Exercise 1: reading a table and converting coordinates/times (10 points)

1. Download the file `fermi_lat_grbs.dat` from today's exercise page on the website. It contains 1000 gamma-ray bursts observed by the Fermi satellite between 2010 and 2018.

2. Use the `astropy.io.ascii.read()` routine to read the file into a table. You need to specify the `header_start`, `data_start`, and `delimiter` arguments.

3. Display the column headers using the `columns` or `colnames` method.

4. Notice that RA and DEC are in sexagesimal format, represented as strings. Use `astropy.coordinates.Angle` to convert them to decimal degrees. Print the table.

5. Do some brief analysis:
   a) Construct a boolean mask array that selects only those bursts with durations $t_{90} < 2$ seconds and relative errors in the duration $\frac{t_{90\_error}}{t_{90}} < 50\%$.
   b) Construct a second boolean mask array that selects $t_{90} > 2$ seconds with the same relative error.
   c) Compare the median peak energy ($f_{lnc\_band\_epeak}$) of the two samples. Use the NumPy `median` function to compute the values.

In [2]:
```
#Code Here
import numpy as np
import astropy
from astropy import units as units
from astropy.table import Table
from astropy import coordinates
from astropy import units as u
# Q.1,2
data = astropy.io.ascii.read(r"C:\Users\eklav\OneDrive - University of Illinois - U
# Q.3
print(data.columns)
# Q.4
data['ra'] = coordinates.Angle(data['ra'],unit = u.hour)

data['dec'] = coordinates.Angle(data['dec'],unit = u.deg)

data['ra'] = (data['ra']).to(u.deg)
data['dec'] = (data['dec']).to(u.deg)

print(data['ra'])
print(data['dec'])

# Q 5
mask_short_bursts = (data['t90'] < 2) & ((data['t90_error'] / data['t90']) < 0.5)
```

```
mask_long_bursts = (data['t90'] > 2) & ((data['t90_error'] / data['t90']) < 0.5)
short_bursts_epeak = data['flnc_band_epeak'][mask_short_bursts]
long_bursts_epeak = data['flnc_band_epeak'][mask_long_bursts]
median_peak_energy_short = np.median(short_bursts_epeak)
median_peak_energy_long = np.median(long_bursts_epeak)
```

```
<TableColumns names=('col0','name','ra','dec','trigger_time','t90','t90_error','t90_start','fluence','fluence_error','flux_1024','flux_1024_error','flux_1024_time','flux_64','flux_64_error','flnc_band_ampl','flnc_band_ampl_pos_err','flnc_band_ampl_neg_err','flnc_band_epeak','flnc_band_epeak_pos_err','flnc_band_epeak_neg_err','flnc_band_alpha','flnc_band_alpha_pos_err','flnc_band_alpha_neg_err','flnc_band_beta','flnc_band_beta_pos_err','flnc_band_beta_neg_err','flnc_spectrum_start','flnc_spectrum_stop','pflx_best_fitting_model','pflx_best_model_redchisq','flnc_best_fitting_model','flnc_best_model_redchisq','_1')>
        ra
       deg
------------------
337.86999999999995
356.95916666666665
211.21999999999997
            209.14
2.8999999999999995
 9.479999999999999
244.03999999999996
20.722916666666666
 311.3299999999999
160.42999999999998
               ...
            308.56
235.66999999999996
159.91083333333333
              52.3
202.26999999999995
 304.9599999999999
246.66083333333327
             59.72
184.44499999999996
284.67999999999995
Length = 1000 rows
        dec
        deg
-------------------
 -80.03999999999999
            -79.905
             -79.69
              -79.1
             -79.01
              -78.2
             -77.86
 -77.78388888888888
              -74.5
             -74.28
                ...
             -39.36
             -39.34
 -39.32805555555556
             -39.21
              -39.2
             -39.18
 -39.15888888888889
              -37.2
-37.086111111111116
```

```
             -37.03
Length = 1000 rows
```

```
C:\Users\eklav\AppData\Local\Packages\PythonSoftwareFoundation.Python.3.11_qbz5n2kfr
a8p0\LocalCache\local-packages\Python311\site-packages\numpy\core\fromnumeric.py:77
1: UserWarning: Warning: 'partition' will ignore the 'mask' of the MaskedColumn.
  a.partition(kth, axis=axis, kind=kind, order=order)
```

In [3]:
```
median_peak_energy_short, median_peak_energy_long
```

Out[3]:
```
(359.3643, 135.48020000000002)
```

Exercise 2: working with and modifying a table (10 points)

Download the files "mcxc.dat" and "mcxc.readme" from today’s exercise page on the website. These files contain a catalog of X-ray-detected clusters of galaxies from Piffaretti et al. (2011) obtained through the VizieR service at the University of Strasbourg.

