coordinates_pt2

March 23, 2016

1 Imports

```
In [1]: import warnings
        warnings.filterwarnings('ignore')
        %matplotlib inline
        import numpy as np
        import matplotlib.pyplot as plt
```

As before, we can change rcParams, to list all of them just call the plt.rcParams.keys() method of the dictionary.

```
In [2]: #plt.rcParams.keys()
```

```
In [3]: try:
            from cycler import cycler
        except:
            pass
        plt.rcParams['patch.linewidth'] = 0.5
        plt.rcParams['patch.antialiased'] = True
        plt.rcParams['font.size'] = 12.0
        plt.rcParams['axes.facecolor'] = 'white'
        plt.rcParams['axes.edgecolor'] = 'black'
        plt.rcParams['axes.linewidth'] = 1
        plt.rcParams['axes.grid'] = False
        plt.rcParams['axes.titlesize'] = 'large'
        plt.rcParams['axes.labelsize'] = 'large'
        plt.rcParams['axes.labelcolor'] =  '555555'
        colorlist = ['#E24A33', '#348ABD', '#988ED5', '#777777', '#FBC15E', '#8EBA42', '#FFB5B8']
        try:
            # newer Matplotlib
            plt.rcParams['axes.prop_cycle'] = cycler('color', colorlist)
        except:
            # older Matplotlib (<1.5 I think)
            plt.rcParams['axes.color_cycle'] = colorlist
        plt.rcParams['grid.color'] = 'grey'
        plt.rcParams['grid.linestyle'] =  '-'
        plt.rcParams['figure.facecolor'] = 'white'
        plt.rcParams['figure.edgecolor'] = 'white'
        plt.rcParams['text.usetex'] = False
        plt.rcParams['mathtext.default'] = 'regular'
```

Same as before

```
In [4]: import astropy
        import astropy.coordinates as coordinates
        import astropy.units as u

        import astropy.constants as c
        from astropy.table import Table
```

2 Plotting images

2.1 Popular packages

-WCSAxes
http://wcsaxes.readthedocs.org/

- APLpy
https://aplpy.github.io/
http://aplpy.readthedocs.org/

-PyWCSGrid2 (discontinued!)
http://leejjoon.github.io/pywcsgrid2/

```
In [5]: from astropy.wcs import WCS
        from astropy.io import fits
        import aplpy
```

2.2 Read in the data

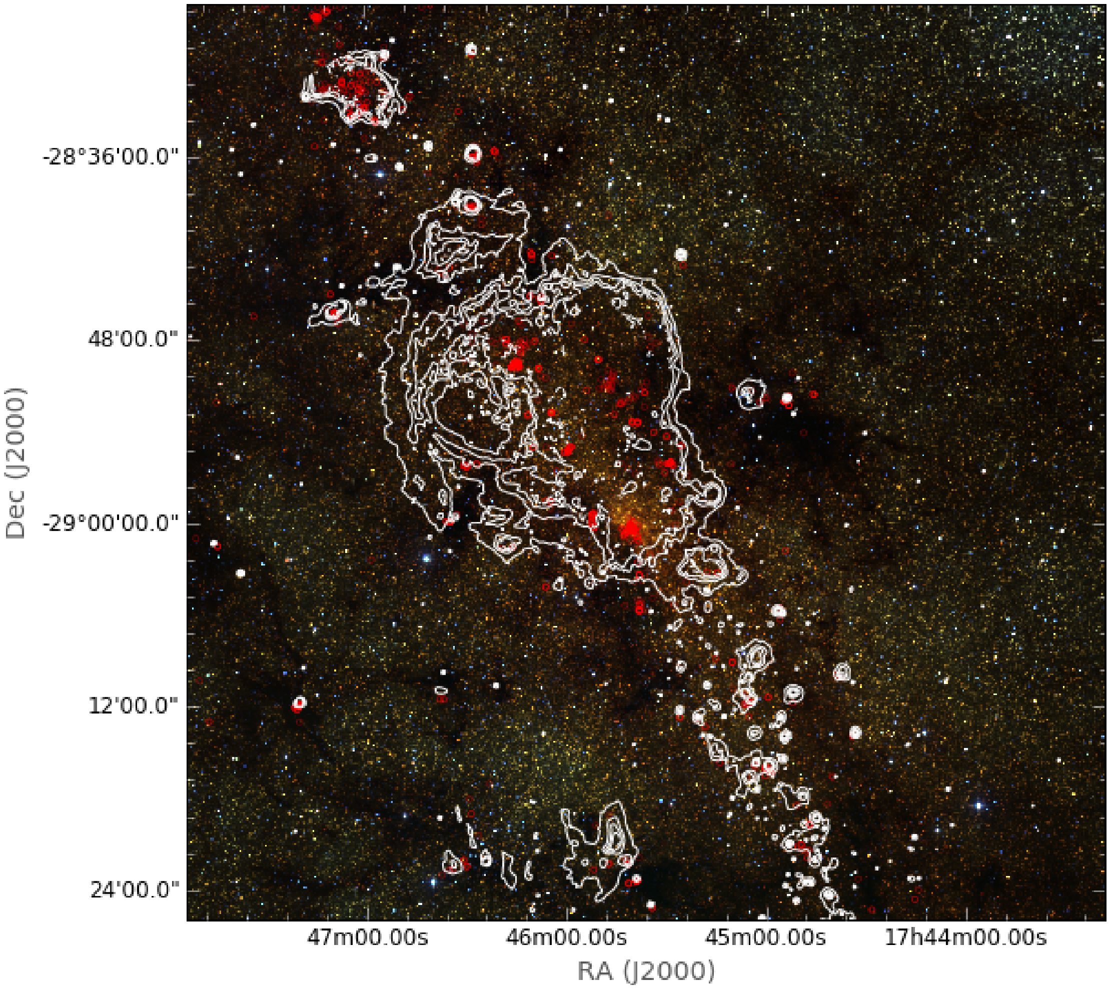
All data set are from the WCSAxes and Aplpy documentation.

```
In [6]: hdu_msx = fits.open('data/msx.fits')[0]
        wcs_msx = WCS(hdu_msx.header)

        hdu_l1558_13co = fits.open('data/l1558_13co.fits')[0]
        wcs_l1558_13co = WCS(hdu_l1558_13co.header)

        hdu_bolocam = fits.open('data/bolocam.fits')[0]
        wcs_bolocam = WCS(hdu_bolocam.header)

        hdu_rosat = fits.open('data/rosat.fits')[0]
        wcs_rosat = WCS(hdu_rosat.header)

        hdu_2mass = fits.open('data/2mass_k.fits')[0]
        wcs_2mass = WCS(hdu_2mass.header)
```

2.3 aplpy

Aplpy has a rather different approach than the other packages. It has its own commands for most things. Each plot is a layer.

