Viewing and manipulating data from FITS tables

Authors

Lia Corrales, Kris Stern

Learning Goals

- Download a FITS table file from a URL
- Open a FITS table file and view table contents
- Make a 2D histogram with the table data
- Close the FITS file after use

Keywords

FITS, file input/output, table, numpy, matplotlib, histogram

Summary

This tutorial demonstrates the use of `astropy.utils.data` to download a data file, then uses `astropy.io.fits` and `astropy.table` to open the file. Lastly, `matplotlib` is used to visualize the data as a histogram.

```python
import numpy as np
from astropy.io import fits
from astropy.table import Table
from matplotlib.colors import LogNorm

# Set up matplotlib
import matplotlib.pyplot as plt

%matplotlib inline
```

The following line is needed to download the example FITS files used in this tutorial.

```python
from astropy.utils.data import download_file
```

FITS files often contain large amounts of multi-dimensional data and tables.

In this particular example, we’ll open a FITS file from a Chandra observation of the Galactic Center. The file contains a list of events with x and y coordinates, energy, and various other pieces of information.

```python
event_filename = download_file(
    "http://data.astropy.org/tutorials/FITS-tables/chandra_events.fits", cache=True
)
```

Opening the FITS file and viewing table contents

Since the file is big, let’s open it with `memmap=True` to prevent RAM storage issues.

```python
hdu_list = fits.open(event_filename, memmap=True)
```

```python
hdu_list.info()
```

```
Filename: /home/runner/.astropy/cache/download/url/333246bccb141ea3b4e86c49e45bf8d6/
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU      30   ()      
  1  EVENTS        1 BinTableHDU    890   483964R x 19C   [1D, 1I, 1I, 1J, 1I, 1I, 1
  2  GTI           3 BinTableHDU     28   1R x 2C   [1D, 1D]   
  3  GTI           2 BinTableHDU     28   1R x 2C   [1D, 1D]   
  4  GTI           1 BinTableHDU     28   1R x 2C   [1D, 1D]   
  5  GTI           0 BinTableHDU     28   1R x 2C   [1D, 1D]   
  6  GTI           6 BinTableHDU     28   1R x 2C   [1D, 1D]   
```

In this case, we’re interested in reading EVENTS, which contains information about each X-ray photon that hit the detector.

To find out what information the table contains, let’s print the column names.

```
print(hdu_list[1].columns)
```

```
ColDefs(
    name = 'time'; format = '1D'; unit = 's'
    name = 'ccd_id'; format = '1I'
    name = 'node_id'; format = '1I'
    name = 'expno'; format = '1J'
    name = 'chipx'; format = '1I'; unit = 'pixel'; coord_type = 'CPCX'; coord_unit =
    name = 'chipy'; format = '1I'; unit = 'pixel'; coord_type = 'CPCY'; coord_unit =
    name = 'tdetx'; format = '1I'; unit = 'pixel'
    name = 'tdety'; format = '1I'; unit = 'pixel'
    name = 'detx'; format = '1E'; unit = 'pixel'; coord_type = 'LONG-TAN'; coord_uni
    name = 'dety'; format = '1E'; unit = 'pixel'; coord_type = 'NPOL-TAN'; coord_uni
    name = 'x'; format = '1E'; unit = 'pixel'; coord_type = 'RA---TAN'; coord_unit =
    name = 'y'; format = '1E'; unit = 'pixel'; coord_type = 'DEC--TAN'; coord_unit =
    name = 'pha'; format = '1J'; unit = 'adu'; null = 0
    name = 'pha_ro'; format = '1J'; unit = 'adu'; null = 0
    name = 'energy'; format = '1E'; unit = 'eV'
    name = 'pi'; format = '1J'; unit = 'chan'; null = 0
    name = 'fltgrade'; format = '1I'
    name = 'grade'; format = '1I'
    name = 'status'; format = '32X'
)
```

Now we’ll take this data and convert it into an astropy table. While it’s possible to access FITS tables directly from the `.data` attribute, using Table tends to make a variety of common tasks more convenient.

```
evt_data = Table(hdu_list[1].data)
```

For example, a preview of the table is easily viewed by simply running a cell with the table as the last line:

```
evt_data
```

