Fitting the continuum flux of astronomical spectra

Original data can be obtained from:

[http://james.as.arizona.edu/~psmith/Fermi/DATA/individual.html (http://james.as.arizona.edu/~psmith/Fermi/DATA/individual.html)](http://james.as.arizona.edu/~psmith/Fermi/DATA/individual.html)

Science Goals:

Explore some spectropolarimetry data (spectrum and polarized flux spectrum) of a $\gamma-$ray bright blazar and determine if the variability in emission is dominated by the accretion disk (non-polarized component) or the jet (polarized component).

1) Import flux spectra and polarized flux spectra from the FITS files they are contained in

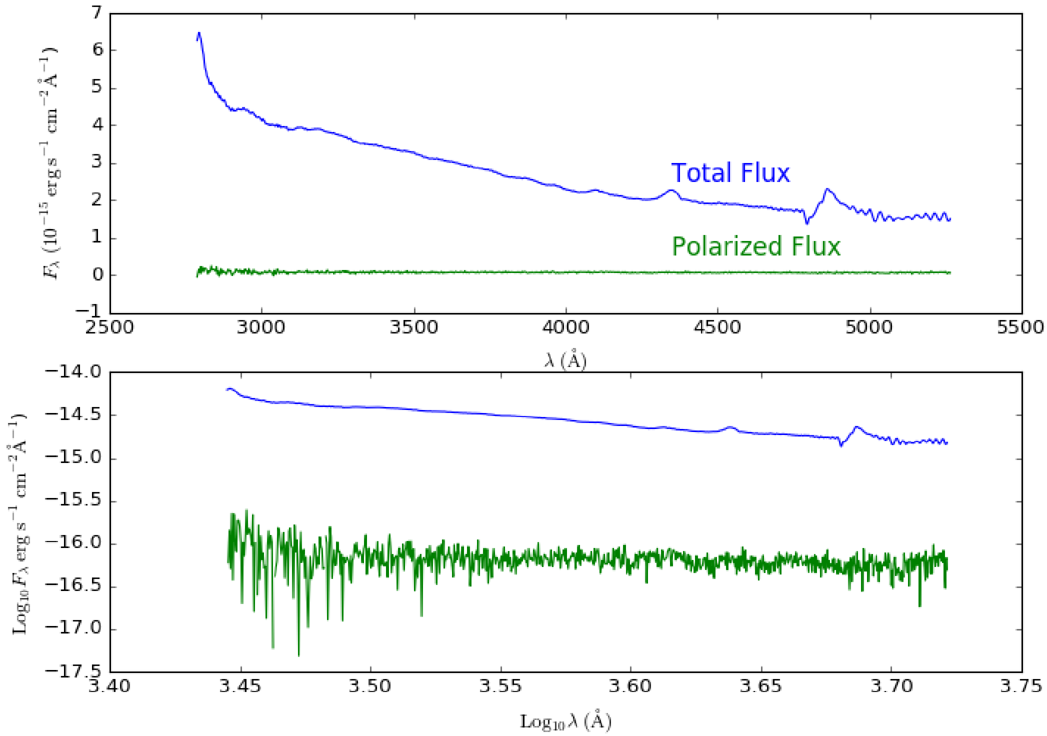
In [1]:
```
import pandas as pd
direc = './spectra'
from spectra_df import spectra_df
fspec, pspec = spectra_df(direc)
```

Plotting the original spectrum and the polarized flux spectrum informs the decision for the type of model to use.

The physics suggest a linear combination of power-laws

$$F_\nu = A\nu^{-\alpha} + B\nu^{-\beta}$$

In [2]:
```
from plot_fig_one import plot_fig_one
%matplotlib nbagg
plot_fig_one(fspec, pspec, 7)
```

