
                 ax.set_yscale(’log’)
                 ax.set_ylim(1e14, 1e22)
```

```
In [23]: sp1 = Stel_Spectrum(filename) # instantiation of an object from the Stel_Spectrum class
         sp2 = Stel_Spectrum(filename2) # another object. They have the same structure, but hols differ
```

```
In [24]: print sp1.filename # access the instace variable
         print sp2.filename
```

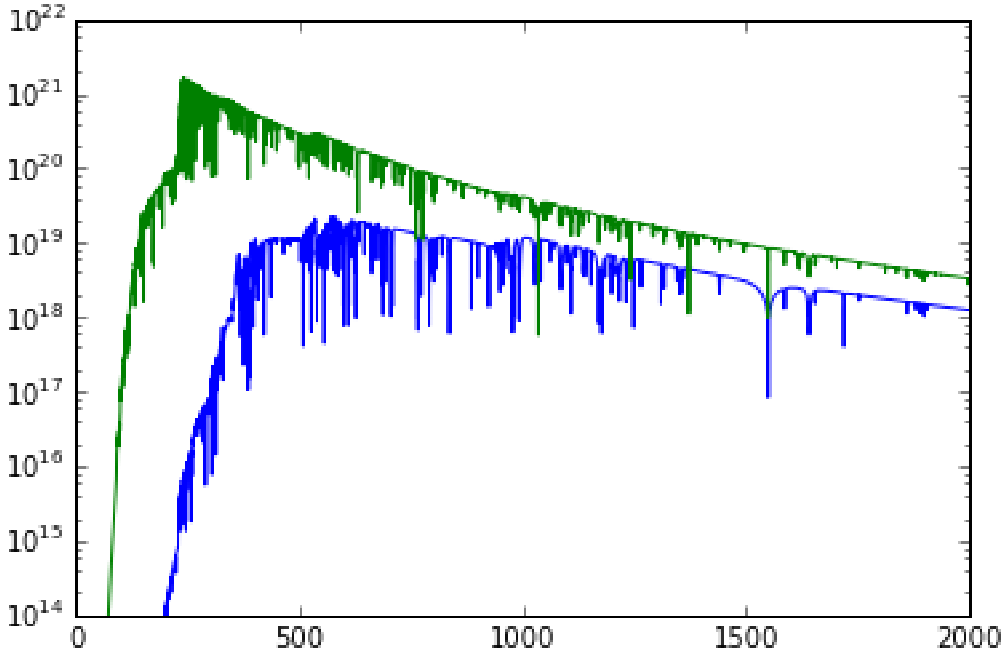
```
0050000_7.00_33_50_02_15.bin_0.1.gz
0110000_7.00_33_50_02_15.bin_0.1.gz
```

```
In [25]: sp1.
```

```
In [26]: sp2.data # the data are available.
```

```
Out[26]: array([(5.0, 1028.0), (5.1, 2393.0), (5.2, 5362.0), ...,
                (1999.8, 3.328e+18), (1999.9, 3.327e+18), (2000.0, 3.326e+18)],
               dtype=[('wl', '<f8'), ('fl', '<f8')])
```

```
In [27]: fig, ax = plt.subplots()
         sp1.plot_spr(ax=ax) # calling the metod
         sp2.plot_spr(ax=ax)
```



```
In [28]: len(sp1.data['wl']) # the data from the object are like any other data.
```

```
Out[28]: 19951
```

We can add comments and a method that gives information about the object itself.

```
In [29]: class Stel_Spectrum(object):
             """
             This object downloads a file from http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/
             and is able to make some plots.
             """
             def __init__(self, filename):
                 """
                 Initialisation of the Stel_Spectrum object.
                 Parameter:
```

```
            - filename e.g. 0050000_7.00_33_50_02_15.bin_0.1.gz
        """
        self.filename = filename
        self.dlfile()
        self.data = np.genfromtxt(filename, comments='*', names='wl, fl')

    def dlfile(self):
        """
        Downloading file if not already here
        """
        if not os.path.exists(filename):
            print('Downloading {}'.format(self.filename))
            stel_file = urllib2.urlopen('http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N
            output = open(filename,'wb')
            output.write(stel_file.read())
            output.close()

    def plot_spr(self, ax=None):
        """
        Plot the spectrum.
        Parameter:
            - ax: an axis (optionnal). If None or absent, axis is created
        """
        if ax is None:
            fig, ax = plt.subplots()
        ax.plot(self.data['wl'], self.data['fl'])
        ax.set_yscale('log')
        ax.set_ylim(1e14, 1e22)

    def print_info(self):
        """
        Print out the filename and the number of points
        """
        print('Filename: {0}, number of points: {1}'.format(self.filename, len(self.data)))
```

```
In [30]: sp1 = Stel_Spectrum(filename) # we have to instatiate again to take the changes into account
         sp2 = Stel_Spectrum(filename2)
         sp1.print_info()
```

```
Filename: 0050000_7.00_33_50_02_15.bin_0.1.gz, number of points: 19951
```

```
In [31]: help(sp1) # the comments are easily accessible
```

```
Help on Stel_Spectrum in module __main__ object:

class Stel_Spectrum(__builtin__.object)
 |  This object downloads a file from http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/
 |  and is able to make some plots.
 |
 |  Methods defined here:
 |
 |  __init__(self, filename)
 |      Initialisation of the Stel_Spectrum object.
 |      Parameter:
 |          - filename e.g. 0050000_7.00_33_50_02_15.bin_0.1.gz
 |
 |  dlfile(self)
 |      Downloading file if not already here
 |
 |  plot_spr(self, ax=None)
 |      Plot the spectrum.
 |      Parameter:
 |          - ax: an axis (optionnal). If None or absent, axis is created
 |
 |  print_info(self)
 |      Print out the filename and the number of points
 |
 |  ----------------------------------------------------------------------
 |  Data descriptors defined here:
 |
 |  __dict__
 |      dictionary for instance variables (if defined)
 |
 |  __weakref__
 |      list of weak references to the object (if defined)
```

```
In [32]: help(sp1.plot_spr)
```

```
Help on method plot_spr in module __main__:

plot_spr(self, ax=None) method of __main__.Stel_Spectrum instance
    Plot the spectrum.
    Parameter:
        - ax: an axis (optionnal). If None or absent, axis is created
```

```
In [33]: print sp1
```

```
<__main__.Stel_Spectrum object at 0x10b718990>
```

Adding more method and changing the name of the data to wl and fl. We can accept T and logg to define the filename and download it. Some error catching process are implemented. We laso add a method to compute the integrale of the flux over the wavelengths.