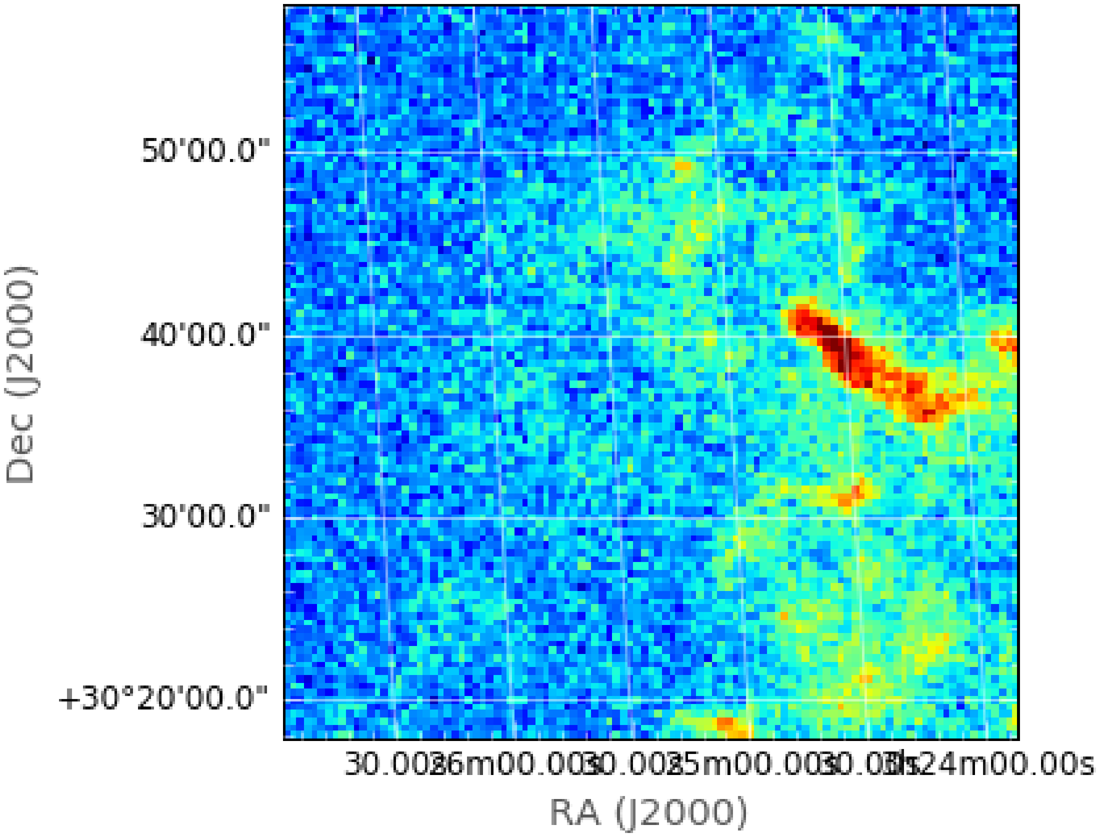
```
In [7]: gc = aplpy.FITSFigure('data/2mass_k.fits')
        gc.show_rgb('data/2MASS_arcsinh_color.png')

        gc.show_contour('data/mips_24micron.fits', colors='white')

        data = np.loadtxt('data/yso_wcs_only.txt')
        ra, dec = data[:, 0], data[:, 1]

        gc.show_markers(ra, dec, layer='marker_set_1', edgecolor='r',
                        facecolor='none', marker='o', s=10, alpha=0.5)
```



We can also slice data, for image cubes this is very convenient. The ^{13}CO data for L1558 is a data cube.

```
In [8]: f = aplpy.FITSFigure('data/l1558_13co.fits', slices=[2],
                             figsize=(5,5))
        f.show_colorscale()
        f.add_grid()
```