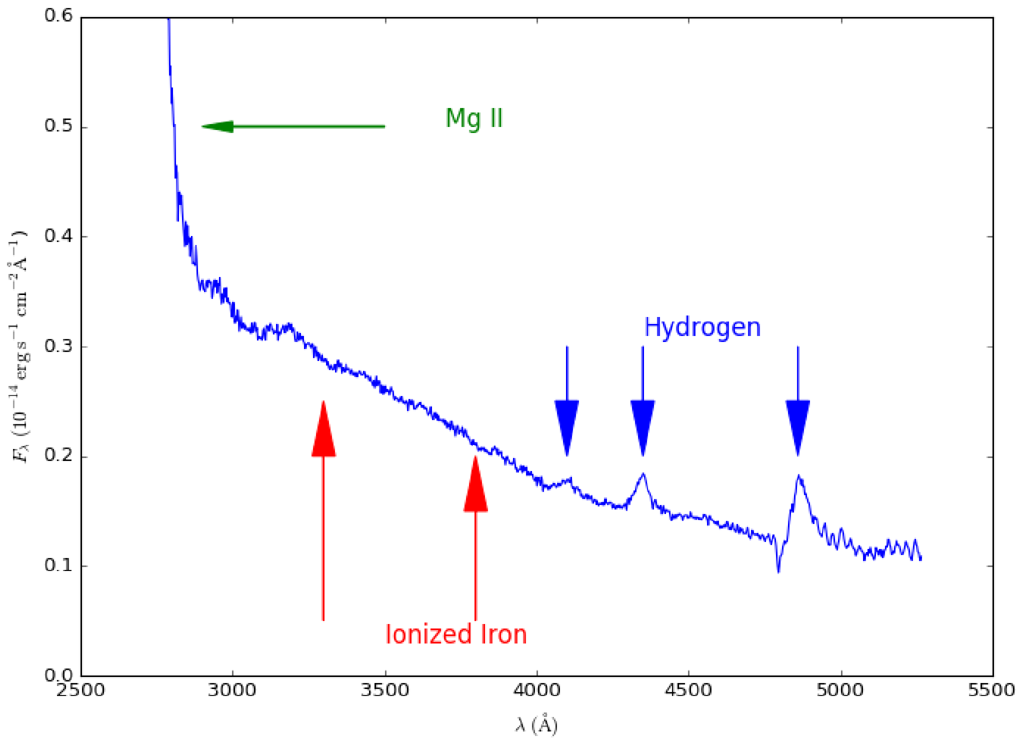


2) Emission lines must be removed before we can fit the continuum

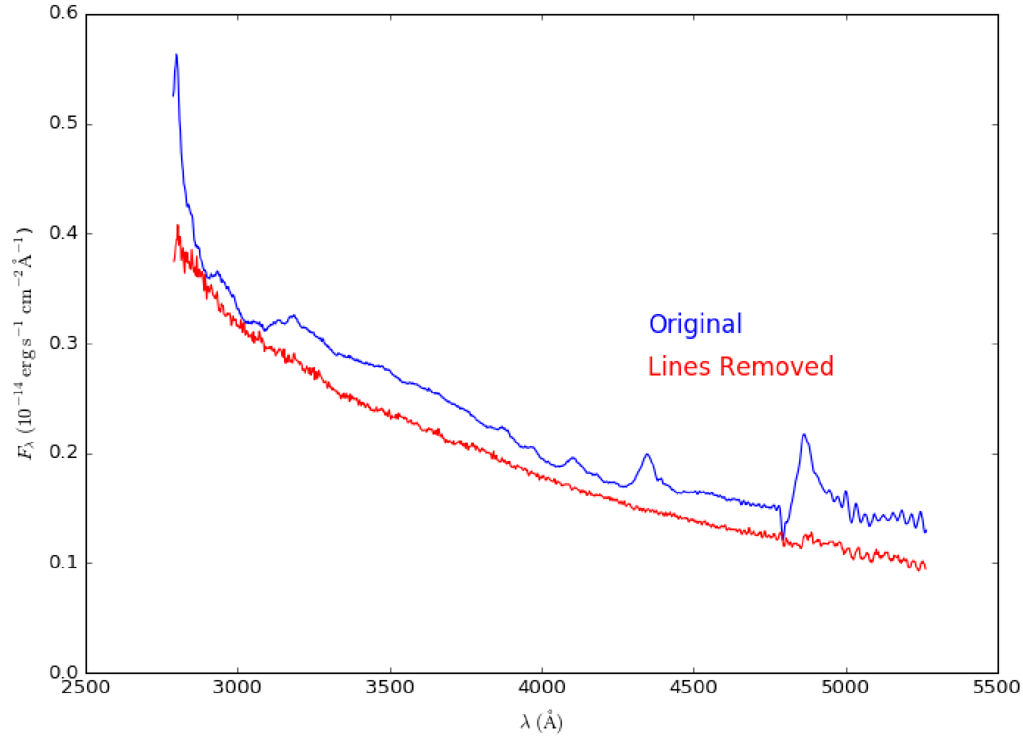
This is accomplished by using a template generated from another spectrum of the same object that covers a higher range of frequencies.