```
In [37]: class Stel_Spectrum(object):
             """
             This object downloads a file from http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/
             and is able to make some plots.
             """
             def __init__(self, filename=None, T=None, logg=None, verbose=False):
                 """
                 Initialisation of the Stel_Spectrum object.
                 Parameter:
                     - filename
                     - T: temperature in K, e.g. 150000
                     - logg: e.g. 7.5
                 The wl attribute is an array of wavelengths in Angstrom.
                 The fl attribute is the flux in erg/s/cm2/A
                 """
                 self.verbose = verbose
                 if filename is None:
```

```
            if T is not None and logg is not None:
                self.T = T
                self.logg = logg
                self.filename = '0{0:06.0f}_{1:.2f}_33_50_02_15.bin_0.1.gz'.format(self.T, sel
            else:
                raise TypeError("T and logg must be given")
        else:
            self.filename = filename
            self.T = float(filename.split('_')[0])
            self.logg = float(filename.split('_')[1])
        self.dlfile()
        if self.file_found:
            data = np.genfromtxt(self.filename, comments='*', names='wl, fl')
            self.fl = data['fl']
            self.wl = data['wl'] # in A
            self.fl /= 1e8 # F LAMBDA  GIVEN IN ERG/CM**2/SEC/CM -> erg/s/cm2/A
            if self.verbose:
                print('Data from {} read.'.format(self.filename))
        else:
            self.wl = None
            self.fl = None

    def dlfile(self):
        """
        Downloading file if not already here. Put it in the curremt directory
        """
        if not os.path.exists(self.filename):
            print('Downloading {}'.format(self.filename))
            try:
                stel_file = urllib2.urlopen('http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He
                                            self.filename)
                output = open(self.filename,'wb')
                output.write(stel_file.read())
                output.close()
                self.file_found=True
            except:
                print('file {} not found'.format(self.filename))
                self.file_found=False
        else:
            self.file_found=True

    def plot_spr(self, ax=None):
        """
        Plot the spectrum.
        Parameter:
            - ax: an axis (optionnal). If Noe or absent, axis is created
        """
        if self.wl is None:
            print('No data to plot')
            return
        if ax is None:
            fig, ax = plt.subplots()
        ax.plot(self.wl, self.fl, label='T3={0:.0f}, logg={1}'.format(self.T/1e3, self.logg))
        ax.set_yscale('log')
        ax.set_ylim(1e6, 1e14)
        ax.set_xlabel('Wavelength (A)')

    def print_info(self):
        """
        Print out the filename and the number of points
        """
        print self.__repr__()

    def __repr__(self):
        """
        This is what is used when calling "print <obj>" or <obj> ENTER
        """
        if self.wl is None:
            return'Filename: {0}, No data'.format(self.filename)
        else:
            return'Filename: {0}, number of points: {1}'.format(self.filename, len(self.wl))

    def get_integ(self):
        """
        Return the integral of Flambda over lambda, in erg/s/cm2
        """
        if self.wl is None:
            print('No data')
            return None
        return simps(self.fl, self.wl) # perform the integral
```

```
In [35]: sp1 = Stel_Spectrum(T=130000, logg=6)
```

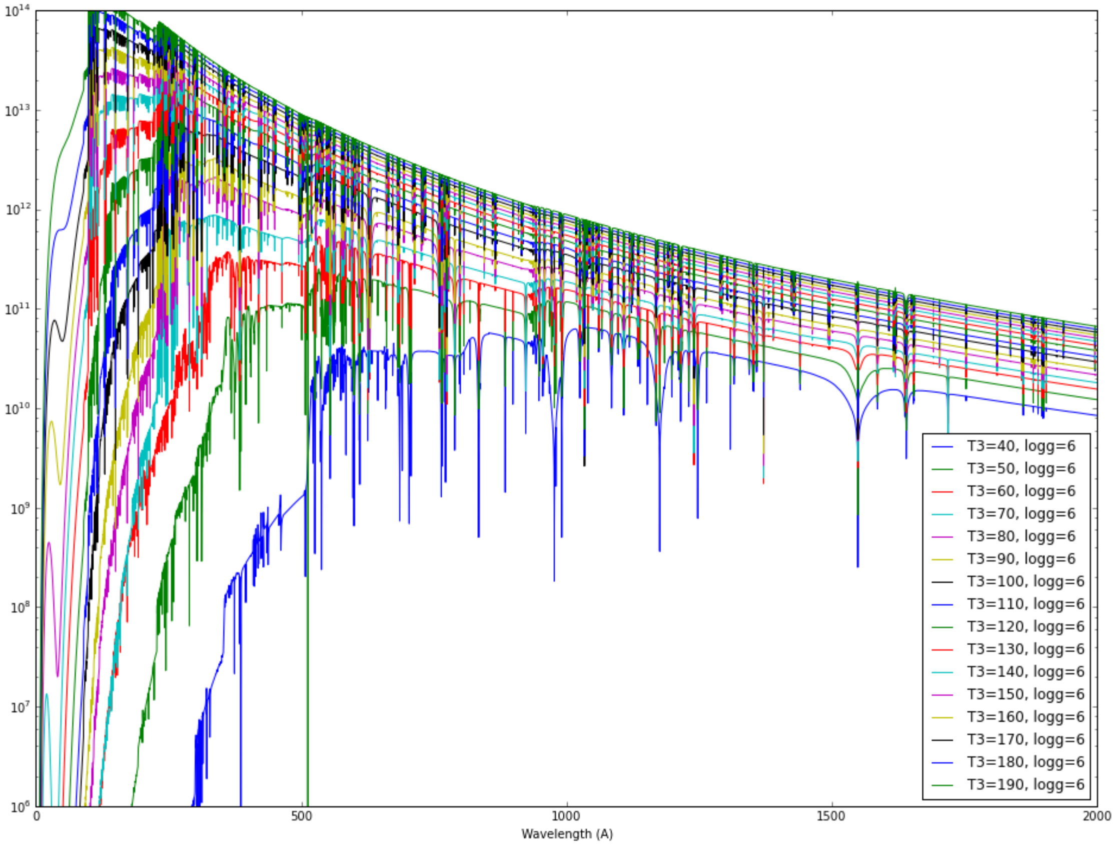
```
In [38]: spectra = [] # we create an empty list
         for T in np.linspace(40000, 190000, 16): # this is the list of available temperature (check th
             spectra.append(Stel_Spectrum(T=T, logg=6, verbose=True)) # we fill the list with the objec
```