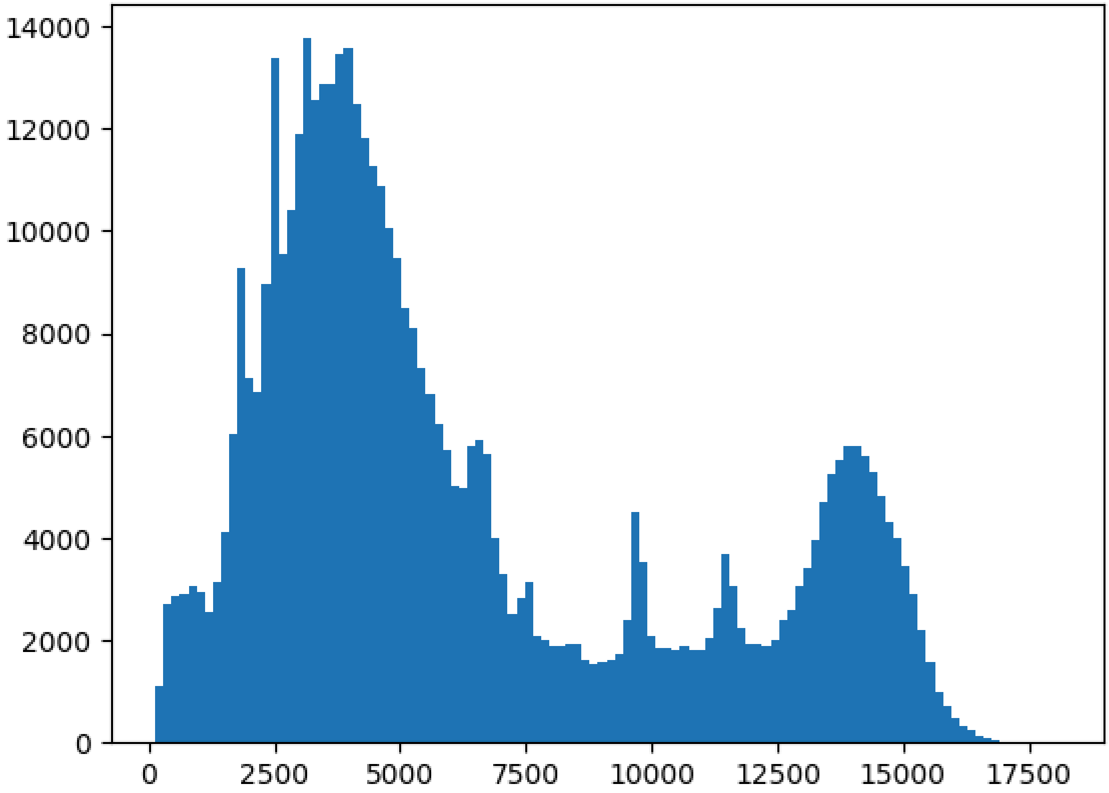
Table length=483964

time	ccd_id	node_id	expno	chipx	chipy	tdetx	tdety	detx	
float64	int16	int16	int32	int16	int16	int16	int16	float32	
238623220.9093583	3	3	68	920	8	5124	3981	5095.641	4
238623220.9093583	3	1	68	437	237	4895	3498	4865.567	46
238623220.9093583	3	2	68	719	289	4843	3780	4814.835	4
238623220.9093583	3	0	68	103	295	4837	3164	4807.3643	4
238623220.9093583	3	1	68	498	314	4818	3559	4788.987	45
238623220.9093583	3	3	68	791	469	4663	3852	4635.4526	4
238623220.9093583	3	3	68	894	839	4293	3955	4266.642	41
238623220.9093583	3	3	68	857	941	4191	3918	4164.815	42
238623220.9093583	3	3	68	910	959	4173	3971	4146.9937	4
...	...	...	...	...	...	...	...	...	
238672393.54971933	1	3	15723	933	199	4933	5040	4902.907	30
238672393.54971933	1	2	15723	596	412	4720	4703	4691.51	34
238672393.54971933	1	3	15723	1000	608	4524	5107	4494.713	30
238672393.54971933	1	1	15723	270	917	4215	4377	4188.3325	37
238672393.54971933	1	0	15723	232	988	4144	4339	4117.6147	37
238672393.59075934	0	1	15723	366	103	3164	4766	3140.9048	33
238672393.59075934	0	3	15723	937	646	3707	4195	3681.2122	39

time	ccd_id	node_id	expno	chipx	chipy	tdetx	tdety	detx	
238672393.59075934	0	1	15723	406	687	3748	4726	3723.4014	3
238672393.59075934	0	1	15723	354	870	3931	4778	3906.07	3
238672393.63179934	6	1	15723	384	821	3259	2523	3230.9204	55