In [3]:

```
from plot_spectrum import plot_spectrum
plot_spectrum(fspec, pspec,1)
```



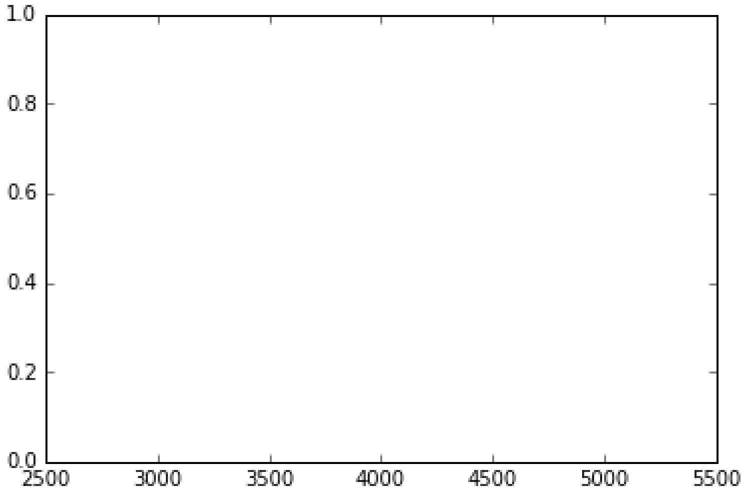
In [4]:
```
import numpy as np
from remove_template import remove_template
from plot_spectrum_linesrm import plot_spectrum_linesrm
spec = fspec
template, newframe = remove_template('template.txt', fspec)
plot_spectrum_linesrm(fspec, newframe, 15)
```



All of the spectra animated

In [5]:
```
%matplotlib inline

import numpy as np
import matplotlib.pyplot as plt

from matplotlib import animation, rc
from IPython.display import HTML
```

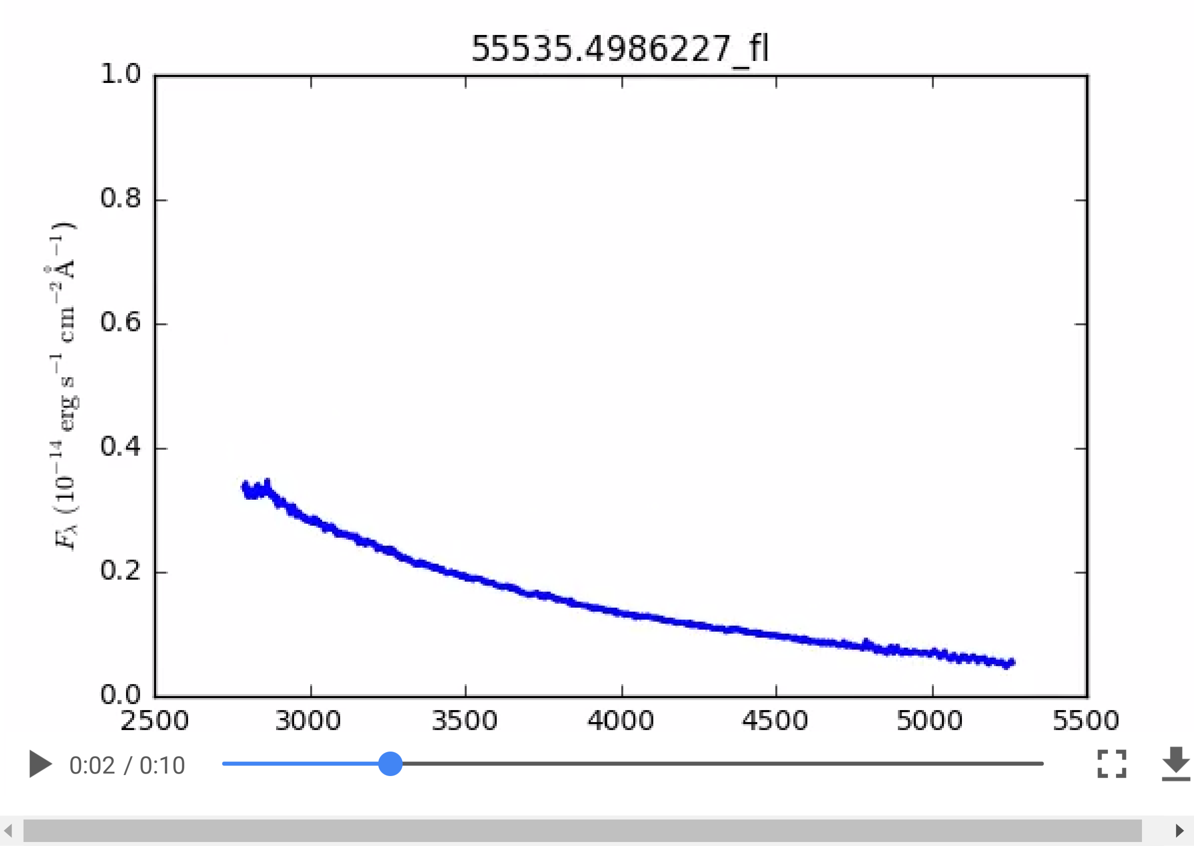
In [6]:
```
fig, ax = plt.subplots()

ax.set_xlim(( 2500, 5500))
ax.set_ylim((0, 1.0))

line, = ax.plot([], [], lw=2)
```