```
Data from 0040000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0050000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0060000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0070000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0080000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0090000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0100000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0110000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0120000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0130000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0140000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0150000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0160000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0170000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0180000_6.00_33_50_02_15.bin_0.1.gz read.
Data from 0190000_6.00_33_50_02_15.bin_0.1.gz read.
```

```
In [39]: spectra # the list hold 16 objects, each one with its own data and methods
```

```
Out[39]: [Filename: 0040000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0050000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0060000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0070000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0080000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0090000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0100000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0110000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0120000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0130000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0140000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0150000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0160000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0170000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0180000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951,
          Filename: 0190000_6.00_33_50_02_15.bin_0.1.gz, number of points: 19951]
```

```
In [40]: fig, ax = plt.subplots(figsize=(16,12))
         for sp in spectra: # easy to loop on the objects
             sp.plot_spr(ax=ax)
         ax.legend(loc=4);
```

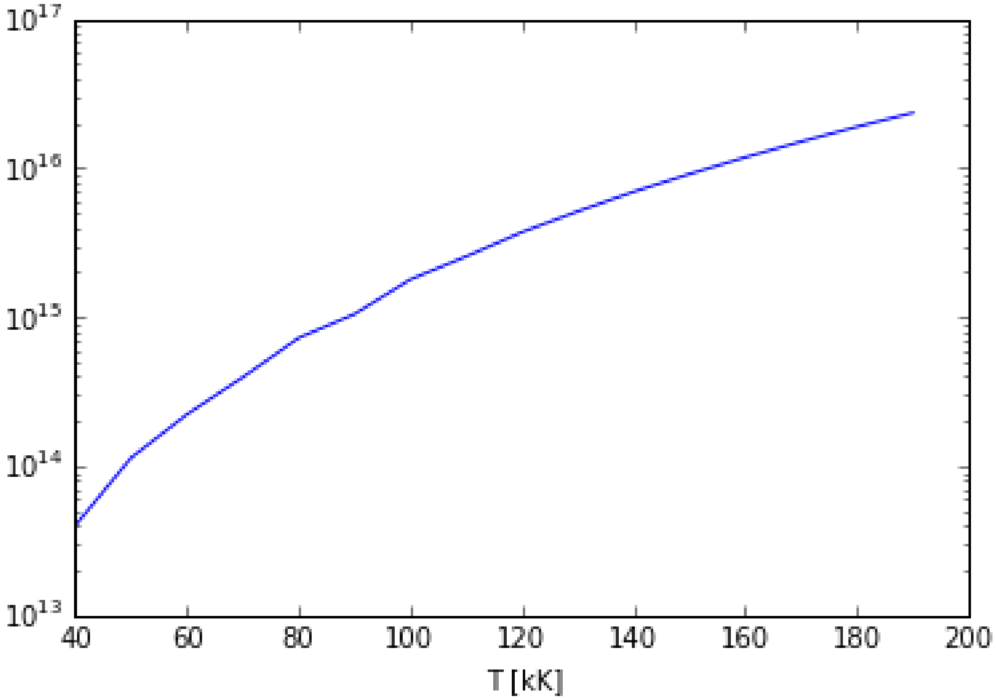


```
In [41]: for sp in spectra:
             print sp.T, sp.get_integ()
```

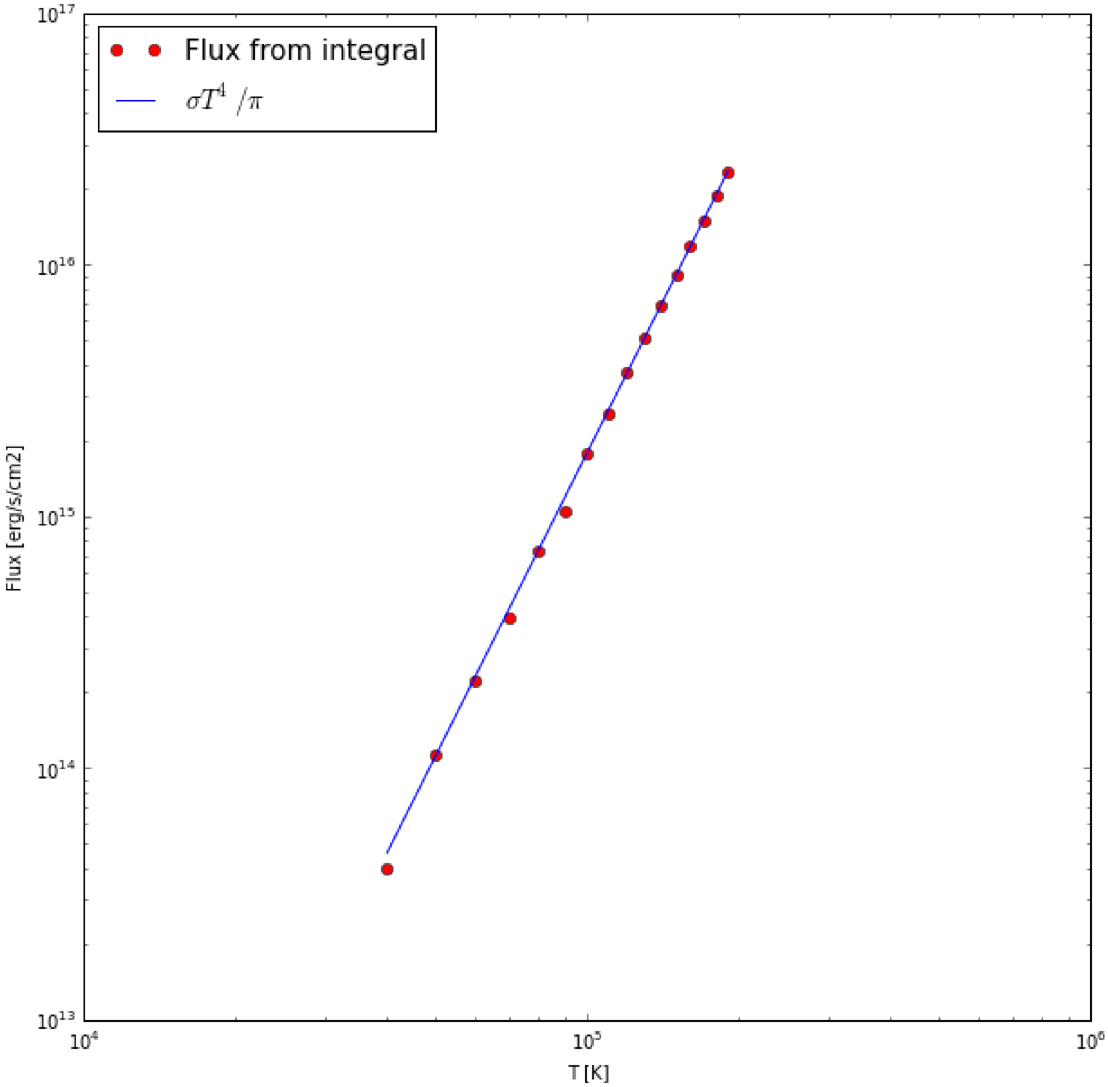
```
40000.0 3.9998068061e+13
50000.0 1.13703254293e+14
```