1. Use `astropy.io.ascii.read()` to read the table and its metadata into Python. This table is in "CDS" format, and you specify the metadata file using the `readme` argument.
2. Extract the log of L500 (luminosity in units of $10^{44}\mathrm{erg/s}$), log of M500 (mass in 10^{14} solar masses), and z (redshift) columns from the data into 1D arrays. Create a mask array selecting those clusters with redshift < 0.1.
3. Now construct the array r containing $r = \log L - 1.64 \log M$. The X-ray luminosity and mass of galaxy clusters are correlated roughly such that $L \propto M^{5/3}$, so the range in r is small.
4. Modify the table to add a masked column (`MaskedColumn` object) for r, and use the description "$r = \log L - 1.64 \log M$" for that column. Use the mask array you created to mask those clusters you don't want to store r values for. Print the table to check whether your column was added correctly. You should see "--" for masked-out rows.
5. Write the modified table to a file named "mcxc_new.csv" in comma-separated value (CSV) format.

In [5]:
```
#Code Here
from astropy.table import Table, MaskedColumn
data = astropy.io.ascii.read(r"C:\Users\eklav\OneDrive - University of Illinois - U

l500 = data['L500'].data
M500 = data['M500'].data
z = data['z'].data
mask = z < 0.1
filter_l500 = l500[mask]
filter_M500 = M500[mask]
filtered_z = z[mask]
```

```
r = filter_l500 - 1.64 * filter_M500
print(r)
r = data['L500'] - 1.64 * data['M500']
mask = data['z'] >= 0.1
r_column = MaskedColumn(r, mask=mask, name='r', description='r = log L - 1.64 log M
```

```
[-1.012892 -0.48837  -1.528762 -1.997207 -1.614681 -1.169538 -2.294202
 -2.34182  -1.294671 -1.260939 -1.572374 -1.259829 -1.815282 -1.163526
 -2.483263 -2.112338 -1.616338 -2.366497 -2.387405 -0.699704 -1.025122
 -1.309052 -0.592733 -2.145387 -3.618647 -2.754706 -1.25405  -2.210964
 -2.621285 -1.921318 -1.446881 -1.106659 -2.60272  -1.785156 -0.581953
 -2.558346 -0.998769 -1.604541 -1.954547 -0.983408 -0.593058 -0.32764
 -1.021002 -0.178581 -1.577728 -0.715587 -0.590573 -1.981609 -0.534731
 -0.860869 -0.043123 -2.062197 -0.5445   -0.403451 -0.583102 -1.208672
 -0.183307 -1.104538 -0.645966 -1.256982 -0.876203 -1.530939 -0.069357
 -2.206527 -2.042895 -1.776408 -0.426818 -1.00719  -0.865692 -1.663936
 -1.736471 -1.315752 -1.438803 -0.918986 -1.672694 -1.453302 -0.356023
 -1.798011 -1.379327 -1.92645  -0.648112 -0.673878 -2.154409 -0.482401
 -1.09285  -3.369212 -3.503389 -2.219902 -1.219815 -0.930073 -0.432375
 -1.306341 -1.331942 -2.218432 -3.391544 -3.869953 -1.255464 -1.508218
 -1.741421 -0.542563 -0.355047 -2.528991 -2.307222 -0.32651  -0.517275
 -1.214832 -0.284539 -3.204957 -0.9648   -0.090326 -1.218576 -1.082294
 -1.518311 -1.461554 -3.223212 -1.592785 -1.671387 -2.394637 -0.943087
 -1.844747 -3.317772 -1.939197 -0.976622 -0.745411 -2.34049  -0.890905
 -3.497623 -2.922362 -1.819904 -1.163596 -1.522558 -2.19611  -2.197663
 -1.08186  -0.869286 -0.178018 -1.59701  -1.923204 -2.122688 -0.973175
 -1.925145 -1.714234 -1.774218 -2.240331 -2.259316 -1.416953 -1.001587
 -2.12274  -1.555549 -1.964482 -1.149787 -0.7182   -0.928189 -1.715283
 -1.933003 -2.913932 -1.283885 -0.627164 -2.244168 -1.438697 -2.624765
 -1.303362 -1.131413 -2.16163  -1.25296  -0.843688 -0.915835 -2.384241
 -1.982299 -2.558719 -1.611904 -2.691456 -1.885201 -3.264093 -3.280667
 -2.373267 -2.561801 -1.697878 -2.214359 -0.631168 -1.419727 -1.411281
 -2.954324 -1.9997   -1.523089 -0.455232 -1.627533 -1.653678 -2.425365
 -0.934185 -0.741919 -0.611806 -1.742705 -1.43583  -2.213051 -1.329487
 -1.311914 -2.889733 -3.2684   -2.050165 -0.236568 -1.98789  -1.780664
 -1.008058 -1.645322 -2.115724 -1.476773 -0.488898 -0.674959 -0.782526
 -0.731917 -1.453925 -1.277303 -0.579634 -3.501476 -2.206081 -2.42164
 -1.170518 -0.489681 -3.227834 -0.388534 -0.208667 -0.403083 -0.313334
 -0.703723 -0.114669 -0.608506 -1.250416 -1.38983  -0.2386   -0.590108
 -1.463845 -1.829536 -1.444607 -2.126429 -1.731004 -1.139978 -0.478544
 -0.967418 -0.61147  -1.198072 -1.991015 -0.198721 -1.319409 -1.893787