We can extract data from the table by referencing the column name. Let’s try making a histogram for the energy of each photon, which will give us a sense for the spectrum (folded with the detector’s efficiency).

```
energy_hist = plt.hist(evt_data["energy"], bins="auto")
```



Making a 2D histogram with some table data

We’ll make an image by binning the x and y coordinates of the events into a 2D histogram.

This particular observation spans five CCD chips. First, we determine the events that only fell on the main (ACIS-I) chips, which have number ids 0, 1, 2, and 3.

```
ii = np.in1d(evt_data["ccd_id"], [0, 1, 2, 3])
np.sum(ii)
```

```
/tmp/ipykernel_3595/3072746623.py:1: DeprecationWarning: `in1d` is deprecated. Use `
  ii = np.in1d(evt_data["ccd_id"], [0, 1, 2, 3])
```

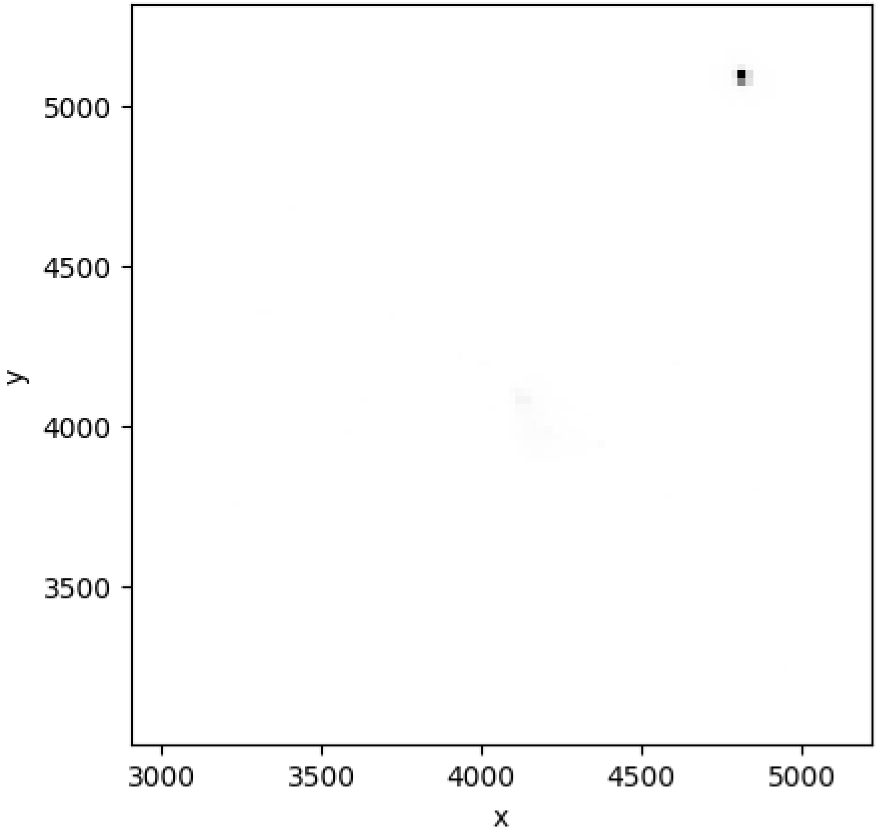
```
np.int64(434858)
```

Method 1: Use numpy to make a 2D histogram and imshow to display it

This method allows us to create an image without stretching:

```
NBINS = (100, 100)

img_zero, yedges, xedges = np.histogram2d(evt_data["x"][ii], evt_data["y"][ii], NBI

extent = [xedges[0], xedges[-1], yedges[0], yedges[-1]]

plt.imshow(
    img_zero, extent=extent, interpolation="nearest", cmap="gist_yarg", origin="lowe
)

plt.xlabel("x")
plt.ylabel("y")

# To see more color maps
# http://wiki.scipy.org/Cookbook/Matplotlib/Show_colormaps
```