```
60000.0 2.22526357929e+14
70000.0 3.95696185164e+14
80000.0 7.25435743437e+14
90000.0 1.04784744936e+15
100000.0 1.79075718082e+15
110000.0 2.55483260388e+15
120000.0 3.7228781289e+15
130000.0 5.13212682334e+15
140000.0 6.93066619748e+15
150000.0 9.11406474868e+15
160000.0 1.18061135259e+16
170000.0 1.50574601651e+16
180000.0 1.89350279443e+16
190000.0 2.34906298088e+16
```

```
In [42]: # using list comprehension to compute on the fly the coordinates of the plot:
         plt.semilogy([sp.T/1e3 for sp in spectra], [sp.get_integ() for sp in spectra])
         plt.xlabel('T [kK]');
```



```
In [43]: # Better to put the values into a numpy array:
         T = np.array([sp.T for sp in spectra])
         F = np.array([sp.get_integ() for sp in spectra])

In [44]: # check that the luminosity increase like sigma.T**4
         from astropy import constants # in real life, it is better to move this to the top of the prog
         sigma = constants.sigma_sb.to('erg/(s K4 cm2)') # convert Steffen-Boltzmann constant into cgs
         fig, ax = plt.subplots(figsize=(10,10))
         ax.loglog(T, F, 'ro',label='Flux from integral')
         ax.loglog(T, sigma.value * T**4 / np.pi, label=r’$\sigma T^4 / \pi$’) # overplot sigma . T^4 /
         ax.legend(loc=2, fontsize=15)
         ax.set_xlabel(’T [K]’)
         ax.set_ylabel(’Flux [erg/s/cm2]’);
```



1.0.3 Using *args and **kwargs in functions

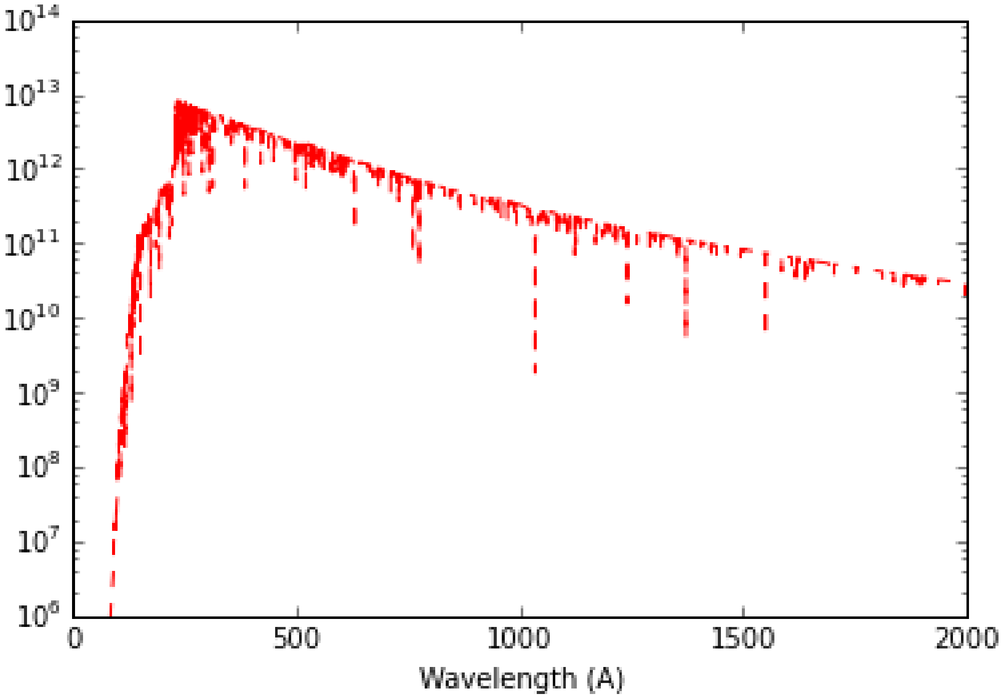
This allows to pass arguments (without and with keyword respectively) to function. No need to know what are the arguments when desining the function.

```
In [45]: class Stel_Spectrum(object):
             """
             This object downloads a file from http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/
             and is able to make some plots.
             """
             def __init__(self, filename=None, T=None, logg=None):
```

```
        """
        Initialisation of the Stel_Spectrum object.
        Parameter:
            - filename
            - T: temperature in K, e.g. 150000
            - logg: e.g. 7.5
        The wl variable is an array of wavelengths in Angstrom.
        The fl variable is the flux in erg/s/cm2/A
        """
        if filename is None:
            if T is not None and logg is not None:
                self.T = T
                self.logg = logg
                self.filename = '0{0:06.0f}_{1:.2f}_33_50_02_15.bin_0.1.gz'.format(self.T, sel
            else:
                raise TypeError("T and logg must be given")
        else:
            self.filename = filename
            self.T = float(filename.split('_')[0])
            self.logg = float(filename.split('_')[1])
        self.dlfile()
        if self.file_found:
            data = np.genfromtxt(self.filename, comments='*', names='wl, fl')
            self.fl = data['fl']
            self.wl = data['wl'] # in A
            self.fl /= 1e8 # F LAMBDA  GIVEN IN ERG/CM**2/SEC/CM -> erg/s/cm2/A
        else:
            self.wl = None
            self.fl = None