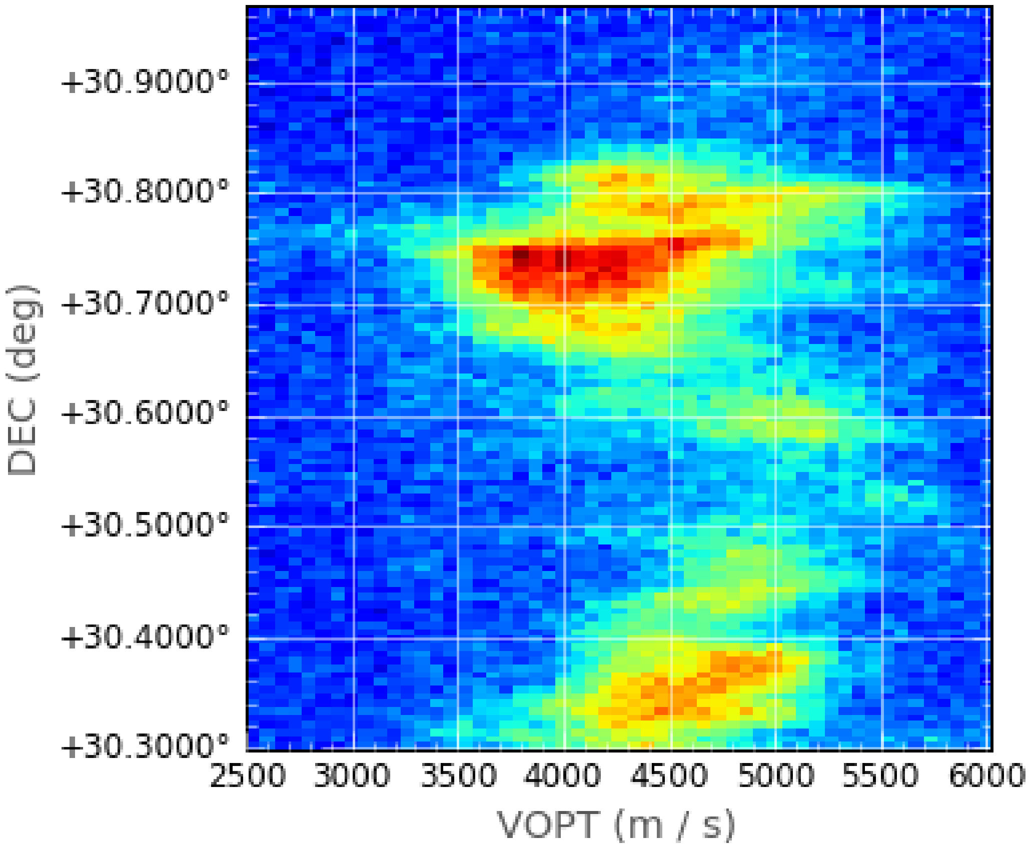
```
WARNING: Cannot determine equinox. Assuming J2000. [aplpy.wcs_util]
WARNING: Cannot determine equinox. Assuming J2000. [aplpy.wcs_util]

INFO: Auto-setting vmin to -5.371e-01 [aplpy.core]
INFO: Auto-setting vmax to  1.660e+00 [aplpy.core]
```



Since we can also change the slicing, we can quickly create a PV-diagram.

```
In [9]: f = aplpy.FITSFigure('data/l1558_13co.fits', dimensions=[2, 1],
                             slices=[50], figsize=(5,5))
        f.show_colorscale(aspect='auto')
        f.add_grid()
        #ax.tick_labels.set_xformat('%.1f');
```

```
INFO: Auto-setting vmin to -5.973e-01 [aplpy.core]
INFO: Auto-setting vmax to  3.503e+00 [aplpy.core]
```



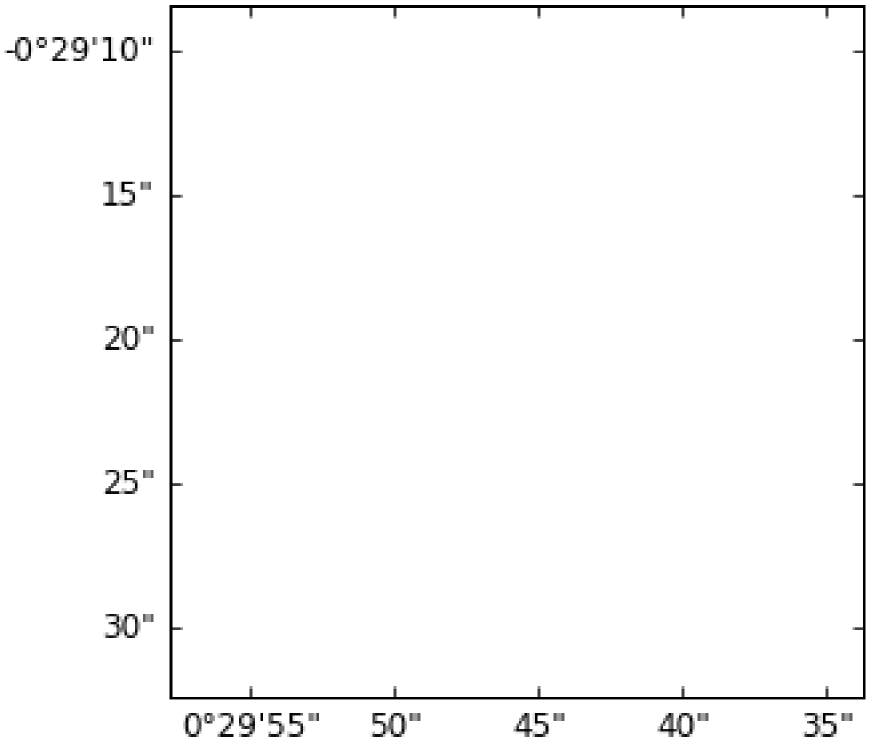
2.4 Exercise

```
- Add contours to the  L1558 maps.
- Change the coordinate display system.
- Change the color map the L1558 maps.
```

2.5 WCSAxes

WCSAxes is intended as a replacement for both APLpy, PyWCSGrid2, trying to take the best from both and is developed by many of the same people. It ties into Matplotlib just like pywcsgrid2.

