Some_examples

May 25, 2017

```
In [1]: %matplotlib inline
        import numpy as np
        import matplotlib.pyplot as plt
        import pyneb as pn
```

0.1 Simple diagnostic diagram

In the following cell, we will write a file that contains observed data on the disk

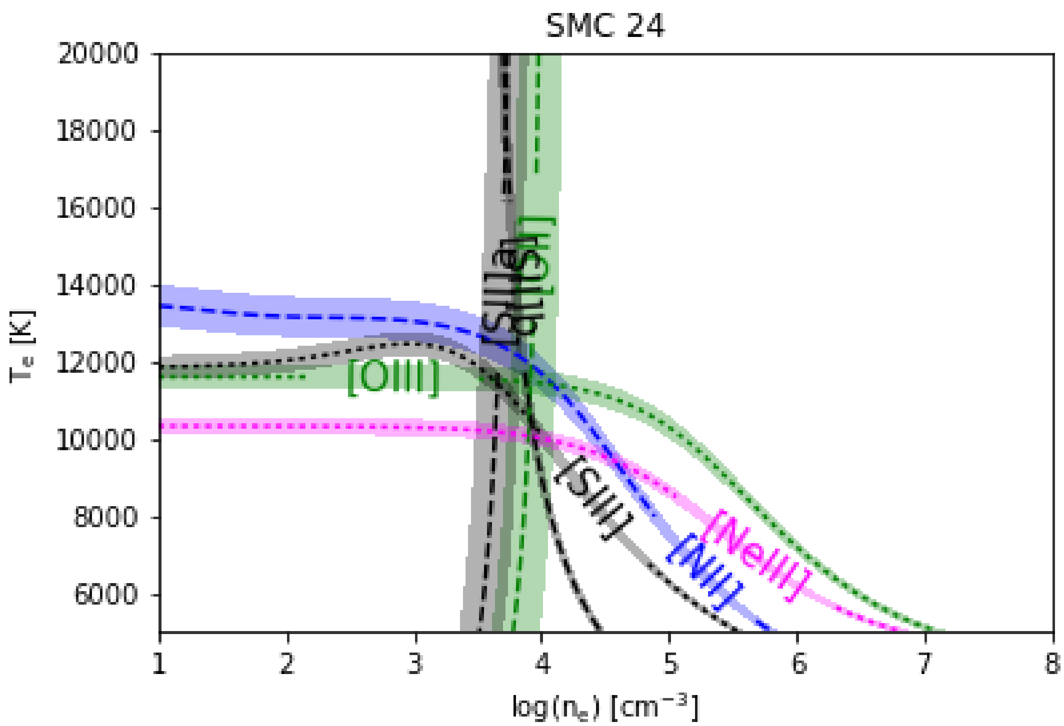
```
In [2]: %%writefile smc24.dat
        NAME SMC_24
        cHbeta      0.047
        S4_10.5m    7.00000
        Ne2_12.8m   8.3000
        Ne3_15.6m 34.10
        S3_18.7m   10.
        O2_3726A   39.700
        O2_3729A   18.600
        Ne3_3869A 18.90
        Ne3_3968A   6.4
        S2_4069A    0.85
        S2_4076A    0.450
        O3_4363A    4.36
        O3_5007A 435.09
        N2_5755A    0.510000
        S3_6312A    0.76
        O1_6300A    1.69
        O1_6364A    0.54
        N2_6548A    6.840000
        N2_6584A   19.00
        S2_6716A    1.220000
        S2_6731A    2.180000
        Ar3_7136A   4.91
        O2_7319A+    6.540000
        O2_7330A+    5.17
        S3_33.6m     8.
```

```
Writing smc24.dat
```

```
In [6]: # Diagnostic plot

        ### General settings
        # Setting verbosity level. Enter pn.my_logging? for details
        pn.log_.level = 2 # set this to 3 to have more details

        # Adopt an extinction law
        extinction_law = 'CCM89'

        # Define the data file
        obs_data = 'smc24.dat'

        # Define plot title
        title = 'SMC 24'

        ### Read and deredden observational data
        # define an Observation object and assign it to name 'obs'
        obs = pn.Observation()

        # fill obs with data read from file obs_data, with lines varying across row
        obs.readData(obs_data, fileFormat='lines_in_rows', err_default=0.05)

        # deredden data with Cardelli's law
        obs.extinction.law = extinction_law
        obs.correctData()

        ### Include the diagnostics of interest
        # instantiate the Diagnostics class
        diags = pn.Diagnostics()
        # include in diags the relevant line ratios
        diags.addDiag([
                      '[NII] 5755/6584',
                      '[OII] 3726/3729',
                      '[OIII] 4363/5007',
                      '[SII] 6731/6716',
                      '[SII] 4072+/6720+',
                      '[SIII] 6312/18.7m',
                      '[NeIII] 3930+/15.6m',
                      ])
        diags.addClabel('[SII] 6731/6716', '[SII]a')
        diags.addClabel('[SII] 4072+/6720+', '[SII]b')

        # Create the emission maps to be compared to the observation data (some ove
        emisgrids = pn.getEmisGridDict(atom_list=diags.getUniqueAtoms(), den_max=1e
```

```
### Plot
# Create the contour plot as the intersection of tem-den emission maps with
diags.plot(emisgrids, obs)

# Place the title
plt.title(title)

# Display the plot
plt.show()

#The observed ratio can be automatically extracted from an Observation obje
Te, Ne = diags.getCrossTemDen('[NII] 5755/6548', '[SII] 6731/6716', obs=obs
print('Te = {0:5.0f} K, Ne = {1:7.1f} cm-1'.format(Te, Ne))
```

```
warng EmissionLine: line 33.6m for atom S3 not valid
```




```
Te = 12071 K, Ne =  4619.6 cm-1
```

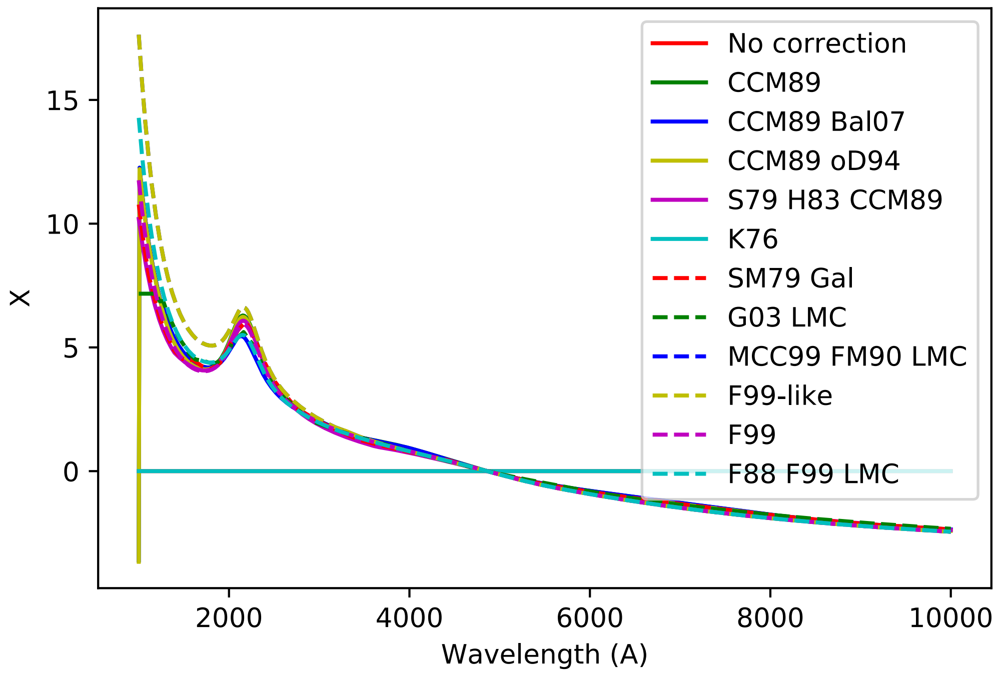
0.2 Extinction

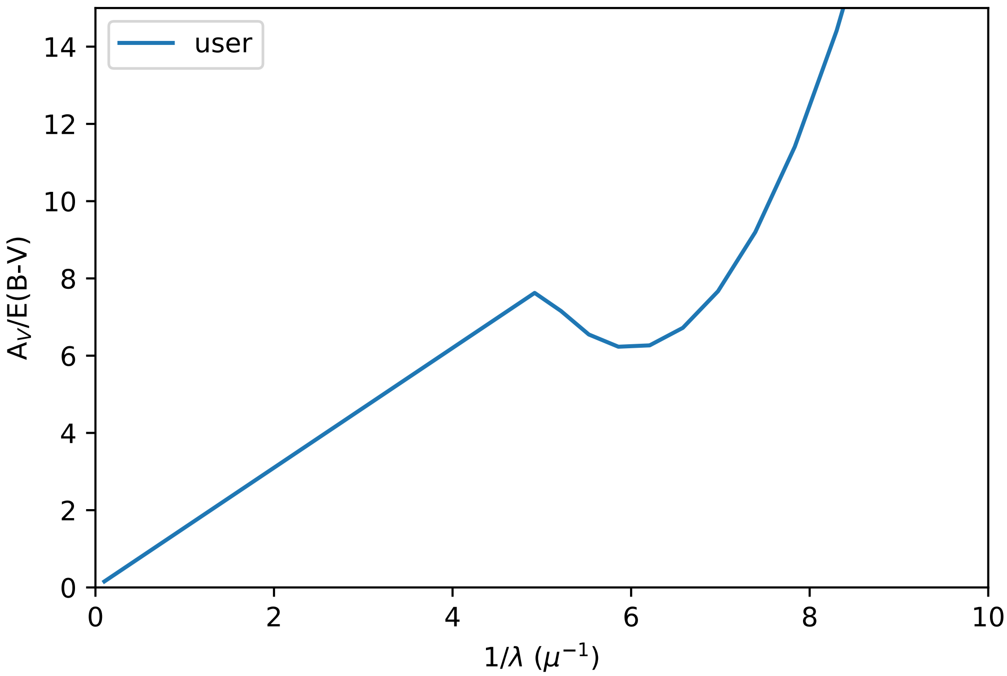
```
In [8]: # Sample extinction in PyNeb
        # shows how to display available extinction laws, select one or define a ne
```

```
# and do some simple dereddening calculations
# Further examples can be found in other sample scripts
%config InlineBackend.figure_format = 'svg'

# Convert wavelength to x
def x(wave):
    return 10000. / wave

# Define an extinction law (to be used below)
def my_X(wave, par=0):
    x = 10000. / wave
    Rv = 3.1
    X_lin = x/2. # linear part of the extinction law
    X_bump = 0.5*x**2. -6*x + 20. # bump part of the extinction law
    return Rv*np.where(x<5., X_lin, X_bump)

# Define a reddening correction object
RC = pn.RedCorr()

# List the available laws
#RC.printLaws()

# Plot the available laws
plt.figure(figsize=(10,10))
RC.plot(laws='all')
plt.show()

# Choose the one we intend to use
RC.law = 'CCM89'
# or define a new one
RC.UserFunction = my_X
RC.law = 'user'

# Plot the selected law as a function of x
# Define an array in lambda to do the plot
wave= np.logspace(2.5, 5, 100)
# Plot commands
fig = plt.figure()
ax = fig.add_subplot(111)
ax.set_ylim([0, 15])
ax.set_xlim([0, 10])
ax.plot(x(wave), my_X(wave), label='%s' % (RC.law))
plt.xlabel('1/$\lambda$ ($\mu^{-1}$)')
plt.ylabel('A$_V$/E(B-V)')
plt.legend(loc='upper left')
plt.show()

# Correct observed line ratios
```

```
wave1 = 5007
I_obs1 = 4.0
wave2 = 4686
I_obs2 = 0.10

# Correct based on the given law and the observed Ha/Hb ratio
RC = pn.RedCorr(law='CCM89')
I_obs_HaHb = 3.5
I_theo_HaHb = 2.86
RC.setCorr(I_obs_HaHb / I_theo_HaHb, 6563., 4861.)
print('Correction based on the given law and the observed Ha/Hb ratio:')
print(str(wave1) + ': I_obs =', I_obs1, ' I_dered =', I_obs1 * RC.getCorrHb
print(str(wave2) + ': I_obs =', I_obs2, ' I_dered =', I_obs2 * RC.getCorrHb

# Correct based on the given law and c(Hb)
RC = pn.RedCorr(law='CCM89', cHbeta=0.3)
print('\nCorrection based on the given law and c(Hbeta):')
print(str(wave1) + ': I_obs =', I_obs1, ' I_dered =', I_obs1 * RC.getCorrHb
print(str(wave2) + ': I_obs =', I_obs2, ' I_dered =', I_obs2 * RC.getCorrHb
```

```
<matplotlib.figure.Figure at 0x122b5da58>
```



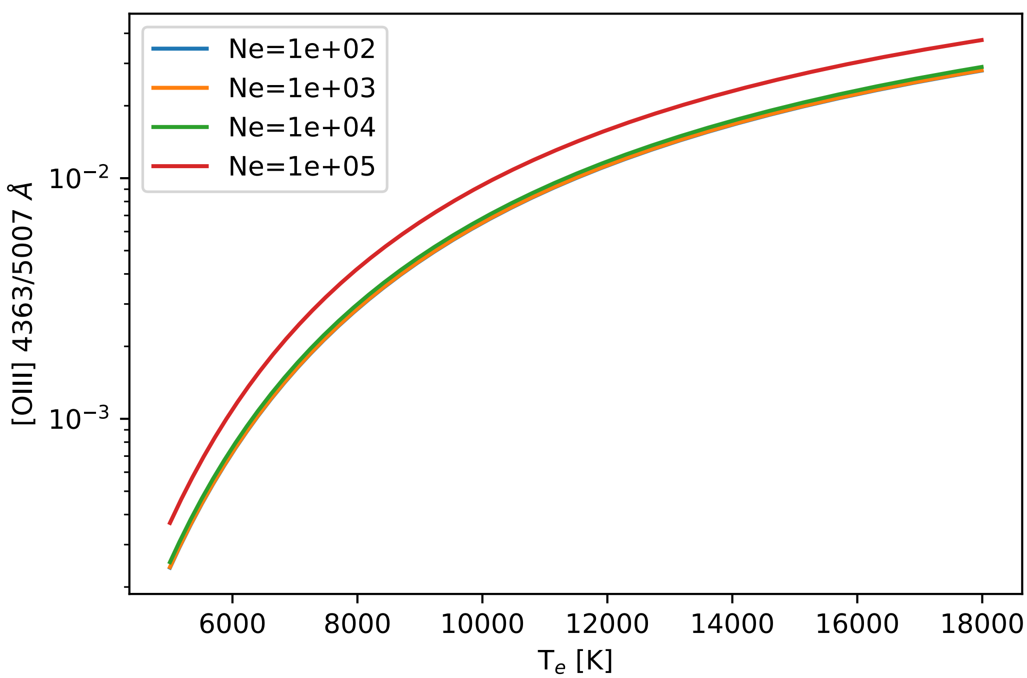



```
Correction based on the given law and the observed Ha/Hb ratio:
5007: I_obs = 4.0  I_dered = 3.89887770727
4686: I_obs = 0.1  I_dered = 0.103424700345

Correction based on the given law and c(Hbeta):
5007: I_obs = 4.0  I_dered = 3.89706278973
4686: I_obs = 0.1  I_dered = 0.103488047966
```

0.3 Line ratio and diagnostics

```
In [12]: """
         Sample PyNeb script
         Plots the [O III] 4363/5007 ratio as a function of Te for several Ne value
         """

         # Set high verbosity level to keep track of atom creation
         pn.log_.level = 1 # Set to 3 if you want all the atoms to be printed out

         # Create a collection of atoms - a bit overkill if we just need O III
         adict = pn.getAtomDict()

         # Lower verbosity level
         pn.log_.level = 2
```

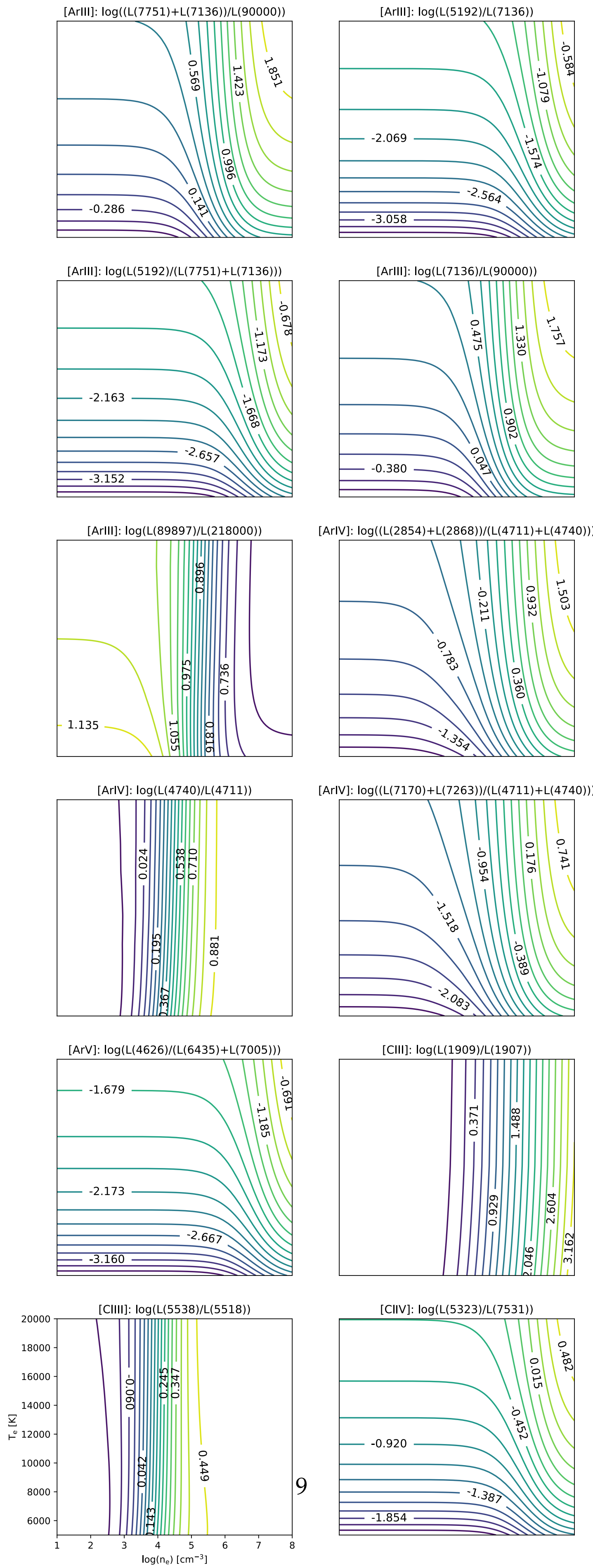
```
# Function to compute line ratio
def line_ratio(atom, wave1, wave2, tem, den):
    emis1 = adict[atom].getEmissivity(tem, den, wave = wave1)
    emis2 = adict[atom].getEmissivity(tem, den, wave = wave2)
    return emis1 / emis2

# Define array of Te
tem = np.arange(5000, 18000, 30)

# Plot
plt.figure(1)
for den in [1e2, 1e3, 1e4, 1e5]:
    plt.semilogy(tem, line_ratio('O3', 4363, 5007, tem, den), label = 'Ne=
plt.xlabel('T$_e$ [K]')
plt.ylabel(r'[OIII] 4363/5007 $\AA$')
plt.legend(loc=2)

plt.show()
```



0.4 Contour plots

In [14]:
```
# Plot the contour diagram of the selected diagnostics
# Warning: it takes a long time to plot the 80 contours
from pyneb.core.diags import diags_dict
```

```
Nx = 2
Ny = 6 # must be changed to 30 to obtain all the plots
pn.log_.level=1
AA = pn.getAtomDict(OmegaInterp='Linear')
    # Loop over all the diags stored in pn.core.diags.diags_dict
fig, axes = plt.subplots(Ny, Nx, figsize=(5*Nx, 5*Ny))
i_ax = 0
for diag in np.sort(list(diags_dict.keys())):
    atom, diag_eval, err = diags_dict[diag]
    # Skip Fe III as they are so many
    if (atom in AA) and (atom != 'Fe3'):
        if i_ax < Nx*Ny:
            ax = axes.ravel()[i_ax]
            grid = pn.EmisGrid(atomObj=AA[atom])
            grid.plotContours(to_eval=diag_eval, ax=ax)
            if i_ax != (Nx * (Ny-1)):
                ax.get_xaxis().set_visible(False)
                ax.get_yaxis().set_visible(False)
            i_ax += 1
plt.show()
```


[ArIII]: log((L(7751)+L(7136))/L(90000))
0.569
1.423
1.851
0.996
0.141
-0.286
[ArIII]: log(L(5192)/L(7136))
-0.584
-1.079
-2.069
-1.574
-2.564
-3.058
[ArIII]: log(L(5192)/(L(7751)+L(7136)))
-0.678
-1.173
-2.163
-1.668
-2.657
-3.152
[ArIII]: log(L(7136)/L(90000))
0.475
1.330
1.757
0.902
0.047
-0.380
[ArIII]: log(L(89897)/L(218000))
0.896
0.975
0.736
1.135
1.055
0.816
[ArIV]: log((L(2854)+L(2868))/(L(4711)+L(4740)))
-0.211
0.932
1.503
-0.783
0.360
-1.354
[ArIV]: log(L(4740)/L(4711))
0.024
0.538
0.710
0.195
0.881
0.367
[ArIV]: log((L(7170)+L(7263))/(L(4711)+L(4740)))
-0.954
0.176
0.741
-1.518
-0.389
-2.083
[ArV]: log(L(4626)/(L(6435)+L(7005)))
-1.679
-0.691
-1.185
-2.173
-2.667
-3.160
[CIII]: log(L(1909)/L(1907))
0.371
1.488
0.929
2.604
3.162
2.046
[ClIII]: log(L(5538)/L(5518))
-0.060
0.245
0.347
0.042
0.449
0.143
T_e [K]
$\log(n_e)$ [cm^{-3}]
[ClIV]: log(L(5323)/L(7531))
0.482
0.015
-0.452
-0.920
-1.387
-1.854

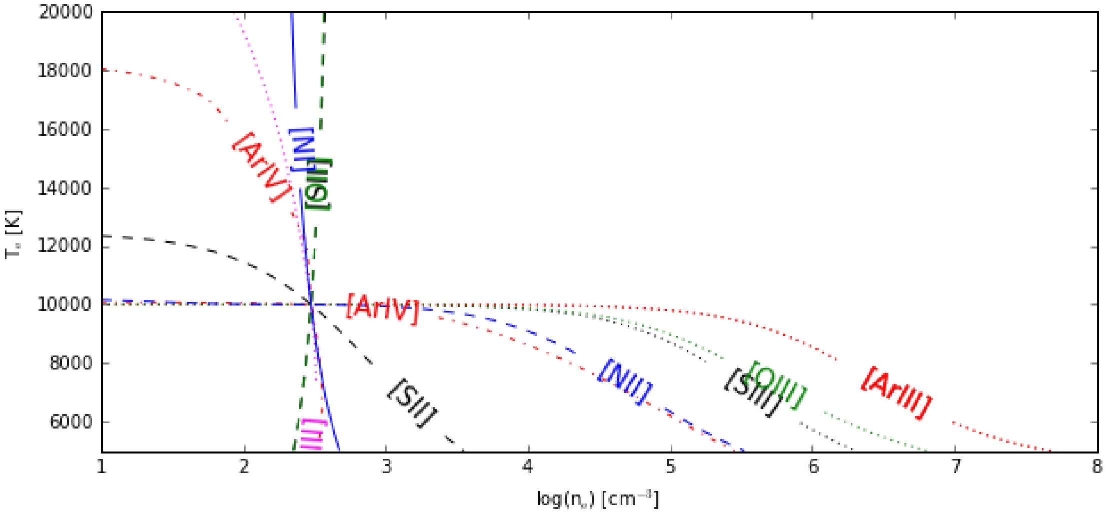
0.5 Diagnostic diagrams of a 2-components region

```
In [3]: # Analysis plot of a simple two-component model, meant to illustrate the bi
        # from assuming that the region is homogeneous in density
        # First, an emission region made up of two different subregions is modelled
        # each with a different mass and density. The resulting overall emissivity
        # Second, the region is analyzed as if it were a homogeneous region

        from pyneb.utils.misc import parseAtom

        def plot_2comp(tem1=1e4, tem2=1e4, dens1=3e2, dens2=5e5, mass1=1, mass2=5e-

            # List of diagnostics used to analyze the region
            diags = pn.Diagnostics()

            diags.addDiag(['[NI] 5198/5200',
                           '[NII] 5755/6548',
                            '[OII] 3726/3729',
                            '[OII] 3727+/7325+',
                            '[OIII] 4363/5007',
                            '[ArIII] 5192/7136',
                            '[ArIII] 5192/7300+',
                            '[ArIV] 4740/4711',
                            '[ArIV] 7230+/4720+',
                            '[SII] 6731/6716',
                            '[SII] 4072+/6720+',
                            '[SIII] 6312/9069',
                            '[ClIII] 5538/5518'
                            ])
            """
            for diag in pn.diags_dict:
                if diag[0:7] != '[FeIII]':
                    diags.addDiag(diag)
                    print 'Adding', diag

            diags.addClabel('[SIII] 6312/9069', '[SIII]A')
            diags.addClabel('[OIII] 4363/5007', '[OIII]A')
            """
            # Define all the ions that are involved in the diagnostics
            adict = diags.atomDict
            pn.log_.message('Atoms built')

            obs = pn.Observation(corrected = True)
            for atom in adict:
                # Computes all the intensities of all the lines of all the ions con
```

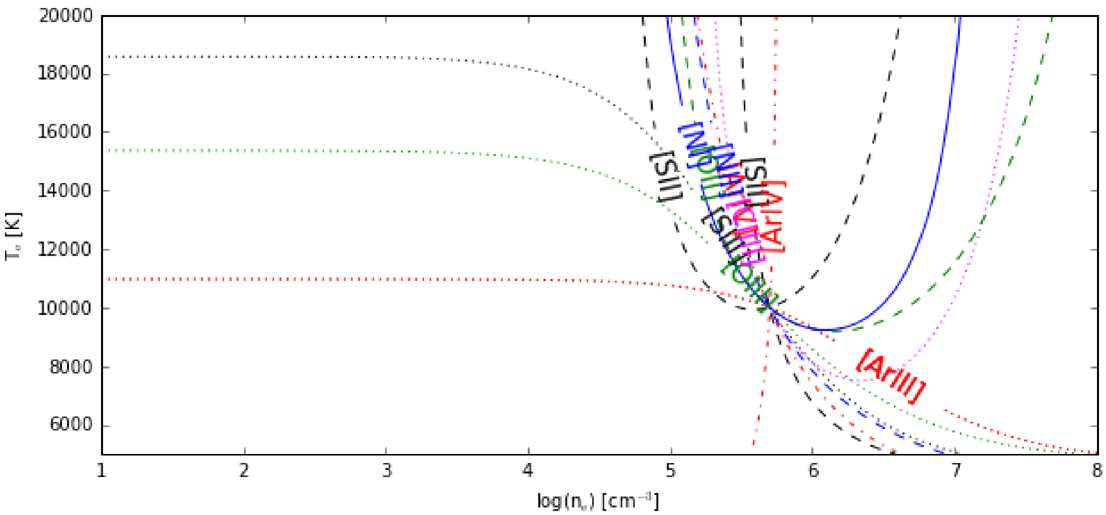
```
                for line in pn.LINE_LABEL_LIST[atom]:
                    if line[-1] == 'm':
                        wavelength = float(line[:-1])*1e4
                    else:
                        wavelength = float(line[:-1])
                    elem, spec = parseAtom(atom)
                    try:
                        intens1 = adict[atom].getEmissivity(tem1, dens1, wave = wav
                        intens2 = adict[atom].getEmissivity(tem2, dens2, wave = wav
                        obs.addLine(pn.EmissionLine(elem, spec, wavelength,
                                                    obsIntens=[intens1, intens2, inter
                                                    obsError=[0.0, 0.0, 0.0]))
                    except:
                        pass
            pn.log_.message('Virtual observations computed')
            emisgrids = pn.getEmisGridDict(atomDict=adict)

            pn.log_.message('EmisGrids available')

            # Produce a diagnostic plot for each of the two regions and another one
            # (misanalyzed) overall region
            f, axes = plt.subplots(3,1, figsize=(10,15))
            for i_obs in (0,1,2):
                diags.plot(emisgrids, obs, i_obs=i_obs, ax=axes[i_obs])

        plot_2comp(tem1=1e4, tem2=1e4, dens1=3e2, dens2=5e5, mass1=1, mass2=5e-4)
        plt.show()
```

```
warng EmissionLine: line 6.4m for atom Ar3 not valid
warng EmissionLine: line 1.0m for atom S2 not valid
ERROR Atom O3: The number of levels 5 does not allow getting this emissivity (6-1).
ERROR Atom O3: The number of levels 5 does not allow getting this emissivity (6-2).
ERROR Atom O3: The number of levels 5 does not allow getting this emissivity (6-3).
ERROR Atom O3: The number of levels 5 does not allow getting this emissivity (6-4).
ERROR Atom O3: The number of levels 5 does not allow getting this emissivity (6-5).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (6-1).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (6-2).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (6-5).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (8-1).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (7-2).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (7-5).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (8-1).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (8-2).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (8-4).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (7-6).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (8-6).
ERROR Atom O2: The number of levels 5 does not allow getting this emissivity (8-7).
warng getEmisGridDict: Emission map not found: ./pypics//emis_Ar3.pypic
```

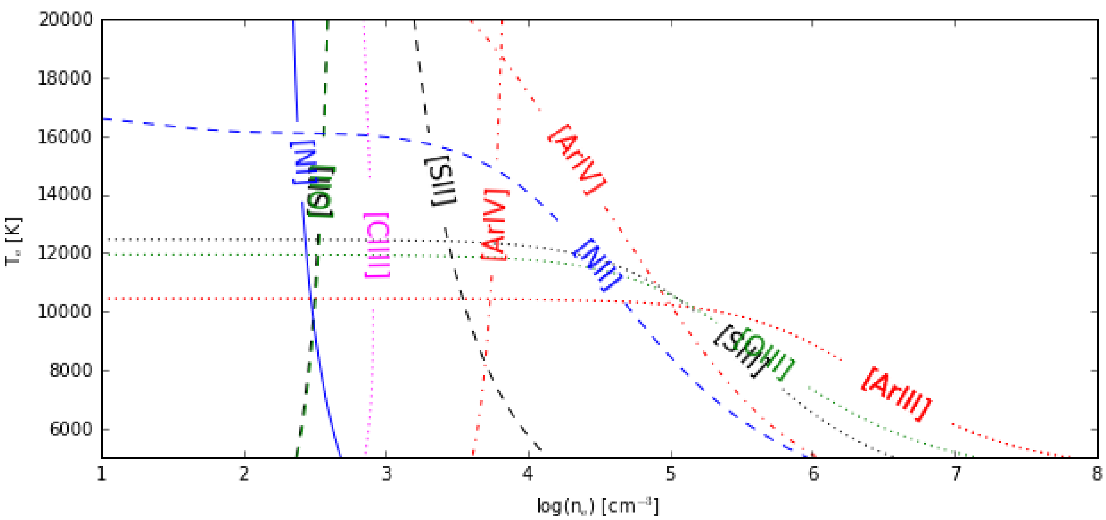
```
warng getEmisGridDict: Emission map not found: ./pypics//emis_Ar4.pypic
warng getEmisGridDict: Emission map not found: ./pypics//emis_N1.pypic
warng getEmisGridDict: Emission map not found: ./pypics//emis_Cl3.pypic
L(6312)/L(9069)
L(5192)/L(7136)
L(5192)/(L(7751)+L(7136))
(L(7170)+L(7263))/(L(4711)+L(4740))
L(4363)/L(5007)
(L(4069)+L(4076))/(L(6716)+L(6731))
L(4740)/L(4711)
L(6731)/L(6716)
(L(3726)+L(3729))/(B("7319A+")+B("7330A+"))
warng Observation: No line for O2_7319A+ from NoneNone at wavelength None (blend=Fa
warng Diagnostics: A line in diagnostic (L(3726)+L(3729))/(B("7319A+")+B("7330A+"))
L(5538)/L(5518)
L(3726)/L(3729)
L(5755)/L(6548)
I(3, 1)/I(2, 1)
L(6312)/L(9069)
L(5192)/L(7136)
L(5192)/(L(7751)+L(7136))
(L(7170)+L(7263))/(L(4711)+L(4740))
L(4363)/L(5007)
(L(4069)+L(4076))/(L(6716)+L(6731))
L(4740)/L(4711)
L(6731)/L(6716)
(L(3726)+L(3729))/(B("7319A+")+B("7330A+"))
warng Observation: No line for O2_7319A+ from NoneNone at wavelength None (blend=Fa
warng Diagnostics: A line in diagnostic (L(3726)+L(3729))/(B("7319A+")+B("7330A+"))
L(5538)/L(5518)
L(3726)/L(3729)
L(5755)/L(6548)
I(3, 1)/I(2, 1)
L(6312)/L(9069)
L(5192)/L(7136)
L(5192)/(L(7751)+L(7136))
(L(7170)+L(7263))/(L(4711)+L(4740))
L(4363)/L(5007)
(L(4069)+L(4076))/(L(6716)+L(6731))
L(4740)/L(4711)
L(6731)/L(6716)
(L(3726)+L(3729))/(B("7319A+")+B("7330A+"))
warng Observation: No line for O2_7319A+ from NoneNone at wavelength None (blend=Fa
warng Diagnostics: A line in diagnostic (L(3726)+L(3729))/(B("7319A+")+B("7330A+"))
L(5538)/L(5518)
L(3726)/L(3729)
L(5755)/L(6548)
I(3, 1)/I(2, 1)
```



[ArV]
[ArIV]
[SII]
[NII]
[SIII]
[OIII]
[ArIII]
Tₑ [K]
log(nₑ) [cm⁻³]



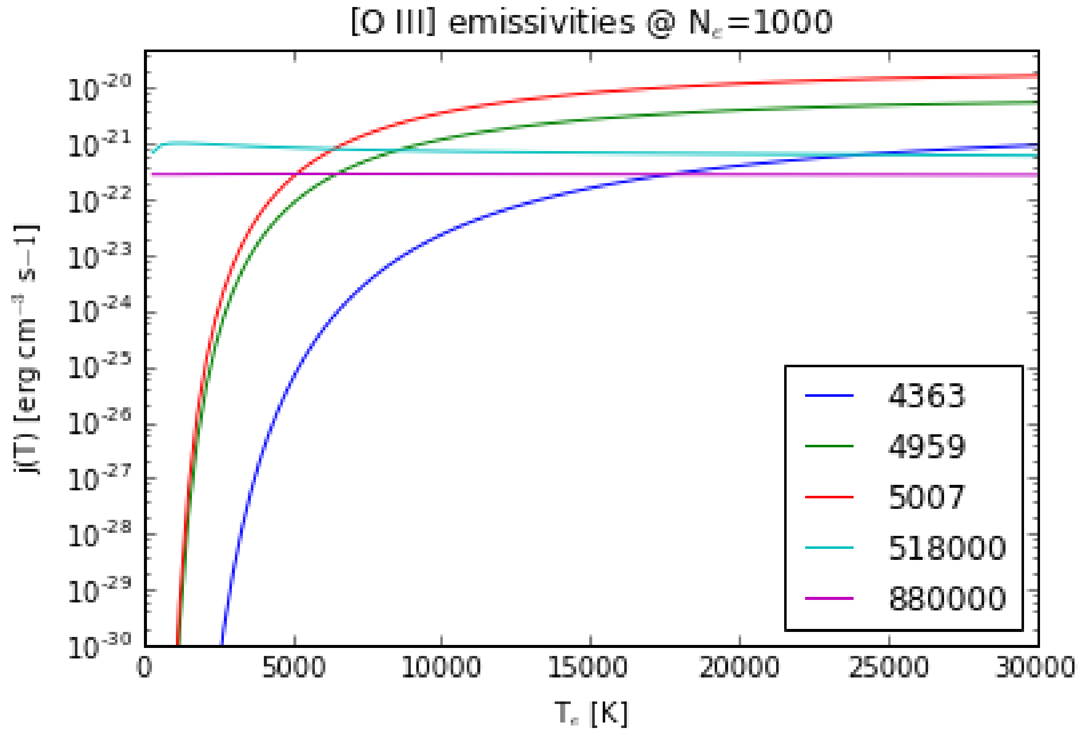
[SII]
[SIII]
[ArIV]
[OIII]
[ArIII]
Tₑ [K]
log(nₑ) [cm⁻³]



[ArV]
[SII]
[ArIV]
[CIII]
[NII]
[SIII]
[OIII]
[ArIII]
Tₑ [K]
log(nₑ) [cm⁻³]

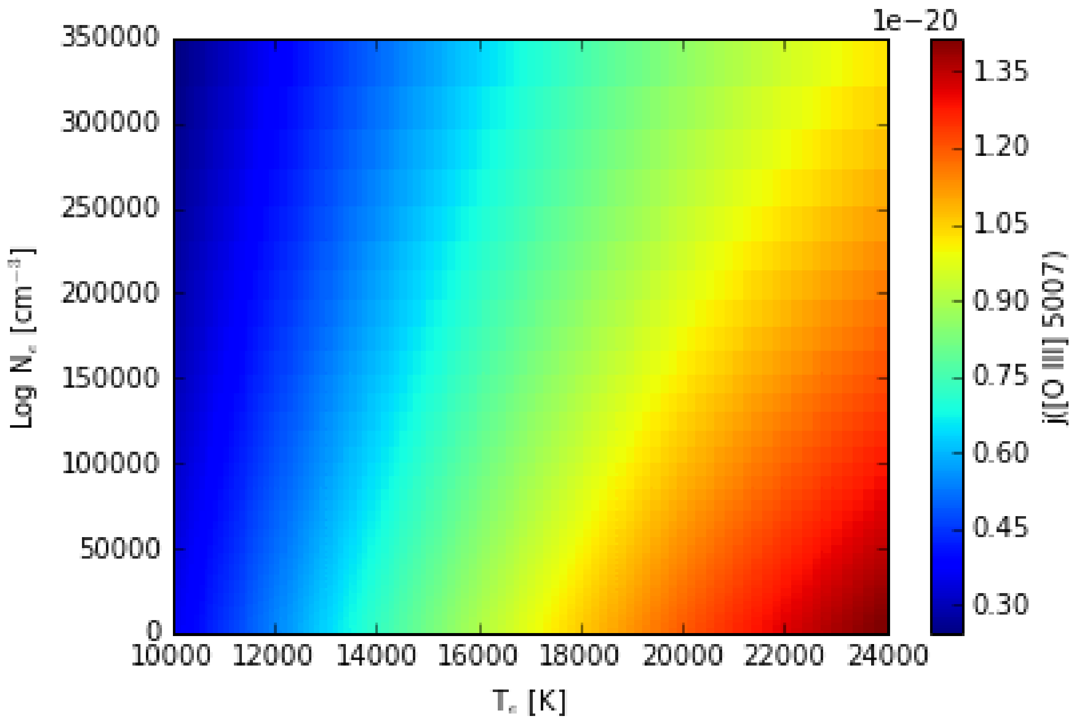
0.6 Plot emissivities

In [4]:
```
# Emissivity plot
# For a quick and dirty plot, see also o3.plotEmiss

# Atom creation and definition of physical conditions
o3=pn.Atom('O', 3)
tem=np.arange(100)*300+300
den = 1000

# Comment the second if you want all the lines to be plotted
lineList=o3.lineList
lineList=[4363, 4959, 5007, 518000, 880000]

# Plot
fig = plt.figure()
ax = fig.add_subplot(111)
ax.set_ylim([1.e-30, 5e-20])

for line in lineList:
    y=o3.getEmissivity(tem, den, wave=line)
    plt.semilogy(tem, y,  label="{:.0f}".format(line))

plt.xlabel('T$_e$ [K]')
plt.ylabel("j(T) [erg cm$^{-3}$ s${-1}$]")
plt.legend(loc='lower right')
plt.title('[O III] emissivities @ N$_e$={:.0f}'.format(den))
plt.show()
```



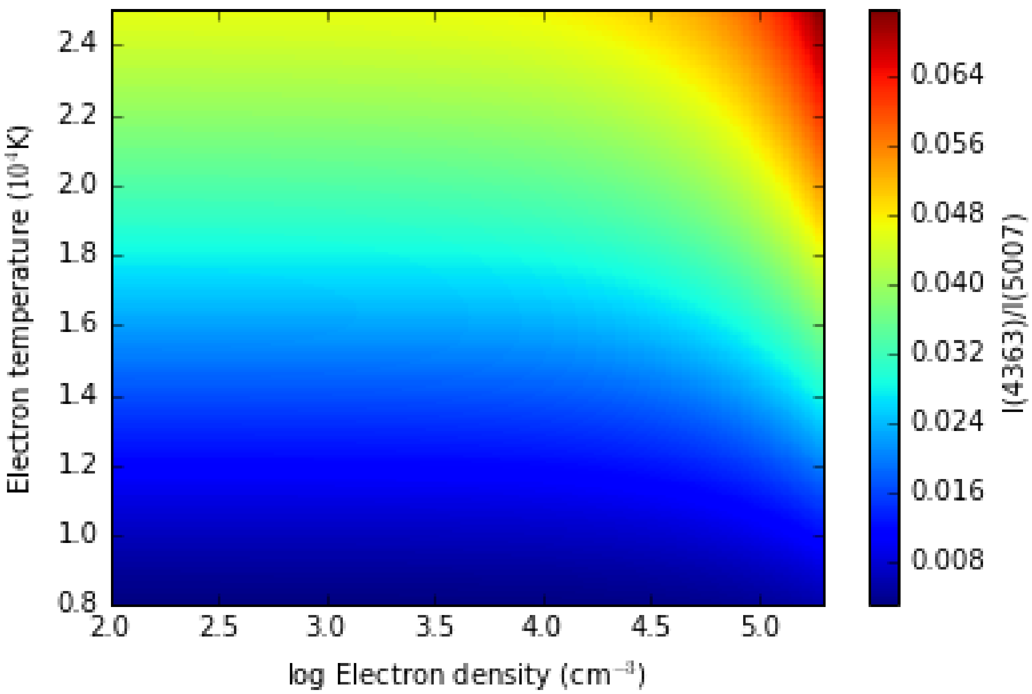
0.7 Emissivity map of a line

```
In [6]: # Emissivity map of [O III] 5007

        # Imports
        import pyneb as pn
        import matplotlib.pyplot as plt

        # Compute the grid
        map=pn.EmisGrid('O', 3, tem_min=10000, tem_max=23999.00, den_min=100, den_m
        X=map.tem2D
        Y=map.den2D
        Z=map.getGrid(wave=5007)

        # Plot
        emap = plt.pcolor(X, Y, Z)
        cbar = plt.colorbar(emap)
        cbar.set_label('j([O III] 5007)')
        plt.xlabel(r'T$_e$ [K]')
        plt.ylabel(r'Log N$_e$ [cm$^{-3}$]')
        plt.show()
```



0.8 Emissivity map of a line ratio

In [7]:
```
# Emissivity map of the [O III] 4363/5007 line ratio

# Imports
import pyneb as pn

# Compute the grid
o3grid = pn.EmisGrid('O', 3, n_tem=200, n_den=200, tem_min=8000, tem_max=25

# Plot the grid
o3grid.plotImage('L(4363)/L(5007)', cblabel='I(4363)/I(5007)');
```



2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
Electron temperature (10^4K)
2.0
2.5
3.0
3.5
4.0
4.5
5.0
log Electron density (cm^{-3})
0.064
0.056
0.048
0.040
0.032
0.024
0.016
0.008
I(4363)/I(5007)


```
In [ ]:
```