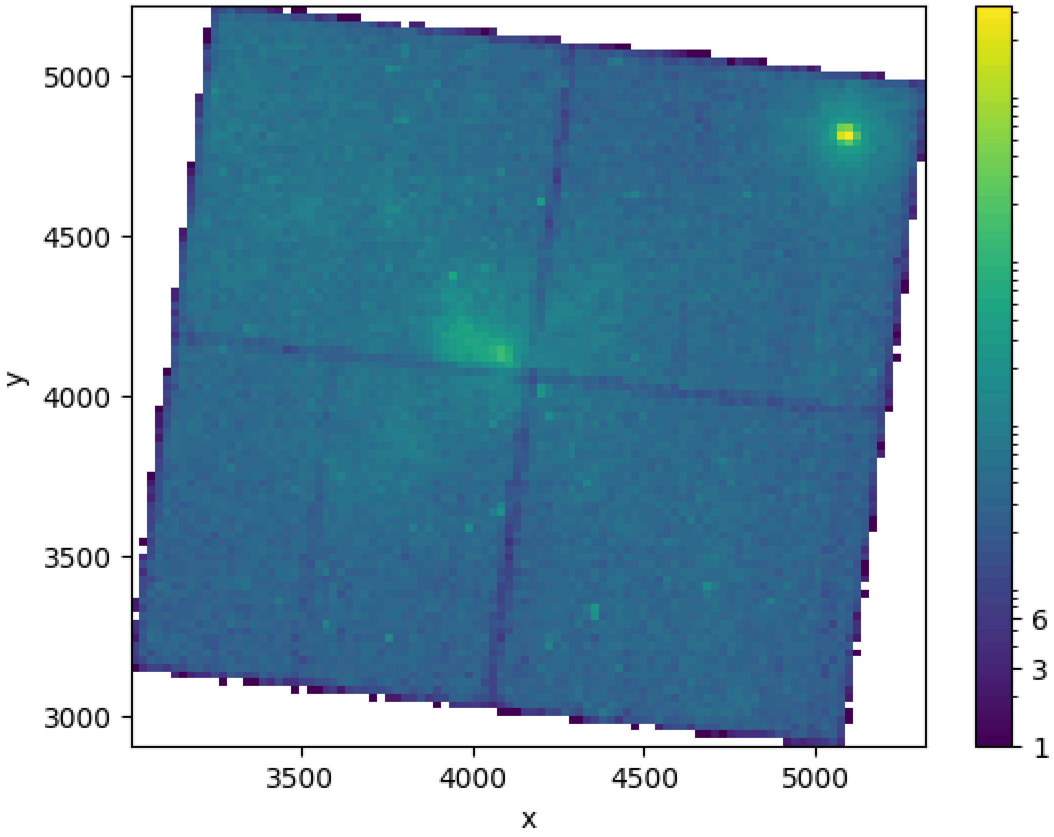
```
Text(0, 0.5, 'y')
```



Method 2: Use hist2d with a log-normal color scheme

```
NBINS = (100, 100)
img_zero_mpl = plt.hist2d(
    evt_data["x"][ii], evt_data["y"][ii], NBINS, cmap="viridis", norm=LogNorm()
)

cbar = plt.colorbar(ticks=[1.0, 3.0, 6.0])
cbar.ax.set_yticklabels(["1", "3", "6"])

plt.xlabel("x")
plt.ylabel("y")
```

```
Text(0, 0.5, 'y')
```



Close the FITS file

When you’re done using a FITS file, it’s often a good idea to close it. That way you can be sure it won’t continue using up excess memory or file handles on your computer. (This happens automatically when you close Python, but you never know how long that might be…)

```
hdu_list.close()
```

Exercises

Make a scatter plot of the same data you histogrammed above. The plt.scatter function is your friend for this. What are the pros and cons of doing it this way?

Try the same with the plt.hexbin plotting function. Which do you think looks better for this kind of data?

Choose an energy range to make a slice of the FITS table, then plot it. How does the image change with different energy ranges?