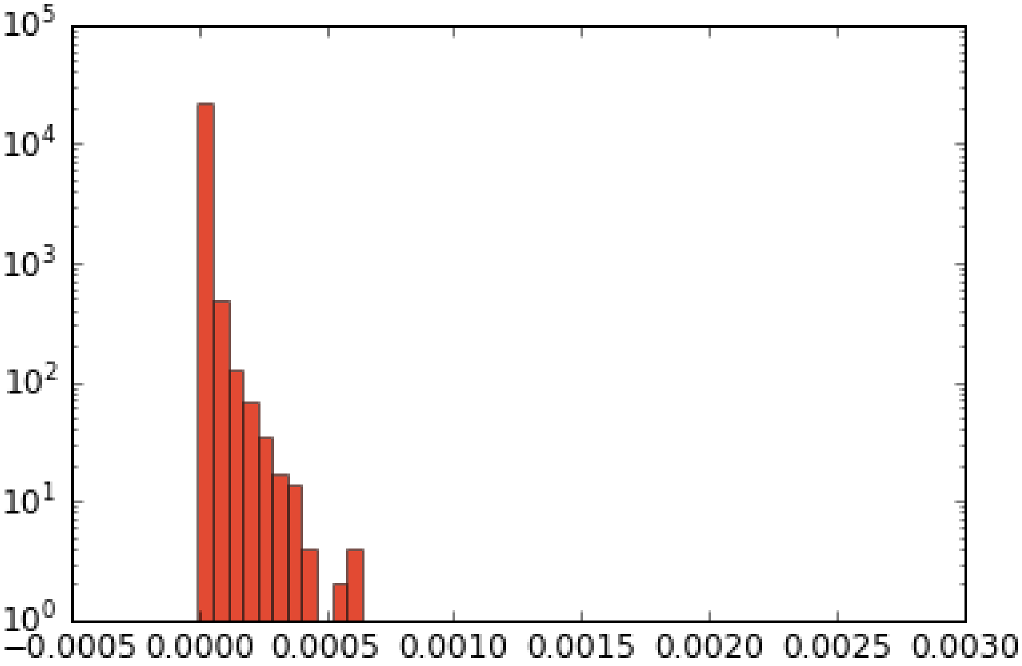
```
In [10]: import matplotlib.pyplot as plt
         fig = plt.figure(figsize=(4,4))
         ax = fig.add_axes([0.1, 0.1, 0.9, 0.9], projection=wcs_msx)
```



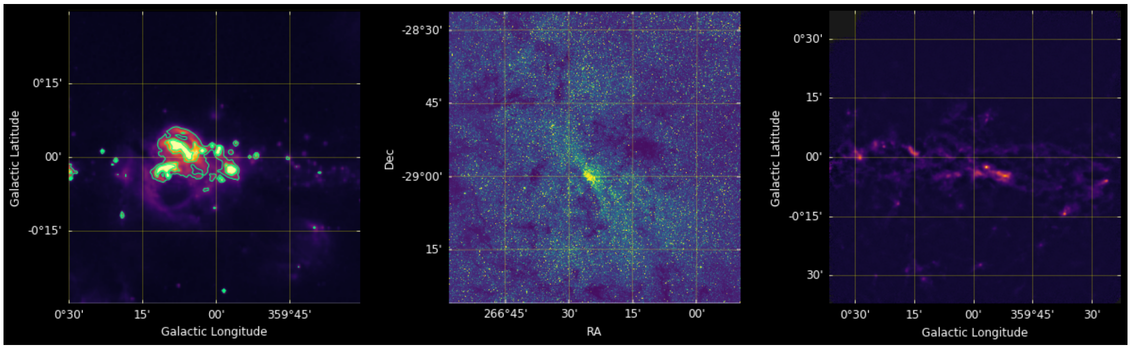
Now we have an axes object just like we usually do with Matplotlib. This is much more convenient, since you do not have to learn special methods and objects, just to change things in the plot.

We can first check the histogram of the whole image, to see what range in values we have.

```
In [11]: _ = plt.hist(hdu_msx.data.flatten(),bins=50);
         plt.yscale('log')
```