In [7]:
```
def init():
    line.set_data([], [])
    return (line,)

def animate(i):
    x = newframe['wl']
    ynorm = 1.0e-14
    y = newframe[newframe.columns[i]]/ynorm
    line.set_data(x, y)
    ax.set_ylabel(r'$F_\lambda \;
(10^{'+str(np.trunc(np.log10(ynorm)).astype(int)) +r'} \; \mathrm{erg
 \; s}^{-1}\;\mathrm{cm}^{-2}\mathrm{\AA}^{-1}$)')
    ax.set_xlabel(r'$\lambda \;(\mathrm{\AA})$')
    ax.set_title(fspec.columns.values[i])
    return (line,)
```

In [8]:
```
anim = animation.FuncAnimation(fig, animate, init_func=init,
                               frames=51, interval=200, blit=True)

HTML(anim.to_html5_video())
```

Out[8]:



3) Fit a power-law to the flux spectrum and polarized flux spectrum

$$F_\lambda = A\lambda^{-\alpha}$$

In [9]:
```
import lmfit
from lmfit import  Model, minimize, Parameters
from find_plaw_resid import find_plaw_resid
import numpy as np
from fit_power_law import fit_power_law
```

```
/usr/local/lib/python2.7/dist-packages/IPython/html.py:14: ShimWarnin
g: The `IPython.html` package has been deprecated since IPython 4.0.
 You should import from `notebook` instead. `IPython.html.widgets` ha
s moved to `ipywidgets`.
  "`IPython.html.widgets` has moved to `ipywidgets`.", ShimWarning)
```

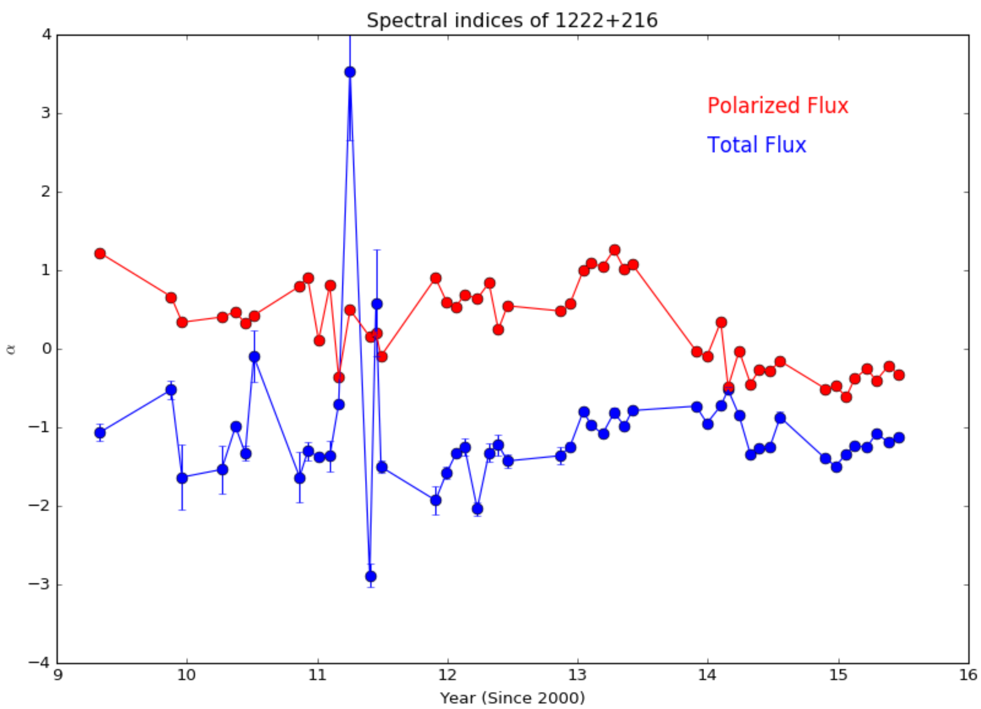
In [10]:

```
fluxplaw_params = fit_power_law(newframe, 13)
print fluxplaw_params['alpha'].value
polplaw_params = fit_power_law(pspec, 13)
print polplaw_params['alpha'].value
```

```
1.59618518278
0.584950439172
```