    def dlfile(self):
        """
        Downloading file if not already here. Put it in the curremt directory
        """
        if not os.path.exists(self.filename):
            print('Downloading {}'.format(self.filename))
            try:
                stel_file = urllib2.urlopen('http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He
                                            self.filename)
                output = open(self.filename,'wb')
                output.write(stel_file.read())
                output.close()
                self.file_found=True
            except:
                print('file {} not found'.format(self.filename))
                self.file_found=False
        else:
            self.file_found=True

    def plot_spr(self, ax=None, *args, **kwargs):
        """
        Plot the spectrum.
        Parameter:
            - ax: an axis (optionnal). If Noe or absent, axis is created
            - any extra parameter is passed to ax.plot
        """
        if self.wl is None:
            print(’No data to plot’)
            return
        if ax is None:
            fig, ax = plt.subplots()
        ax.plot(self.wl, self.fl,
                label=’T3={0:.0f}, logg={1}’.format(self.T/1e3, self.logg),
                *args, **kwargs) # Here are the transmissions of extra parameters to plot
        ax.set_yscale(’log’)
        ax.set_ylim(1e6, 1e14)
        ax.set_xlabel(’Wavelength (A)’)

    def print_info(self):
        """
        Print out the filename and the number of points
        """
        print self.__repr__()

    def __repr__(self):
        """
        This is what is used when calling "print <obj>" or <obj> ENTER
        """
        if self.wl is None:
            return’Filename: {0}, No data’.format(self.filename)
        else:
            return’Filename: {0}, number of points: {1}’.format(self.filename, len(self.wl))

    def get_integ(self):
        """
        Return the integral of Flambda over lambda, in erg/s/cm2
        """
        if self.wl is None:
            print(’No data’)
            return None
        return simps(self.fl, self.wl) # perform the integral
```

```
In [46]: sp1 = Stel_Spectrum(T=100000, logg=5)
         print sp1
         fig, ax = plt.subplots()
         sp1.plot_spr(ax, ’r’, linestyle=’--’) # any extra argument is passed to plot
```

```
Filename: 0100000_5.00_33_50_02_15.bin_0.1.gz, number of points: 19951
```



1.0.4 Class variables or class attributes

They are known and share between all the instanciations of a class. Usefull to count the number of objects of the same class.

```
In [48]: class Stel_Spectrum(object):
             """
             This object downloads a file from http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/
             and is able to make some plots.
             """

             spec_count = 0 # This attibute is at the level of the class, not of the object.
             def __init__(self, filename=None, T=None, logg=None):
                 """
                 Initialisation of the Stel_Spectrum object.
                 Parameter:
                     - filename
                     - T: temperature in K, e.g. 150000
                     - logg: e.g. 7.5
                 The wl variable is an array of wavelengths in Angstrom.
                 The fl variable is the flux in erg/s/cm2/A
                 """
                 if filename is None:
                     if T is not None and logg is not None:
                         self.T = T
                         self.logg = logg
                         self.filename = '0{0:06.0f}_{1:.2f}_33_50_02_15.bin_0.1.gz'.format(self.T, sel
                     else:
```

```
                raise TypeError("T and logg must be given")
        else:
            self.filename = filename
            self.T = float(filename.split('_')[0])
            self.logg = float(filename.split('_')[1])
        self.dlfile()
        if self.file_found:
            data = np.genfromtxt(self.filename, comments='*', names='wl, fl')
            self.fl = data['fl']
            self.wl = data['wl'] # in A
            self.fl /= 1e8 # F LAMBDA  GIVEN IN ERG/CM**2/SEC/CM -> erg/s/cm2/A
        else:
            self.wl = None
            self.fl = None
        Stel_Spectrum.spec_count += 1

    def dlfile(self):
        """
        Downloading file if not already here. Put it in the curremt directory
        """
        if not os.path.exists(self.filename):
            print('Downloading {}'.format(self.filename))
            try:
                stel_file = urllib2.urlopen('http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He-
                                            self.filename)
                output = open(self.filename,'wb')
                output.write(stel_file.read())
                output.close()
                self.file_found=True
            except:
                print('file {} not found'.format(self.filename))
                self.file_found=False
        else:
            self.file_found=True

    def plot_spr(self, ax=None, *args, **kwargs):
        """
        Plot the spectrum.
        Parameter:
            - ax: an axis (optionnal). If None or absent, axis is created
            - any extra parameter is passed to ax.plot
        """
        if self.wl is None:
            print('No data to plot')
            return
        if ax is None:
            fig, ax = plt.subplots()
        ax.plot(self.wl, self.fl,
                label='T3={0:.0f}, logg={1}'.format(self.T/1e3, self.logg),
                *args, **kwargs) # Here are the transmissions of extra parameters to plot
        ax.set_yscale('log')
        ax.set_ylim(1e6, 1e14)
        ax.set_xlabel('Wavelength (A)')
```

```
             def print_info(self):
                 """
                 Print out the filename and the number of points
                 """
                 print self.__repr__()

             def __repr__(self):
                 """
                 This is what is used when calling "print <obj>" or <obj> ENTER
                 """
                 if self.wl is None:
                     return'Filename: {0}, No data'.format(self.filename)
                 else:
                     return'Filename: {0}, number of points: {1}'.format(self.filename, len(self.wl))

             def get_integ(self):
                 """
                 Return the integral of Flambda over lambda, in erg/s/cm2
                 """
                 if self.wl is None:
                     print('No data')
                     return None
                 return simps(self.fl, self.wl) # perform the integral

             def __del__(self):
                 Stel_Spectrum.spec_count -= 1
```

```
In [49]: sp1 = Stel_Spectrum(T=100000, logg=5)
         sp2 = Stel_Spectrum(T=100000, logg=6)
         sp3 = Stel_Spectrum(T=100000, logg=7)
         print Stel_Spectrum.spec_count
         print sp1.spec_count
```

```
3
3
```

```
In [50]: del sp1
         print Stel_Spectrum.spec_count
```

```
2
```

```
In [51]: for logg in (5, 6, 7, 8):
             sp = Stel_Spectrum(T=100000, logg=logg)
         print Stel_Spectrum.spec_count # the deleted objects are not count (it would have been the cas
```