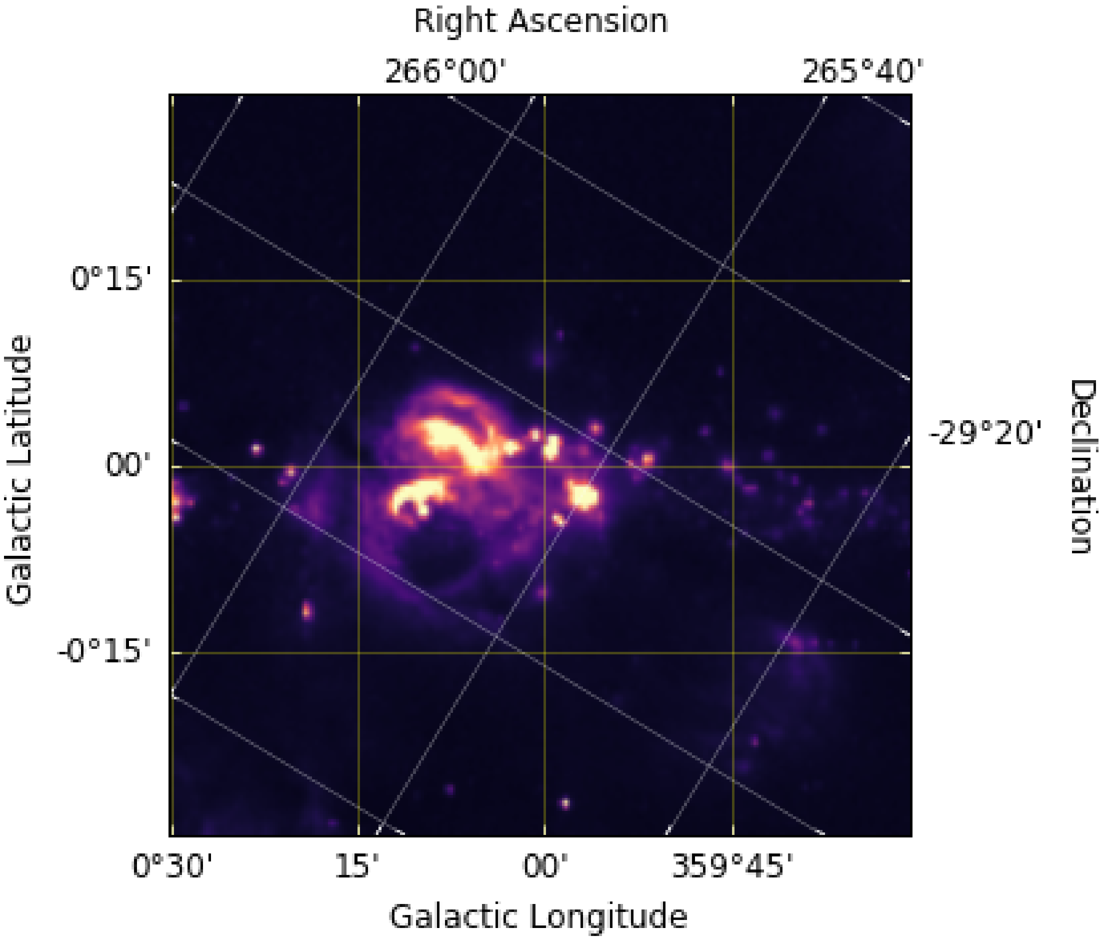


```
In [12]: np.nanmax(hdu_bolocam.data.flatten())

Out[12]: 9.8875465

In [13]: hdu_bolocam.data.shape

Out[13]: (638, 640)

In [30]: with plt.style.context('dark_background'):
             fig = plt.figure(figsize=(20,15))

             ax1 = fig.add_subplot(131, projection=wcs_msx)
             ax1.imshow(hdu_msx.data, vmin=-1e-5, vmax=2.e-4, cmap=plt.cm.inferno,
                        origin='lower')
             ax1.contour(hdu_msx.data,
                         levels=np.linspace(-1e-5,2e-4,4),
                         colors=plt.cm.winter_r(np.linspace(-1e-5,2e-4,4)))

             ax1.coords['glon'].set_ticks(color='white')
             ax1.coords['glat'].set_ticks(color='white')

             ax1.coords['glon'].set_axislabel('Galactic Longitude')
             ax1.coords['glat'].set_axislabel('Galactic Latitude')
             ax1.coords.grid(color='yellow', linestyle='solid', alpha=0.5)



             ax2 = fig.add_subplot(132, projection=wcs_2mass)
             ax2.imshow(hdu_2mass.data, vmin=450, vmax=1e3, cmap=plt.cm.viridis,
                       origin='lower')


             ax2.coords['ra'].set_ticks(color='white')
             ax2.coords['dec'].set_ticks(color='white')

             ax2.coords['ra'].set_axislabel('RA')
             ax2.coords['dec'].set_axislabel('Dec')
             ax2.coords.grid(color='yellow', linestyle='solid', alpha=0.5)


             ax3 = fig.add_subplot(133, projection=wcs_bolocam)
             import matplotlib
             cmap = matplotlib.cm.inferno
             cmap.set_bad('0.1',1.)

             ax3.imshow(hdu_bolocam.data, vmin=-1, vmax=10, cmap=cmap,
                       origin='lower')

             ax3.set_xlim(10,628)
             ax3.set_ylim(10,630)

             ax3.coords['glon'].set_ticks(color='white')
             ax3.coords['glat'].set_ticks(color='white')

             ax3.coords['glon'].set_axislabel('Galactic Longitude')
             ax3.coords['glat'].set_axislabel('Galactic Latitude')
             ax3.coords.grid(color='yellow', linestyle='solid', alpha=0.5)

             fig.subplots_adjust(wspace=0.3)
```



```
In [15]: fig = plt.figure(figsize=(6,5))

         ax = fig.add_subplot(111, projection=wcs_msx)
         ax.imshow(hdu_msx.data,
                   vmin=-1e-5, vmax=2.e-4,
                   cmap=plt.cm.magma,
                   origin='lower')
         overlay = ax.get_coords_overlay('fk5')
```

```
ax.coords['glon'].set_ticks(color='white')
ax.coords['glat'].set_ticks(color='white')

ax.coords['glon'].set_axislabel('Galactic Longitude')
ax.coords['glat'].set_axislabel('Galactic Latitude')

ax.coords.grid(color='yellow', linestyle='solid', alpha=0.5)

overlay['ra'].set_ticks(color='white')
overlay['dec'].set_ticks(color='white')

overlay['ra'].set_axislabel('Right Ascension')
overlay['dec'].set_axislabel('Declination')

overlay.grid(color='white', linestyle='solid', alpha=0.5)
```

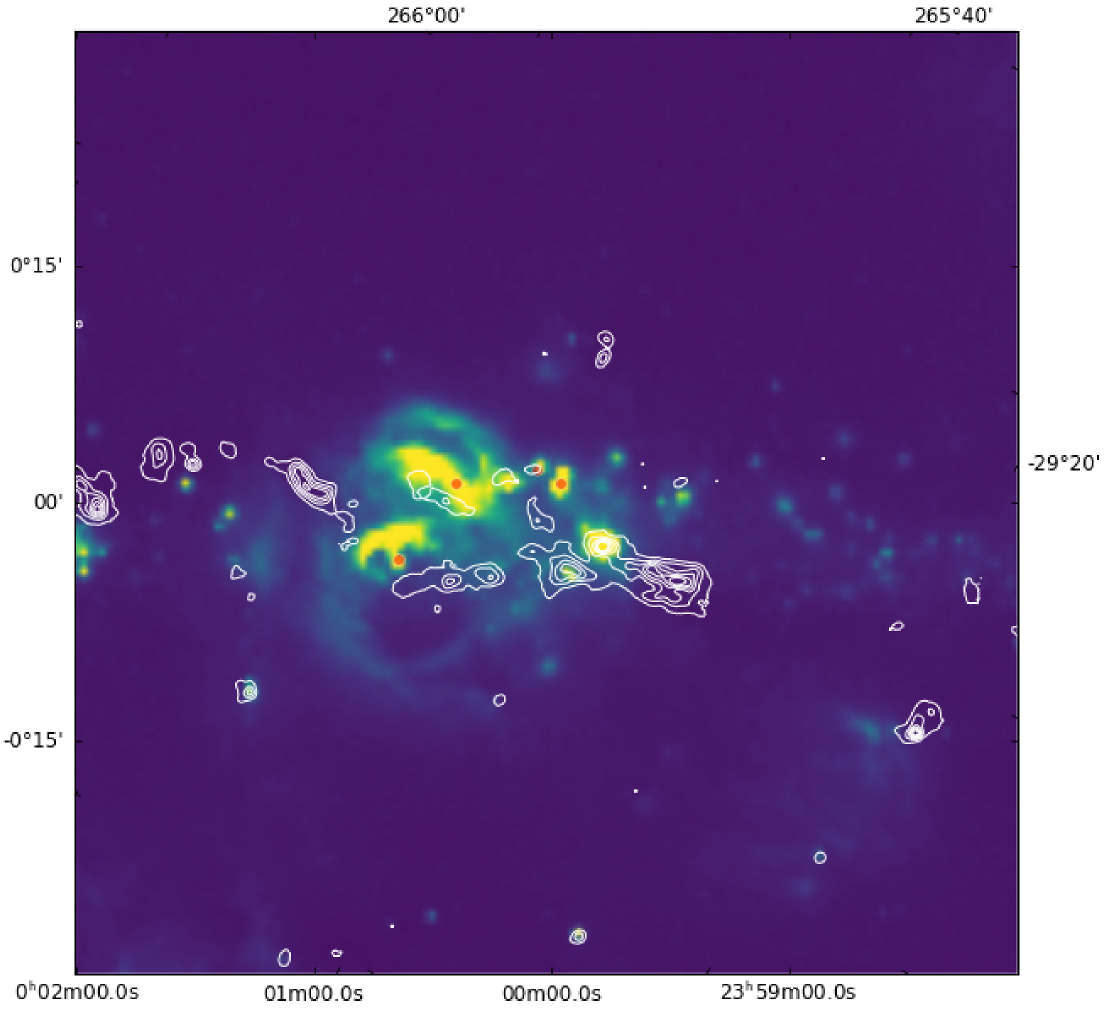


2.5.1 Exercise

```
- Mark some coordinates of interest in the map.
- Try different color maps.
- Try different vmin and vmax.
- Change coordinates to Equatorial.\
- Add axis labels
```

2.5.2 A more complicated figure

```
In [16]: fig = plt.figure(figsize=(15,10))

         ax = fig.add_subplot(111, projection=wcs_msx)
         ax.imshow(hdu_msx.data, vmin=-1e-5, vmax=2.e-4, cmap=plt.cm.viridis,
                   origin='lower')

         # change display of coordinates
         xcoord = ax.coords[0]
         ycoord = ax.coords[1]
         xcoord.set_ticks(number=4)
         xcoord.set_major_formatter('hh:mm:ss.s')
         xcoord.set_separator(('$^{\sf h}$', "m", 's'))

         # add contours from a different data set
         ax.contour(hdu_bolocam.data, transform=ax.get_transform(WCS(hdu_bolocam.header)),
                    levels=[1,2,3,4,5,6], colors='white');

         # mark some points of interest
         tr_gal = ax.get_transform("galactic")
         l = [-0.01, 0.015, 0.10, 0.16]
         b = [0.02, 0.035, 0.02, -0.06]
         ax.scatter(l, b, transform=tr_gal, s=40,
                    edgecolor='white', facecolor='r', alpha=0.5)

         # overlay a second coordinate system.
         overlay = ax.get_coords_overlay('fk5')

         ax.set_xlim(-0.5, 148.5)
         ax.set_ylim(-0.5, 148.5);
```



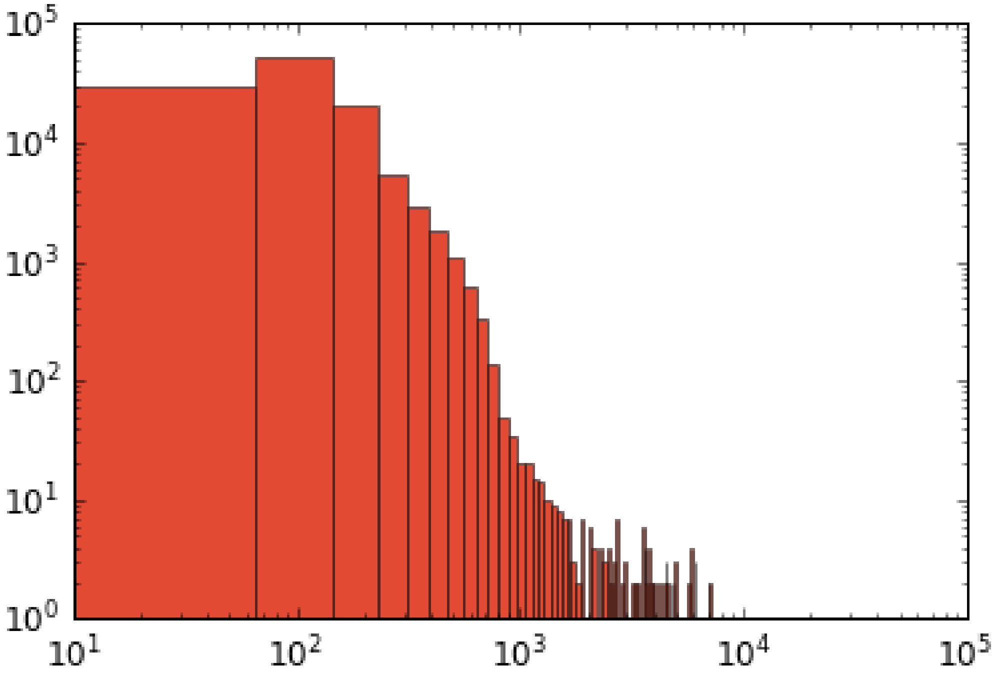
2.5.3 Exercise

```
- Change images, and overlay different layers of the L1558 $^{13}$CO cube as contours with different col
- Change contour colors.
- If you have your own data, load that in and display it.
- Add axis labels.
```

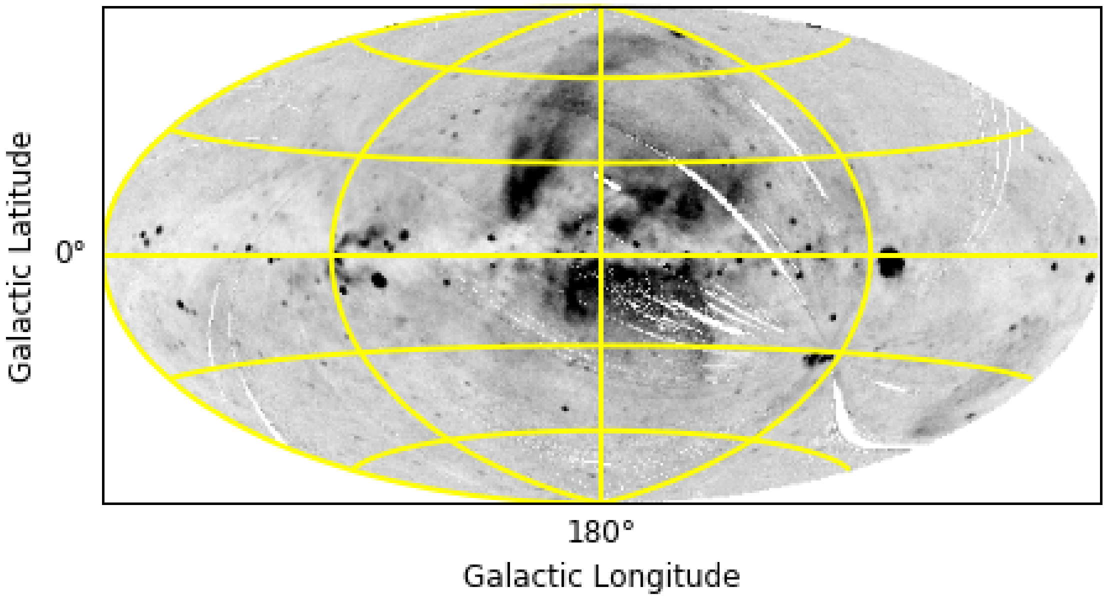
2.6 ROSAT

All sky plots again…

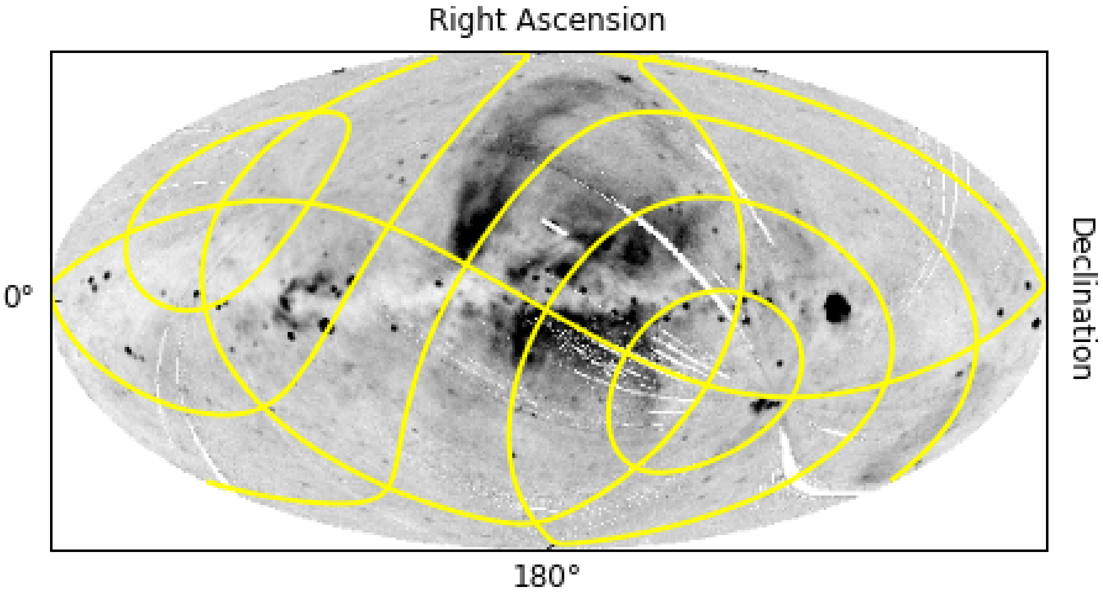
```
In [17]: plt.hist(hdu_rosat.data.flatten(), bins=500)
         plt.yscale('log')
         plt.xscale('log')
```



```
In [18]: import matplotlib.pyplot as plt
         fig = plt.figure(figsize=(7,7))
         ax = fig.add_axes([0.15, 0.1, 0.8, 0.8], projection=wcs_rosat)
         ax.imshow(hdu_rosat.data, vmin=0, vmax=6e2, cmap=plt.cm.gray_r,
                   origin='lower');
         overlay = ax.get_coords_overlay('fk5')
         ax.coords['glon'].set_ticks(color='white')
         ax.coords['glat'].set_ticks(color='white')

         ax.coords['glon'].set_axislabel('Galactic Longitude')
         ax.coords['glat'].set_axislabel('Galactic Latitude')

         ax.coords.grid(color='yellow', linestyle='solid', alpha=1, lw=2)
```



```
In [19]: import matplotlib.pyplot as plt
         fig = plt.figure(figsize=(7,7))
         ax = fig.add_axes([0.15, 0.1, 0.8, 0.8], projection=wcs_rosat)
         ax.imshow(hdu_rosat.data, vmin=0, vmax=6e2, cmap=plt.cm.gray_r,
                   origin='lower');
         overlay = ax.get_coords_overlay('fk5')

         overlay['ra'].set_ticks(color='white')
         overlay['dec'].set_ticks(color='white')

         overlay['ra'].set_axislabel('Right Ascension')
         overlay['dec'].set_axislabel('Declination')

         overlay.grid(color='yellow', linestyle='solid', alpha=1, lw=2)
```



2.6.1 Exercise

- Get the 2 MASS catalog from previous session and plot the galaxies over the ROSAT data.
- Change colors and labels to something nicer.
- Look at the other data sets that we have loaded at the top create plots for them too.

```
In [ ]:
```

```
In [ ]:
```

3 Spectral cubes

```
In [20]: import spectral_cube as sp
```

```
In [21]: data = sp.SpectralCube.read('data/l1558_13co.fits')
```

```
In [22]: data
```

```
Out[22]: SpectralCube with shape=(53, 105, 105):
          n_x:    105  type_x: RA---SFL  unit_x: deg    range:    50.924417 deg:   51.740103 deg
          n_y:    105  type_y: DEC--SFL  unit_y: deg    range:    30.301945 deg:   30.966389 deg
          n_s:     53  type_s: VOPT      unit_s: m / s  range:     2528.195 m / s:    5982.223 m / s
```

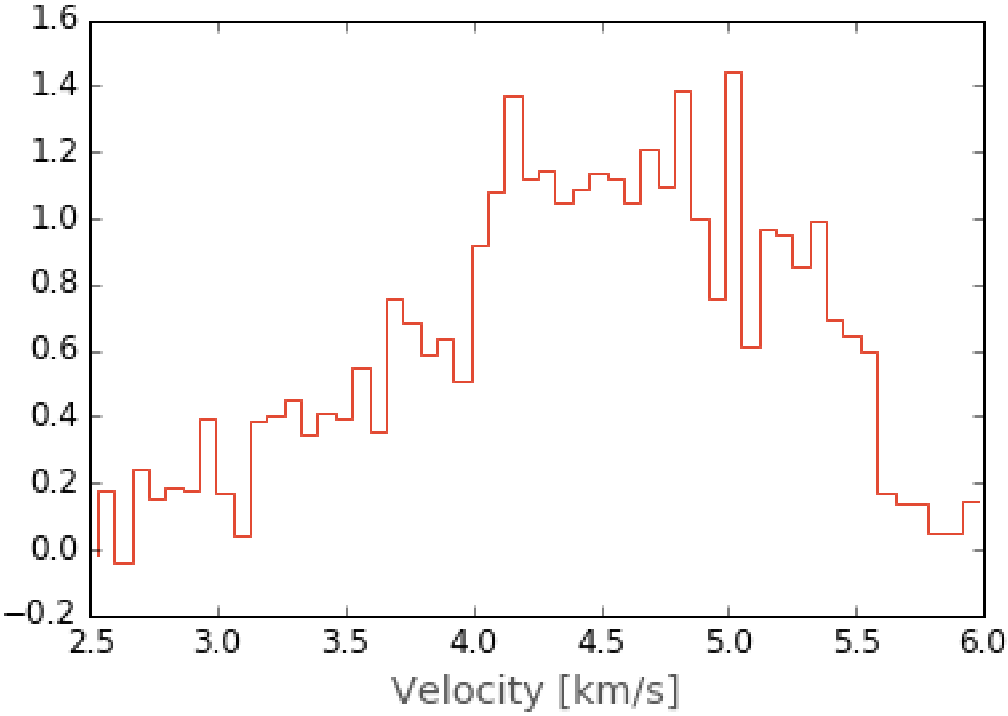
```
In [23]: data.spectral_axis.to(u.km/u.s)
```

```
Out[23]:
    [2.5281949, 2.5946185, 2.6610421, 2.7274657, 2.7938893, 2.8603129, 2.9267366, 2.9931602, 3.0595838, 3.1260074, 3.19243
```

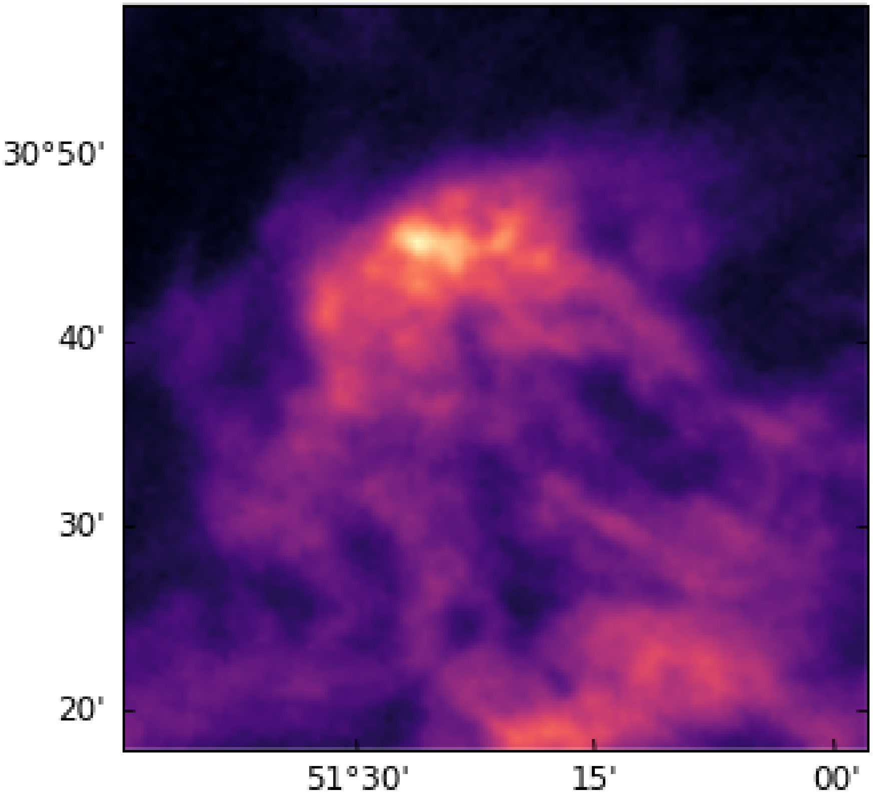
```
In [24]: data.shape
```

```
Out[24]: (53, 105, 105)
```

```
In [26]: plt.step(data.spectral_axis.to(u.km/u.s), data[:,50,50])
         plt.xlabel('Velocity [km/s]')
         # there's no unit for the data. :(
         plt.ylabel(data.unit);
```



```
In [43]: data.moment0().value.shape

Out[43]: (105, 105)

In [50]: fig = plt.figure(figsize=(6,5))
         ax = fig.add_subplot(111, projection=WCS(data.moment0().hdu.header))
         ax.imshow(data.moment0().value,
                   cmap=plt.cm.magma,
                   origin='lower');
```



```
In [ ]:
```