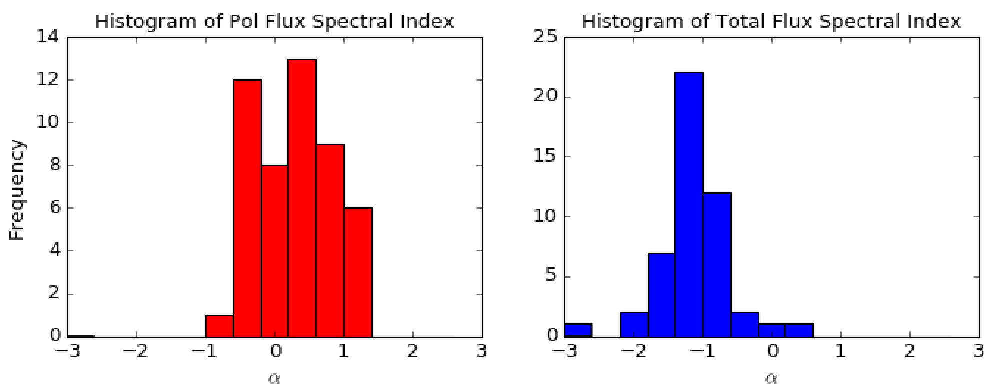
4) Is a multi-component model justified?

In [11]:
```
%matplotlib nbagg
indices = pd.read_csv('alphaoutput.csv')
models = pd.read_csv('spectral_component_flux.csv')
models['total'] = models['bbbmodel'] + models['synmodel'] + models['b
bodymodel']
thermcol = models['bbbmodel']+models['bbodymodel']
models= models.assign(total_thermal=thermcol)

from astropy.time import Time as tm
t = tm(indices['MJD'], format= 'mjd')
fig = plt.figure(4, figsize=(12,8))
plt.plot(t.byear-2000, indices['alpha_flux']*(-1), marker='o', color
= 'blue',
         markersize=8, linestyle = '')
plt.plot(t.byear-2000, indices['alpha_pol']* (-1), marker='o', color
= 'red',
         markersize=8, linestyle = '')
plt.ylim((-4,4));
plt.xlim((9, 16));
plt.errorbar(t.byear-2000, indices['alpha_flux']* (-1),indices['sigm
a'], color = 'blue')
plt.errorbar(t.byear-2000, indices['alpha_pol']* (-1),indices['sigma_
alpha_pol'], color = 'red')
plt.xlabel('Year (Since 2000)')
plt.ylabel(r'$\alpha$')
plt.text(14, 3, 'Polarized Flux', color='red', fontsize=15)
plt.text(14, 2.5, 'Total Flux', color='blue', fontsize=15)
plt.title('Spectral indices of 1222+216')
```



Out[11]: <matplotlib.text.Text at 0x7fb3f9a0f910>

In [12]:
```
%matplotlib nbagg

fig = plt.figure(5, figsize=(10,7))
ax1 = plt.subplot(221)
ax1.hist(indices['alpha_pol']* (-1),bins=np.arange(-3, 3, 0.4) ,color
 = 'red')
ax1.set_xlabel(r'$\alpha$')
ax1.set_ylabel('Frequency')
ax1.set_title('Histogram of Pol Flux Spectral Index', fontsize=12)
ax2 = plt.subplot(222)
ax2.hist(indices['alpha_flux']* (-1), bins=np.arange(-3, 3, 0.4), col
or = 'blue')
ax2.set_title('Histogram of Total Flux Spectral Index', fontsize=12)
ax2.set_xlabel(r'$\alpha$')
```