```
3
```

```
In [52]: sp = 3
         print Stel_Spectrum.spec_count
```

```
2
```

That can be used for example to change a value for a class variable used everywhere (e.g. the reddening correction to be applied to all the spectra before plotting them. . .)

1.0.5 Adding functionnality to classes and objects (monkey-patch)

```
In [53]: sp1 = Stel_Spectrum(T=100000, logg=5) # Instanciation of a class
         def print_ok(): # defining a function outside the class
             print 'ok'
         sp1.print_ok = print_ok # include the function to the object
         sp1.print_ok() # works, the instance is modified
```

```
ok
```

```
In [55]: def print_ok2(self):
             print self.T
         Stel_Spectrum.print_ok2 = print_ok2 # include the function to the class
         sp1.print_ok2() # the class has been modified, and it applies immediatly on the already instat
```

```
100000
```

```
In [56]: sp2 = Stel_Spectrum(T=100000, logg=6)
         sp2.print_ok2()
         sp2.print_ok() # ERROR : the print_ok was only included to an object, not to the class
```

```
100000


        ---------------------------------------------------------------------------
    AttributeError                            Traceback (most recent call last)

        <ipython-input-56-9b9e27dbd5fd> in <module>()
          1 sp2 = Stel_Spectrum(T=100000, logg=6)
          2 sp2.print_ok2()
    ----> 3 sp2.print_ok() # ERROR : the print_ok was only included to an object, not to the class


        AttributeError: 'Stel_Spectrum' object has no attribute 'print_ok'
```

```
In [57]: def print_T(self): # self could have been named otherwise
             print self.T
         sp1.print_T = print_T # adding to the object
         sp1.print_T() # ERROR: the object has no self reference
```

```
        ---------------------------------------------------------------------------
    TypeError                                 Traceback (most recent call last)

        <ipython-input-57-22b0360f0c63> in <module>()
          2     print self.T
          3 sp1.print_T = print_T # adding to the object
    ----> 4 sp1.print_T() # ERROR: the object has no self reference


        TypeError: print_T() takes exactly 1 argument (0 given)
```

```
In [58]: Stel_Spectrum.print_T = print_T # Adding to the class
         sp2 = Stel_Spectrum(T=100000, logg=5) # works immediatly
         sp2.print_T()
```

```
100000
```

```
In [59]: def print_T(self): # changing the definition of print_T
             print('T={}'.format(self.T))
         sp2.print_T() # does NOT affect the class nor the object
```

```
100000
```

```
In [60]: Stel_Spectrum.print_T = print_T # Adding to the class
         sp2.print_T() # now it changes the behaviour
```

```
T=100000
```

```
In [61]: # The same function can also be called passing the object. Good for testing and developping
         print_T(sp2)
```

```
T=100000
```

The monkey patch is usefull for testing purpose. When everything is working fine, better to incorporate the method to the class definition.

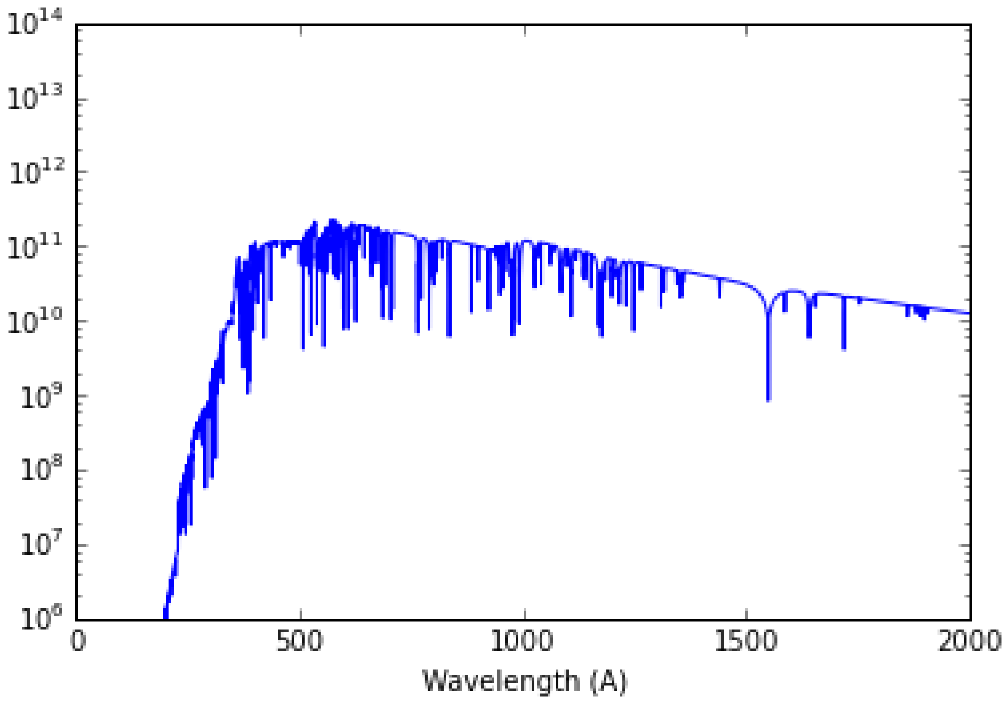
1.0.6 Class inheritance

This is very easy to create a new class from an existing one.

```
In [62]: class Stel_Sp2(Stel_Spectrum):

             def __init__(self, *args, **kwds):
                 super(Stel_Sp2, self).__init__(*args, **kwds)

             def print_logg(self):
                 print('logg = {}'.format(self.logg))
```

```
In [63]: print filename
         sp2 = Stel_Sp2(filename)
         sp2.plot_spr()
         sp2.print_logg()
```

```
0050000_7.00_33_50_02_15.bin_0.1.gz
logg = 7.0
```



```
In [64]: # One can even overwrite methods
         class Stel_Sp2(Stel_Spectrum):

             def __init__(self, *args, **kwds):
                 super(Stel_Sp2, self).__init__(*args, **kwds)

             def print_logg(self):
                 print(’logg = {}’.format(self.logg))

             def print_info(self):
                 """
                 Print out new information
                 """
                 print(’File: {}, T={}, logg={}’.format(filename, self.T, self.logg))

         sp1 = Stel_Spectrum(T=100000, logg=5)
         sp2 = Stel_Sp2(T=100000, logg=5)
         sp1.print_info()
         sp2.print_info()
```

```
Filename: 0100000_5.00_33_50_02_15.bin_0.1.gz, number of points: 19951
File: 0050000_7.00_33_50_02_15.bin_0.1.gz, T=100000, logg=5
```

One can mix inheritances, using multiple parents to generate children (!). A lot of examples on the web…

1.0.7 Properties

It is sometimes useful to have things that behave like attributes (print A.b, A.c = 2), but that call some routines. This is the goal of the properties.

For example here, we want the data to be updated if one change T or logg.

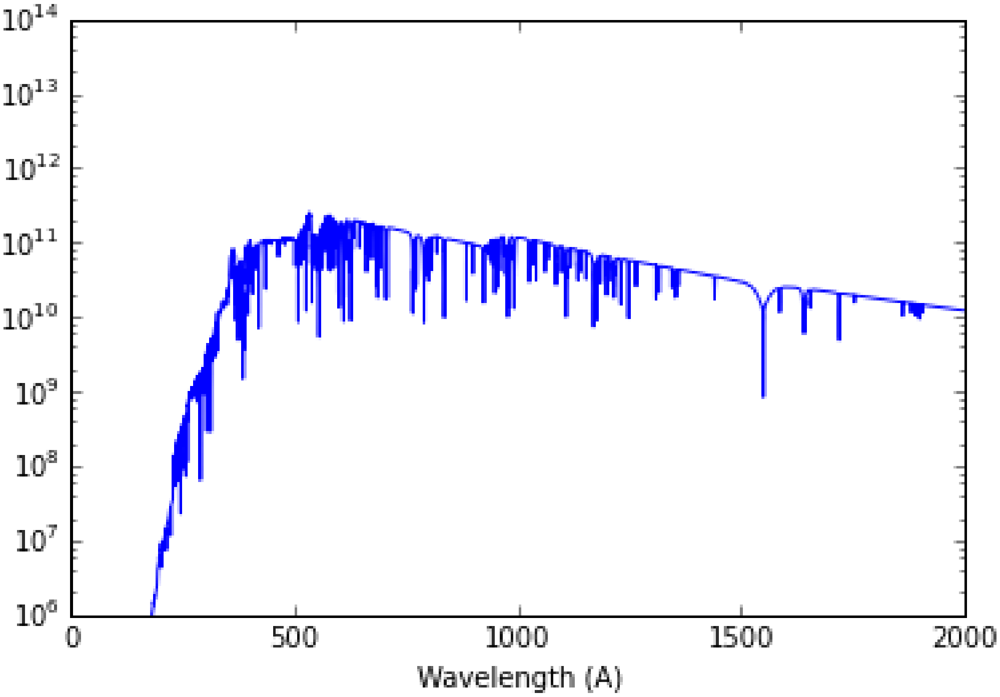
```
In [65]: class Stel_Spectrum(object):
             """
             This object downloads a file from http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He+C+N+O/
             and is able to make some plots.
             """

             spec_count = 0 # This attibute is at the level of the class, not of the object.
             def __init__(self, filename=None, T=None, logg=None, verbose=False):
                 """
                 Initialisation of the Stel_Spectrum object.
                 Parameter:
                     - filename
                     - T: temperature in K, e.g. 150000
                     - logg: e.g. 7.5
                     - verbose: if True, some info are printed out
                 The wl variable is an array of wavelengths in Angstrom.
                 The fl variable is the flux in erg/s/cm2/A
                 The variables T and logg are properties: changing them will reload the data
                 """
                 self.verbose = verbose
                 if filename is None:
                     if T is not None and logg is not None:
                         self.__T = T # We need to initialize the hidden values, as logg is still not d
                         self.logg = logg
                         self.filename = '0{0:06.0f}_{1:.2f}_33_50_02_15.bin_0.1.gz'.format(self.T, sel
                     else:
                         raise TypeError("T and logg must be given")
                 else:
                     self.filename = filename
                     self.__T = float(filename.split('_')[0]) # We need to initialize the hidden values
                     self.logg = float(filename.split('_')[1])
                 Stel_Spectrum.spec_count += 1
                 if self.verbose:
                     print('Instantiation done')

             def dlfile(self):
                 """
                 Downloading file if not already here. Put it in the current directory
                 """
                 if not os.path.exists(self.filename):
                     if self.verbose:
                         print('Downloading {}'.format(self.filename))
                     try:
                         stel_file = urllib2.urlopen('http://astro.uni-tuebingen.de/~rauch/TMAF/NLTE/He
                                                     self.filename)
                         output = open(self.filename,'wb')
                         output.write(stel_file.read())
                         output.close()
                         self.file_found=True
```

```
            except:
                if self.verbose:
                    print('file {} not found'.format(self.filename))
                self.file_found=False
        else:
            if self.verbose:
                print('{} already on disk'.format(self.filename))
            self.file_found=True

    def read_data(self):
        """
        read the data from the file
        """
        if self.file_found:
            data = np.genfromtxt(self.filename, comments='*', names='wl, fl')
            self.fl = data['fl']
            self.wl = data['wl'] # in A
            self.fl /= 1e8 # F LAMBDA  GIVEN IN ERG/CM**2/SEC/CM -> erg/s/cm2/A
            if self.verbose:
                print('Read data from {}'.format(self.filename))
        else:
            if self.verbose:
                print('file not found {}'.format(self.filename))
            self.wl = None
            self.fl = None

    def plot_spr(self, ax=None, *args, **kwargs):
        """
        Plot the spectrum.
        Parameter:
            - ax: an axis (optionnal). If Noe or absent, axis is created
            - any extra parameter is passed to ax.plot
        """
        if self.wl is None:
            print('No data to plot')
            return
        if ax is None:
            fig, ax = plt.subplots()
        ax.plot(self.wl, self.fl,
                label='T3={0:.0f}, logg={1}'.format(self.T/1e3, self.logg),
                *args, **kwargs) # Here are the transmissions of extra parameters to plot
        ax.set_yscale('log')
        ax.set_ylim(1e6, 1e14)
        ax.set_xlabel('Wavelength (A)')

    def get_integ(self):
        """
        Return the integral of Flambda over lambda, in erg/s/cm2
        """
        if self.wl is None:
            print('No data')
            return None
        return simps(self.fl, self.wl) # perform the integral
```

```
def __getT(self):
    return self.__T

def __setT(self, value):
    if not isinstance(value, (int, long, float)): # check the type of the input
        raise TypeError(’T must be an integer or a float’)
    if float(value) not in np.linspace(40000, 190000, 16): # check the value of the input
        raise ValueError(’T value must be between 40000 and 190000K, by 10000K steps’)
    elif self.__T != value:
        self.__T = value
        self.filename = ’0{0:06.0f}_{1:.2f}_33_50_02_15.bin_0.1.gz’.format(self.T, self.log
        self.dlfile() # will download new data
        self.read_data() # will update the data

def __delT(self):
    print(’T is needed’)

T = property(__getT, __setT, __delT, "Stellar effective temperature")

def __getlogg(self):
    return self.__logg

def __setlogg(self, value):
    try:
        self.__logg
    except:
        self.__logg = -1
    if not isinstance(value, (int, long, float)):
        raise TypeError(’logg must be an integer or a float’)
    if float(value) not in (-1., 5., 6., 7. ,8., 9.):
        raise ValueError(’Error, logg must be 6, 7, 8, or 9’)
        self.__logg = None
    elif self.__logg != value:
        self.__logg = value
        self.filename = ’0{0:06.0f}_{1:.2f}_33_50_02_15.bin_0.1.gz’.format(self.T, self.log
        self.dlfile() # will download new data
        self.read_data() # will update the data

def __dellogg(self):
    print(’logg is needed’)

logg = property(__getlogg, __setlogg, __dellogg, "Stellar logg")

def print_info(self):
    """
    Print out the filename and the number of points
    """
    print self.__repr__()

def __repr__(self):
    """
    This is what is used when calling "print <obj>" or <obj> ENTER
    """
    if self.wl is None:
        return'Filename: {0}, No data'.format(self.filename)
    else:
        return'Filename: {0}, number of points: {1}'.format(self.filename, len(self.wl))

def __del__(self):
    Stel_Spectrum.spec_count -= 1
```

In [66]:
```
sp2 = Stel_Spectrum(T=50000, logg=6, verbose=True)
print sp2.T
sp2.plot_spr()
```

```
0050000_6.00_33_50_02_15.bin_0.1.gz already on disk
Read data from 0050000_6.00_33_50_02_15.bin_0.1.gz
Instantiation done
50000
```



In [67]:
```
# The properties are used to control type and values of the inputs
sp2.T = 1800
```

```
    ---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)

    <ipython-input-67-e0d29c1a86f4> in <module>()
      1 # The properties are used to control type and values of the inputs
----> 2 sp2.T = 1800
```

```
        <ipython-input-65-4f518246dde0> in __setT(self, value)
        109             raise TypeError('T must be an integer or a float')
        110         if float(value) not in np.linspace(40000, 190000, 16): # check the value of the inpu
    --> 111             raise ValueError('T value must be between 40000 and 190000K, by 10000K steps')
        112         elif self.__T != value:
        113             self.__T = value


        ValueError: T value must be between 40000 and 190000K, by 10000K steps
```

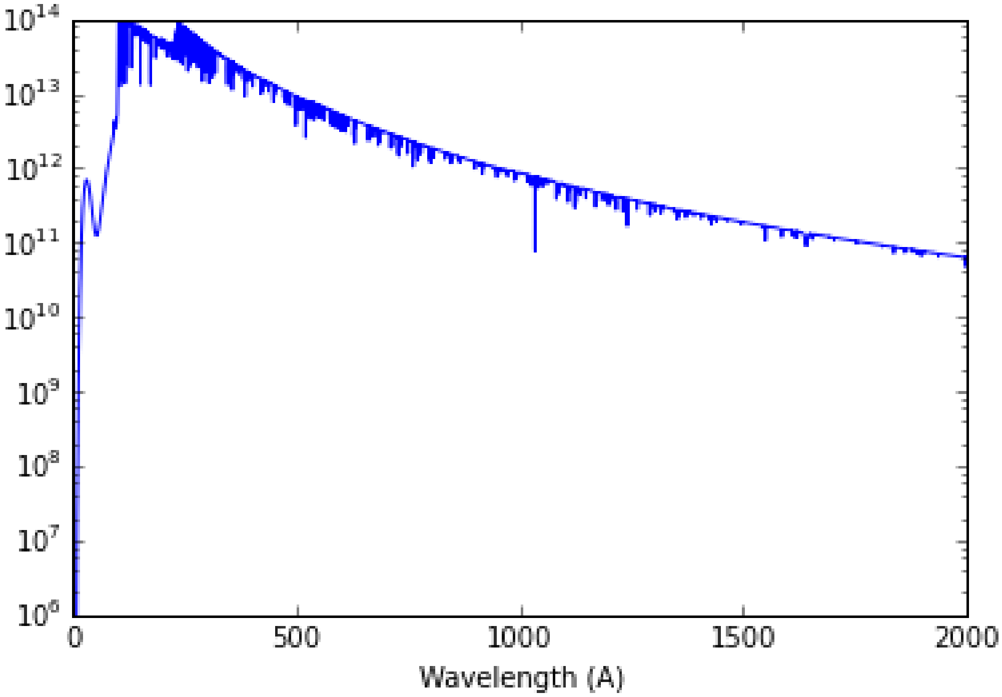
```
In [68]: sp2.logg = 'tralala'
```

```
        ---------------------------------------------------------------------------
    TypeError                                 Traceback (most recent call last)

        <ipython-input-68-cd5b2befd4fb> in <module>()
    ----> 1 sp2.logg = 'tralala'


        <ipython-input-65-4f518246dde0> in __setlogg(self, value)
        130             self.__logg = -1
        131         if not isinstance(value, (int, long, float)):
    --> 132             raise TypeError('logg must be an integer or a float')
        133         if float(value) not in (-1., 5., 6., 7. ,8., 9.):
        134             raise ValueError('Error, logg must be 6, 7, 8, or 9')


        TypeError: logg must be an integer or a float
```

```
In [69]: sp2.T = 180000
         sp2.logg = 7
         print sp2
         print sp2.T
```

```
0180000_6.00_33_50_02_15.bin_0.1.gz already on disk
Read data from 0180000_6.00_33_50_02_15.bin_0.1.gz
0180000_7.00_33_50_02_15.bin_0.1.gz already on disk
Read data from 0180000_7.00_33_50_02_15.bin_0.1.gz
Filename: 0180000_7.00_33_50_02_15.bin_0.1.gz, number of points: 19951
180000
```

```
In [70]: sp2.plot_spr()
```


10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{7}
10^{6}
0
500
1000
1500
2000
Wavelength (A)