 -0.515603 -1.7774   -2.049322 -1.616152 -0.338746 -0.58973  -0.600557
 -1.510017 -1.850323 -0.392465 -0.635819 -0.560194 -0.860873 -1.471095
 -1.762714 -0.666579 -0.842487 -2.234448 -2.260766 -0.791851 -1.358076
 -0.019137 -0.165794 -1.229306 -0.6343   -0.378619 -1.158739 -0.568373
 -1.090561 -1.263052 -2.867855 -0.66546  -1.578461 -2.404669 -1.936852
 -1.406939 -0.982155 -1.849109 -1.609347 -1.639068 -0.92315  -1.870055
 -1.645096 -0.473708 -0.943486 -1.352558 -0.869308 -1.032098 -0.608945
 -1.910906 -1.035689 -3.145264 -2.136122 -0.051536 -0.794452 -0.015591
 -0.876452 -1.33259  -0.735004 -1.557981 -1.74679  -1.558019 -0.302538
 -1.661832 -0.408616 -1.921694 -1.608531 -2.065681 -0.191857 -2.436911
 -1.327779 -0.018331 -1.966088 -2.163983 -0.408702 -1.296123 -1.861315
 -2.317982 -1.875101 -1.103761 -1.426818 -2.900173 -0.28169  -2.506779
 -3.288286 -1.895551 -3.350619 -3.571188 -0.656331 -0.497962 -1.873914
 -1.892853 -2.147914 -0.342392 -1.551815 -2.105045 -1.700304 -0.313256
 -0.738406 -0.737978 -1.200788 -1.942401 -0.423331 -2.015383 -2.083155
 -2.771178 -3.379005 -0.26201  -0.558943 -0.262865 -2.026193 -0.252799
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 -1.143301 -0.967108 -0.240728 -3.571068 -3.587853 -0.45241  -2.418899
 -1.224629 -2.218614 -1.172911 -0.755027 -3.055102 -2.231792 -1.792346
 -0.40124  -1.411325 -3.298319 -0.853582 -1.576897 -2.176764 -0.170295
```

```
-2.136164 -1.976552 -0.551587 -1.418276 -0.130238 -2.314801 -1.533683
-1.8872   -1.013161 -2.445823 -0.26864  -1.177391 -0.66509  -1.977489
-0.363432 -0.202953 -3.197403 -2.498036 -0.620923 -2.721357 -2.648922
-1.564369 -2.795161 -2.653129 -3.124918 -2.403253 -1.492943 -1.219233
-0.51858  -2.975198 -1.822422 -2.893395 -2.148227 -1.860131 -1.274017
-2.688437 -3.172087 -1.851496 -2.586148 -1.888634 -1.656304 -1.238875
-0.806471 -0.490635 -1.631005 -1.068927 -2.408324 -0.534358 -0.937917
-2.593647 -0.557032 -0.566908 -1.159607 -2.957973 -1.170439 -0.69917
-1.889398 -3.638457 -2.12927  -0.453168 -2.937571 -0.987867 -1.371302
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-1.551183 -3.319686 -3.426861 -2.083115 -2.314727 -2.733948 -1.327181
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-1.311458 -0.361789 -1.218899 -0.328675 -1.056523 -2.996398 -1.34638
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-0.303414 -0.895578 -0.462214 -0.106699 -2.292391 -1.950173 -0.387698
-1.300304 -0.619345 -0.240008 -2.823289 -0.122868 -0.666223 -0.441209
-1.676341 -0.952213 -0.450215 -1.380621 -0.384784 -1.732374 -2.679678
-1.363181 -1.600554 -1.678747 -0.771663 -0.346491 -1.865918 -0.391963
-2.240597 -2.097079 -2.08738  -1.549607 -1.361621 -2.351067 -1.821141
-3.626787 -2.115392 -2.445654 -1.808796 -2.319712 -2.472441 -0.118487
-0.543271 -1.792802 -1.964453 -3.425885 -0.103347 -1.051602 -0.21325
-3.606211 -1.866195 -0.42053  -1.895131 -1.504949 -2.700463 -3.153695
-0.31148  -0.692401 -0.958589 -1.601445 -0.265687 -1.584555 -0.64816
-1.230331 -1.128903 -1.651972 -1.834474 -1.792488 -0.939038 -0.540875
-1.955043 -1.416027 -1.495058 -1.3877   -1.905384 -1.077056 -2.709489
-0.321519 -0.635124 -2.668089 -2.249986 -2.102249 -2.018373 -1.545485
-1.698908 -0.724762 -1.374567 -2.10386  -2.62333  -2.90388  -2.726209
-1.526178 -1.195995 -2.232193 -2.052756 -1.769778 -3.321541 -2.053815
-1.2781   -2.323064 -3.090323 -1.226374 -3.065216 -0.46924  -0.692919
-2.517618 -2.725523 -2.670822 -2.110539 -1.914086 -2.762536 -2.042309
-0.711583 -2.144658 -1.577506 -2.077412 -0.893511 -2.101287 -1.124154
-0.963665 -3.008839 -0.457373 -3.098251 -0.476041 -2.612046 -0.736442
-1.291315 -1.710905 -1.398658 -1.503314 -2.55116  -2.823661 -0.825819
-2.352053 -1.668644 -1.346296 -1.338956 -0.86651  -2.596195 -0.465179
-2.078877 -1.753874 -2.615996 -2.260918 -1.755869 -3.300709 -1.317805
-2.962304 -1.476309 -1.658059 -1.231028 -1.609297 -2.092455 -1.551878
-2.77563  -2.167596 -0.369748 -2.313311 -2.208298 -2.201311 -2.461703
-0.566465 -1.980936 -1.373977 -2.74229  -2.179097]
```

In [6]:
```
data.add_column(r_column)
print(data)
data.write(r'C:\Users\eklav\OneDrive - University of Illinois - Urbana\astro_310\la
```

MCXC	OName	AName	...	L500r4	r
			...		1e+37 W
J0000.1+0816	RXC J0000.1+0816	UGC 12890	...	--	-1.012892
J0000.4-0237	RXC J0000.4-0237	--	...	--	-0.48836999999999997
J0001.6-1540	RXC J0001.6-1540	--	...	--	--
J0001.9+1204	RXC J0001.9+1204	A2692	...	--	--
J0003.1-0605	RXCJ0003.1-0605	A2697	...	--	--
J0003.2-3555	RXCJ0003.2-3555	A2717	...	--	-1.528762
J0003.8+0203	RXCJ0003.8+0203	A2700	...	--	-1.9972069999999997
J0004.9+1142	RXC J0004.9+1142	UGC 00032	...	--	-1.614681
J0005.3+1612	RXC J0005.3+1612	A2703	...	--	--
J0006.0-3443	RXCJ0006.0-3443	A2721	...	--	--
...	...	...	...	...	...
J2354.2-1024	RXCJ2354.2-1024	A2670	...	--	-2.461702999999999
J2355.1-1500	BVH2007 242	VMF98 223	...	--	-0.5664649999999999
J2355.6+1120	RXC J2355.6+1120	A2675	...	--	-1.9809359999999998
J2355.7+1138	A2678	A2678	...	--	-1.3739769999999998
J2355.8+3423	RXC J2355.8+3423	A2677	...	--	--
J2357.0-3445	RXCJ2357.0-3445	A4059	...	--	-2.74229
J2359.3-6042	RXCJ2359.3-6042	A4067	...	--	-2.1790969999999996
J2359.4-3418	MS2356.9-3434	--	...	--	--
J2359.5-3211	RX J2359.5-3211	BSe RXJ2359.5-3211	...	--	--
J2359.9-3928	RXCJ2359.9-3928	A4068	...	--	--

Length = 1743 rows