Out[12]: <matplotlib.text.Text at 0x7fb3f98a1350>

5) Results

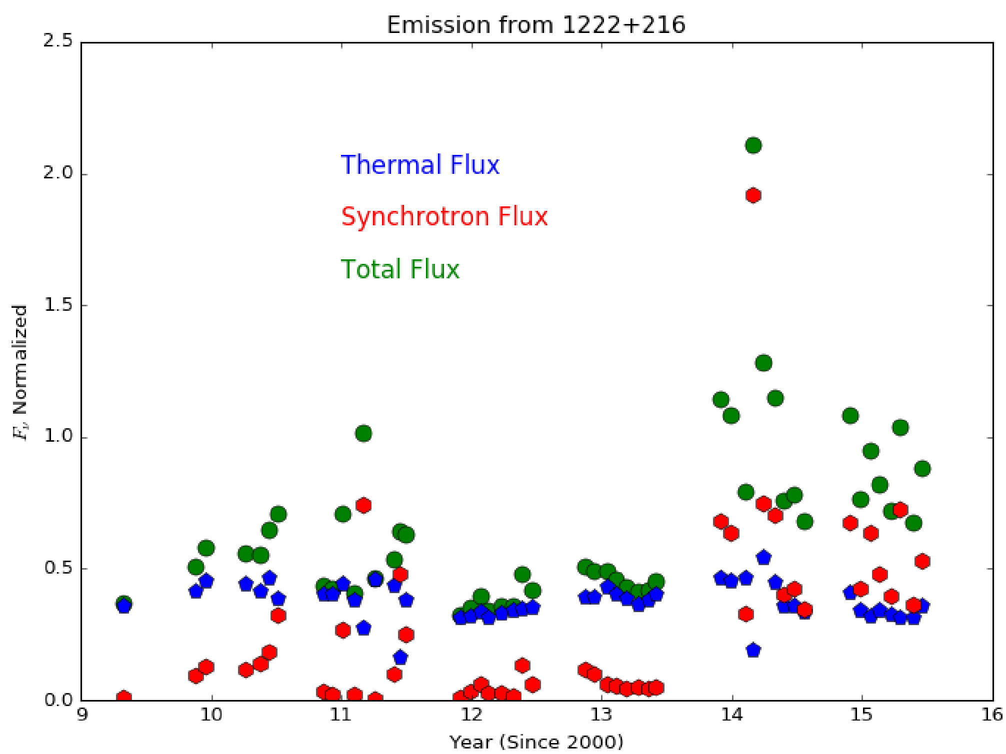
Paramaterize the variability of each of the components by $\frac{\sigma_x}{\langle F_{Total} \rangle}$

In [13]:

```
indices = pd.read_csv('alphaoutput.csv')
models = pd.read_csv('spectral_component_flux.csv')
models['total'] = models['bbbmodel'] + models['synmodel'] + models['b
bodymodel']
thermcol = models['bbbmodel']+models['bbodymodel']
models= models.assign(total_thermal=thermcol)
thermal_variation
=models['total_thermal'].std()/models['total'].mean()
synchrotron_variation=
models['synmodel'].std()/models['total'].mean()
print thermal_variation, synchrotron_variation
```

```
0.102232824893 0.513095740591
```

In [15]:
```
%matplotlib nbagg
import matplotlib.pyplot as plt
from astropy.time import Time as tm
t = tm(models['mjdarr'], format= 'mjd')
fig = plt.figure(6, figsize=(10,7))
normal = 1.0e-11
plt.plot(t.byear-2000.0, models['total']/normal, marker='o', color =
'green',
         markersize=10, linestyle = '')
plt.plot(t.byear-2000.0, models['total_thermal']/normal, marker='p',
color = 'blue',
         markersize=10, linestyle = '')
plt.plot(t.byear-2000.0, models['synmodel']/normal, marker='h', color
 = 'red',
         markersize=10, linestyle = '')
#plt.plot(indices['MJD'], indices['alpha_pol']* (-1), marker='o', col
or = 'red',
   #      markersize=5, linestyle = '')
plt.ylim((0,2.5));
plt.xlabel('Year (Since 2000)')
plt.ylabel(r'$F_{\nu}$ Normalized')
plt.text(11, 2, 'Thermal Flux', color='blue', fontsize=15)
plt.text(11, 1.8, 'Synchrotron Flux', color='red', fontsize=15)
plt.text(11, 1.6, 'Total Flux', color='green', fontsize=15)
plt.title('Emission from 1222+216')
```



Out[15]: <matplotlib.text.Text at 0x7fb3f966b2d0>

In [ ]: