project_3

April 6, 2025

1 Project 3 - NICER

The purpose of this notebook is to produce the necessary plots and perform any auxiliary calculations required for the analysis steps associated with the project. As such, any answers to questions involving the reason for performing the various steps is left to the submission pdf writeup.

[215]:
```
#Module imports
import numpy as np
import matplotlib.pyplot as plt
from astropy.io import fits
import os
```

[216]:
```
#function for producing nice plots of fits file data
def plot_fits(data, title, xlabel, ylabel, fontsize):
    plt.figure()
    plt.rcParams.update({
        'text.usetex': True,
        'font.family': 'serif',
        'font.serif': ['Palatino']
    })
    plt.plot(data[0], data[1])
    plt.title(title, fontsize = fontsize)
    plt.xlabel(xlabel, fontsize= fontsize-1)
    plt.ylabel(ylabel, fontsize= fontsize-1)
    plt.show()
```

1.1 Installation

1.1.1 Downloading and Installing CALDB

We need to use the associated calibration file found at ./data/nicer/xti/cpf/arf/nixtiaveonaxis20170601v001.arf and plot the spectral response as a function of energy.

Loading in and taking a look at the spectral response of the first Ancillary Response File (ARF).

[217]:
```
arf_file_path = 'caldb/data/nicer/xti/cpf/arf/nixtiaveonaxis20170601v001.arf'
arf_file = fits.open(arf_file_path)
```

```
#Inspect the fits file to find the correct key for our desired data (specresp␣
 ↪in this case)
arf_file.info()
```

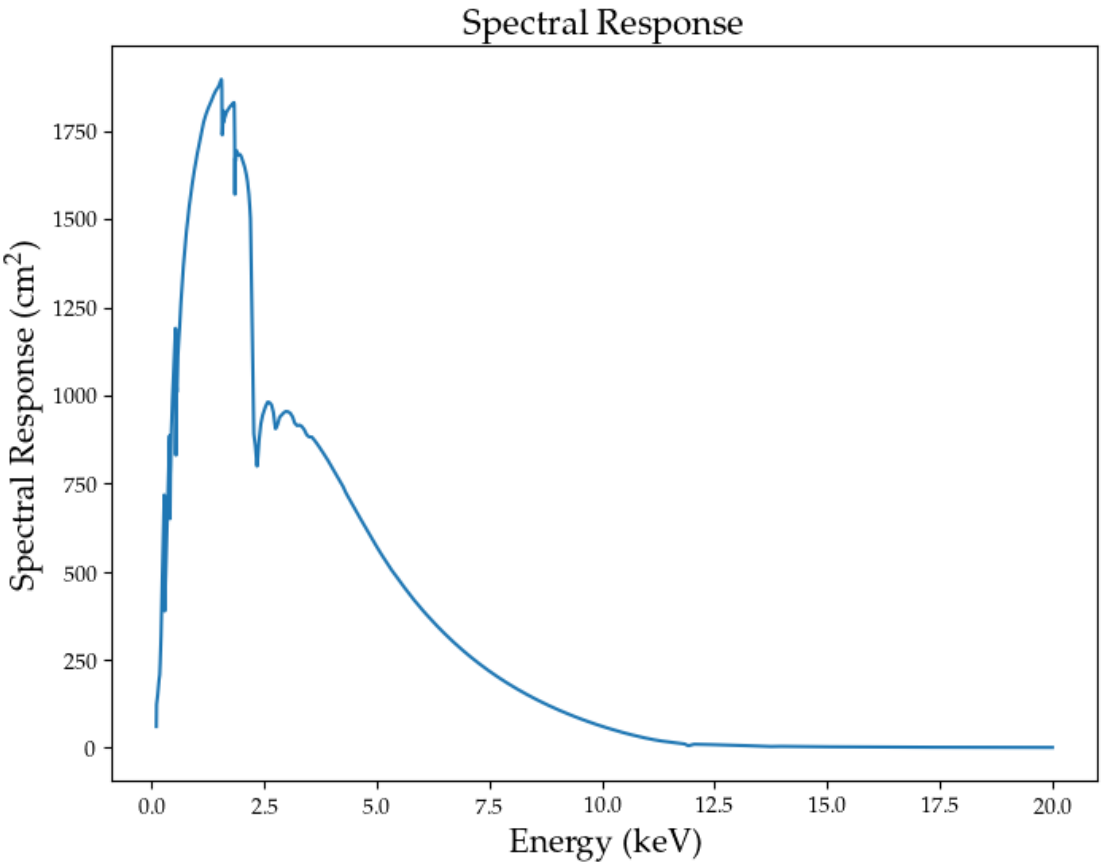
```
Filename: caldb/data/nicer/xti/cpf/arf/nixtiaveonaxis20170601v001.arf
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU      30   ()
  1  SPECRESP      1 BinTableHDU     81   3980R x 8C   [E, E, E, E, E, E, E, E]
```

[218]:
```
#print out the columns of the data set to see where energy and specresp are
arf_file[1].columns
```

[218]:
```
ColDefs(
    name = 'ENERG_LO'; format = 'E'; unit = 'keV'
    name = 'ENERG_HI'; format = 'E'; unit = 'keV'
    name = 'SPECRESP'; format = 'E'; unit = 'cm**2'
    name = 'ENERGY'; format = 'E'; unit = 'keV'
    name = 'XRCAREA'; format = 'E'; unit = 'cm2'
    name = 'QE'; format = 'E'
    name = 'WINDOW'; format = 'E'
    name = 'THERMALSD'; format = 'E'
)
```

[219]:
```
#define energy and spectral response variables for plotting
energy = arf_file[1].data['ENERGY']
specresp = arf_file[1].data['SPECRESP']

#plot the spectral response as a function of energy
plot_fits((energy, specresp), 'Spectral Response', 'Energy (keV)', 'Spectral␣
 ↪Response (cm$^{2}$)', fontsize=16)
```



1.2 Data Prep and Data Investigation

1.2.1 Examining the Cleaned (cl.evt) File

[220]:
```
cl_path = 'obs_id_data/2584010501/xti/event_cl/ni2584010501_0mpu7_cl.evt'
hdul_cl_path = fits.open(cl_path)
```

[221]:
```
#examine possible data sets in the cleaned file (we are interested in the␣
↪events)
hdul_cl_path.info()
```

```
Filename: obs_id_data/2584010501/xti/event_cl/ni2584010501_0mpu7_cl.evt
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU      32   ()
  1  EVENTS        1 BinTableHDU    284   2415871R x 14C   [1D, 1B, 1B, 1I, 1I,
1B, 1B, 8X, 1K, I, J, 1I, 1I, 1E]
  2  FPM_SEL       1 BinTableHDU    122   22977R x 3C   [1D, 56B, 56I]
  3  GTI           1 BinTableHDU    254   25R x 2C   [D, D]
  4  GTI_DET10     1 BinTableHDU    229   24R x 2C   [D, D]
  5  GTI_MPU0      1 BinTableHDU    253   25R x 2C   [D, D]
```

```
  6  GTI_MPU1      1 BinTableHDU    253   25R x 2C   [D, D]
  7  GTI_MPU2      1 BinTableHDU    253   25R x 2C   [D, D]
  8  GTI_MPU3      1 BinTableHDU    253   25R x 2C   [D, D]
  9  GTI_MPU4      1 BinTableHDU    253   25R x 2C   [D, D]
 10  GTI_MPU5      1 BinTableHDU    253   25R x 2C   [D, D]
 11  GTI_MPU6      1 BinTableHDU    253   25R x 2C   [D, D]
```

[222]:
```
#retrieve the time and energy columns
print(hdul_cl_path[1].columns)
time_cl = hdul_cl_path[1].data['TIME']  #Time of events

#note we are taking the uncalibrated gain data
energy_cl = hdul_cl_path[1].data['PHA']   #PHA: Pulse Height Analyzer -␣
 ↪detector measured quantity
```

```
ColDefs(
    name = 'TIME'; format = '1D'; unit = 's'; disp = 'F20.9'
    name = 'RAWX'; format = '1B'; unit = 'pixel'; coord_type = 'RAWX';
coord_ref_point = 0; coord_ref_value = 0.0; coord_inc = 1.0
    name = 'RAWY'; format = '1B'; unit = 'pixel'; coord_type = 'RAWY';
coord_ref_point = 0; coord_ref_value = 0.0; coord_inc = 1.0
    name = 'PHA'; format = '1I'; unit = 'chan'; null = -32768
    name = 'PHA_FAST'; format = '1I'; unit = 'chan'; null = -32768
    name = 'DET_ID'; format = '1B'; disp = 'I2.2'
    name = 'DEADTIME'; format = '1B'; unit = 's'; bscale = 6.202e-07; bzero =
3.101e-07; disp = 'F11.9'
    name = 'EVENT_FLAGS'; format = '8X'
    name = 'TICK'; format = '1K'
    name = 'MPU_A_TEMP'; format = 'I'; unit = 'Celsius'; null = -1; bscale =
0.10600843; bzero = -273.42105; disp = 'F6.3'
    name = 'MPU_UNDER_COUNT'; format = 'J'; null = -1
    name = 'PI_FAST'; format = '1I'; unit = 'chan'; null = -32768
    name = 'PI'; format = '1I'; unit = 'chan'; null = -32768
    name = 'PI_RATIO'; format = '1E'
)
```

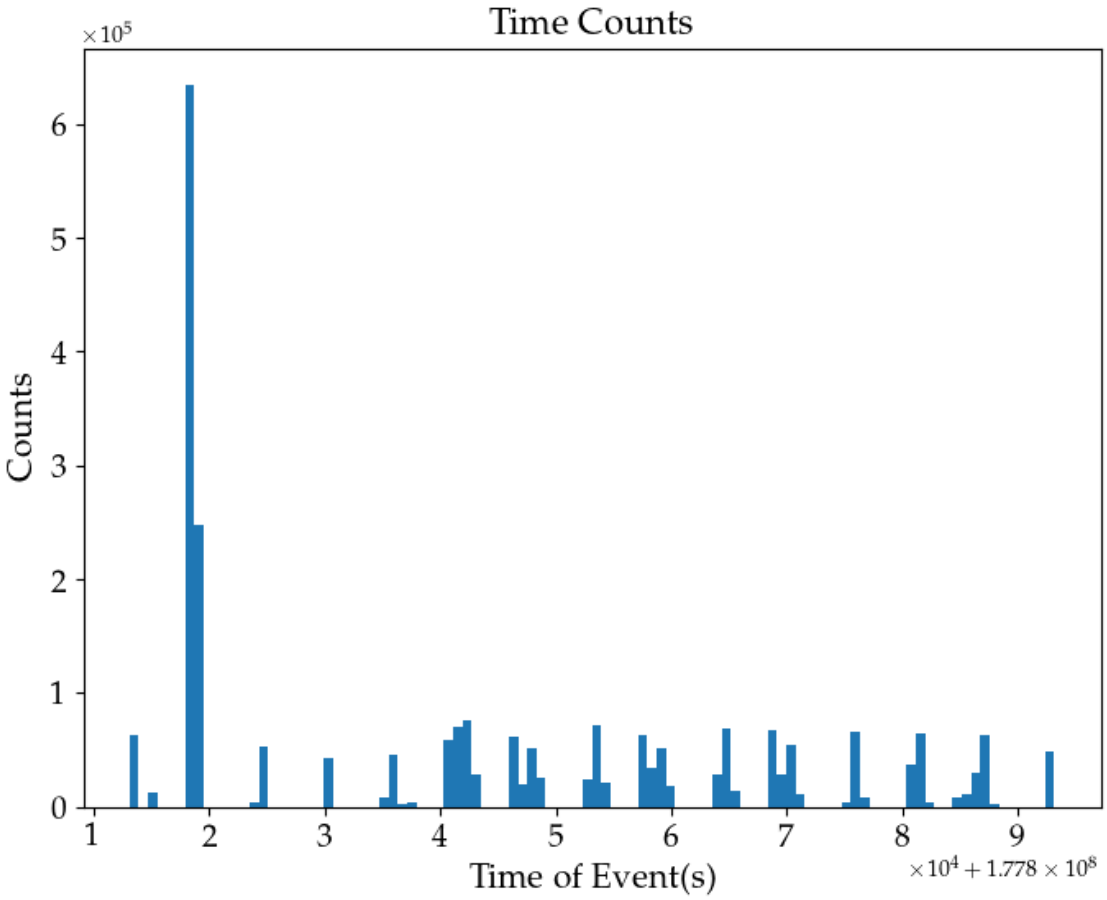
Time and Raw Energy Plots

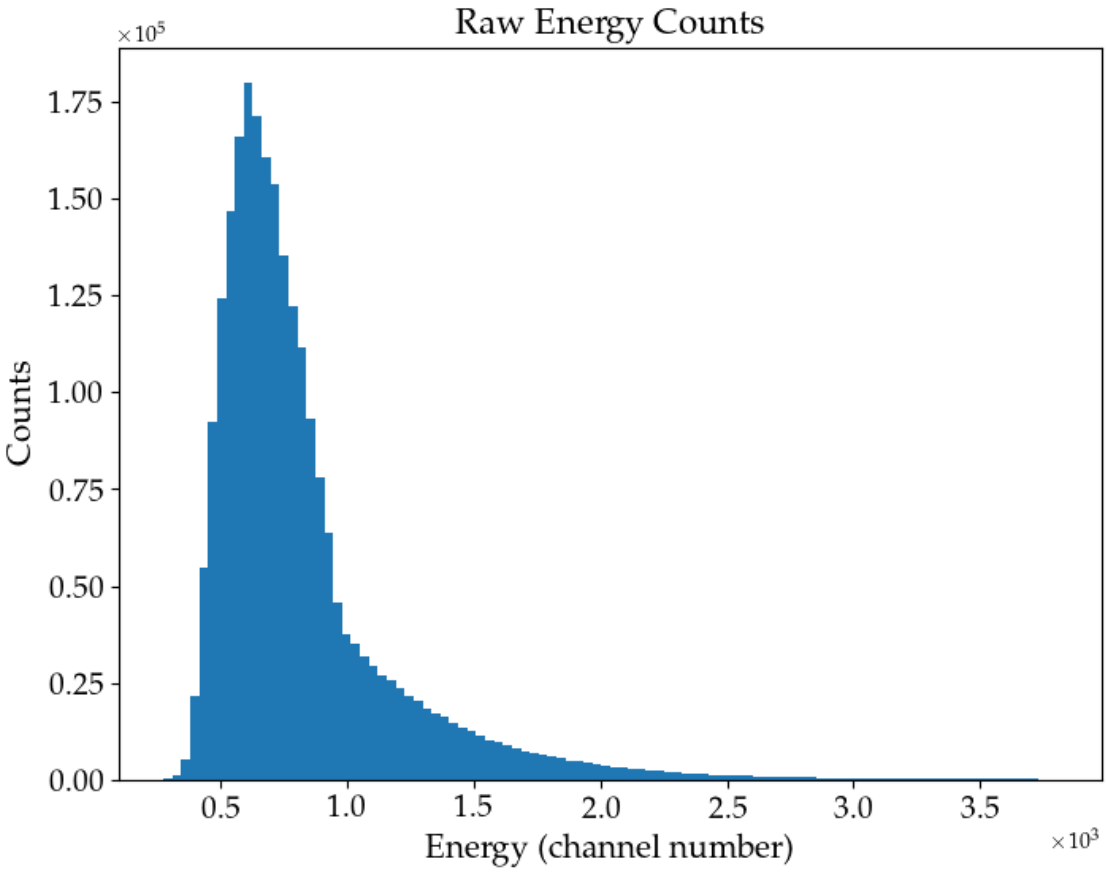
[223]:
```
plt.rcParams.update({
    'text.usetex': True,
    'font.family': 'serif',
    'font.serif': ['Palatino']
})
fontsize=16
plt.rcParams['figure.figsize'] = (8, 6)

#plot time and raw energy histograms
fig = plt.hist(time_cl, bins=100)
```

```
plt.title('Time Counts', fontsize = fontsize)
plt.xlabel('Time of Event(s)', fontsize= fontsize-1)
plt.ylabel('Counts', fontsize= fontsize-1)
plt.ticklabel_format(axis='both', style='sci', scilimits=(0,0))
plt.tick_params(labelsize=fontsize-2)
plt.show()

fig = plt.hist(energy_cl, bins=100)
plt.title('Raw Energy Counts', fontsize = fontsize)
plt.xlabel('Energy (channel number)', fontsize= fontsize-1)
plt.ylabel('Counts', fontsize= fontsize-1)
plt.tick_params(labelsize=fontsize-2)
plt.ticklabel_format(axis='both', style='sci', scilimits=(0,0))
plt.show()
```





1.2.2 Barycenter correction

[224]:
```
bary_corr_file = 'obs_id_data/2584010501/xti/event_cl/
 ↪ni2584010501_0mpu7_cl_barycorr.evt'
hdul_barycorr = fits.open(bary_corr_file)
hdul_barycorr.info()  #look for the EVENTS row
```

```
Filename: obs_id_data/2584010501/xti/event_cl/ni2584010501_0mpu7_cl_barycorr.evt
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU      32   ()
  1  EVENTS        1 BinTableHDU    310   2415871R x 14C   [1D, 1B, 1B, 1I, 1I,
1B, 1B, 8X, 1K, I, J, 1I, 1I, 1E]
  2  FPM_SEL       1 BinTableHDU    129   22977R x 3C   [1D, 56B, 56I]
  3  GTI           1 BinTableHDU    261   25R x 2C   [D, D]
  4  GTI_DET10     1 BinTableHDU    234   24R x 2C   [D, D]
  5  GTI_MPU0      1 BinTableHDU    260   25R x 2C   [D, D]
  6  GTI_MPU1      1 BinTableHDU    260   25R x 2C   [D, D]
  7  GTI_MPU2      1 BinTableHDU    260   25R x 2C   [D, D]
  8  GTI_MPU3      1 BinTableHDU    260   25R x 2C   [D, D]
```

```
  9  GTI_MPU4      1 BinTableHDU    260   25R x 2C   [D, D]
 10  GTI_MPU5      1 BinTableHDU    260   25R x 2C   [D, D]
 11  GTI_MPU6      1 BinTableHDU    260   25R x 2C   [D, D]
```

[225]:
```
barycenter_data = hdul_barycorr[1].data
barycenter_data.columns  #inspect the columns of the EVENTS row
```

[225]:
```
ColDefs(
    name = 'TIME'; format = '1D'; unit = 's'; disp = 'F20.9'
    name = 'RAWX'; format = '1B'; unit = 'pixel'; coord_type = 'RAWX';
coord_ref_point = 0; coord_ref_value = 0.0; coord_inc = 1.0
    name = 'RAWY'; format = '1B'; unit = 'pixel'; coord_type = 'RAWY';
coord_ref_point = 0; coord_ref_value = 0.0; coord_inc = 1.0
    name = 'PHA'; format = '1I'; unit = 'chan'; null = -32768
    name = 'PHA_FAST'; format = '1I'; unit = 'chan'; null = -32768
    name = 'DET_ID'; format = '1B'; disp = 'I2.2'
    name = 'DEADTIME'; format = '1B'; unit = 's'; bscale = 6.202e-07; bzero =
3.101e-07; disp = 'F11.9'
    name = 'EVENT_FLAGS'; format = '8X'
    name = 'TICK'; format = '1K'
    name = 'MPU_A_TEMP'; format = 'I'; unit = 'Celsius'; null = -1; bscale =
0.10600843; bzero = -273.42105; disp = 'F6.3'
    name = 'MPU_UNDER_COUNT'; format = 'J'; null = -1
    name = 'PI_FAST'; format = '1I'; unit = 'chan'; null = -32768
    name = 'PI'; format = '1I'; unit = 'chan'; null = -32768
    name = 'PI_RATIO'; format = '1E'
)
```

Comparing times

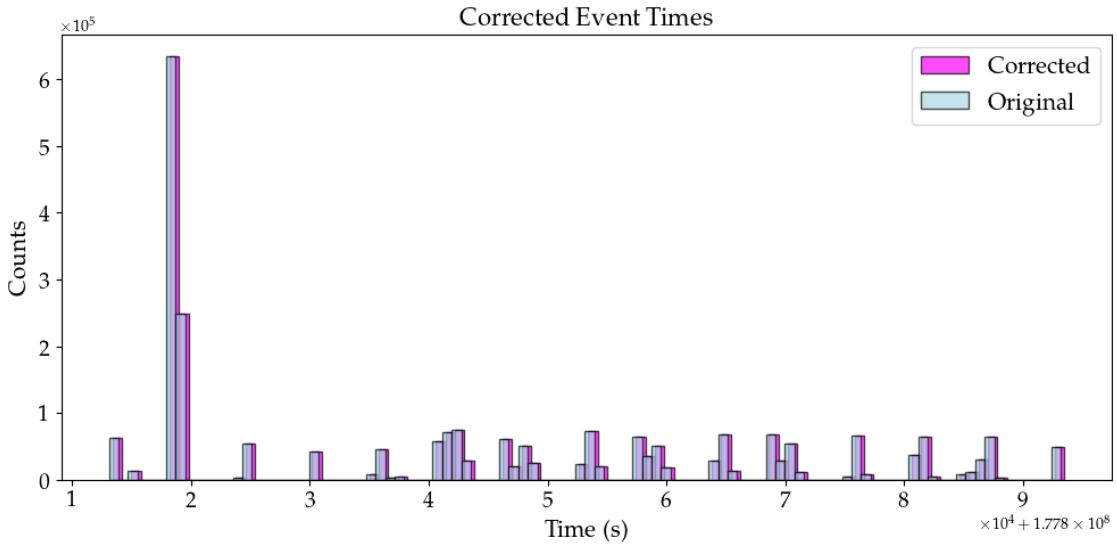
[226]:
```
#load the original and corrected event files
original_file = fits.open('obs_id_data/2584010501/xti/event_cl/
 ↪ni2584010501_0mpu7_cl.evt')
corrected_file = fits.open('obs_id_data/2584010501/xti/event_cl/
 ↪ni2584010501_0mpu7_cl_barycorr_no_clobber.evt')

#extract event times from both files
original_times = original_file[1].data['TIME']
corrected_times = corrected_file[1].data['TIME']

#plot histograms comparing time distributions
plt.figure(figsize=(10, 5))

#plot comparing event times
fontsize=16
fig = plt.hist(corrected_times, bins=100, color='magenta', alpha=0.7,␣
 ↪edgecolor='black', label="Corrected")
```

```
fig = plt.hist(original_times, bins=100, color='lightblue', alpha=0.7,␣
 ↪edgecolor='black', label="Original")
plt.title("Corrected Event Times", fontsize=fontsize)
plt.xlabel("Time (s)", fontsize=fontsize-1)
plt.ylabel("Counts", fontsize=fontsize-1)
plt.tick_params(labelsize=fontsize-2)
plt.ticklabel_format(axis='both', style='sci', scilimits=(0,0))
plt.legend(fontsize=fontsize-1)
plt.tight_layout()
plt.show()
```



1.3 Light Curves

1.3.1 Conversion from channel to eV

From the gain/energy scale documentation:

First, the PHA data should not be used for any real analysis since it has not been calibrated.

- units of PHA and PI are channels
  - this is the standard unit for pulse height channel quantities
- directly related to photon energy though the following:
  - each PI and PI_FAST bin is 10 eV or 0.01 keV
  - this is a linear scale, so eg PI = 100 corresponds to 1.00 to 1.01 keV
  - the full range of PI from 0 to 1501 is therefore 0.0 to 15.01 keV

We want to produce 3 light curves with the following parameters:

1. 0.1s time bins, 0.3 - 10 keV
2. 0.1s time bin, 3 - 10 keV
3. 0.1s time bin, 0.3 - 1 keV

the input suffix in the nicerl3-lc command calls for time in units of seconds and energy in PI value. therefore we actually want the following configurations:

1. 0.1s, 30-1000
2. 0.1s, 300-1000
3. 0.1s, 30-100

[227]:
```
#conversions between channel number and keV
print(0.3/0.01)
print(10/0.01)
print()
print(3/0.01)
print()
print(1/0.01)
```

```
30.0
1000.0

300.0

100.0
```

1.3.2 Plotting Flare Dominated Regions

[228]:
```
lc_congif1_file = 'obs_id_data/2584010501/xti/event_cl/
 ↪ni2584010501mpu7_srconfig_1.lc'
lc_congif2_file = 'obs_id_data/2584010501/xti/event_cl/
 ↪ni2584010501mpu7_srconfig_2.lc'
lc_congif3_file = 'obs_id_data/2584010501/xti/event_cl/
 ↪ni2584010501mpu7_srconfig_3.lc'

hdul_lc_congif1 = fits.open(lc_congif1_file)
hdul_lc_congif2 = fits.open(lc_congif2_file)
hdul_lc_congif3 = fits.open(lc_congif3_file)
```

[229]:
```
hdul_lc_congif1.info()
```

```
Filename: obs_id_data/2584010501/xti/event_cl/ni2584010501mpu7_srconfig_1.lc
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU     215   ()
  1  RATE          1 BinTableHDU    281   183570R x 5C   [D, E, E, E, 1E]
  2  GTI           1 BinTableHDU     53   25R x 2C   [1D, 1D]
```

[230]:
```
lc_congif1_data = hdul_lc_congif1['RATE'].data
lc_congif2_data = hdul_lc_congif2['RATE'].data
lc_congif3_data = hdul_lc_congif3['RATE'].data
lc_congif1_data.columns
```

[230]:
```
ColDefs(
    name = 'TIME'; format = 'D'; unit = 's'
    name = 'RATE'; format = 'E'; unit = 'count/s/52FPM'
    name = 'ERROR'; format = 'E'; unit = 'count/s/52FPM'
    name = 'FRACEXP'; format = 'E'
    name = 'NUM_FPM_SEL'; format = '1E'
)
```

[231]:
```
#lc time data from each configuration
lc_config1_time = lc_congif1_data['TIME']
lc_config2_time = lc_congif2_data['TIME']
lc_config3_time = lc_congif3_data['TIME']

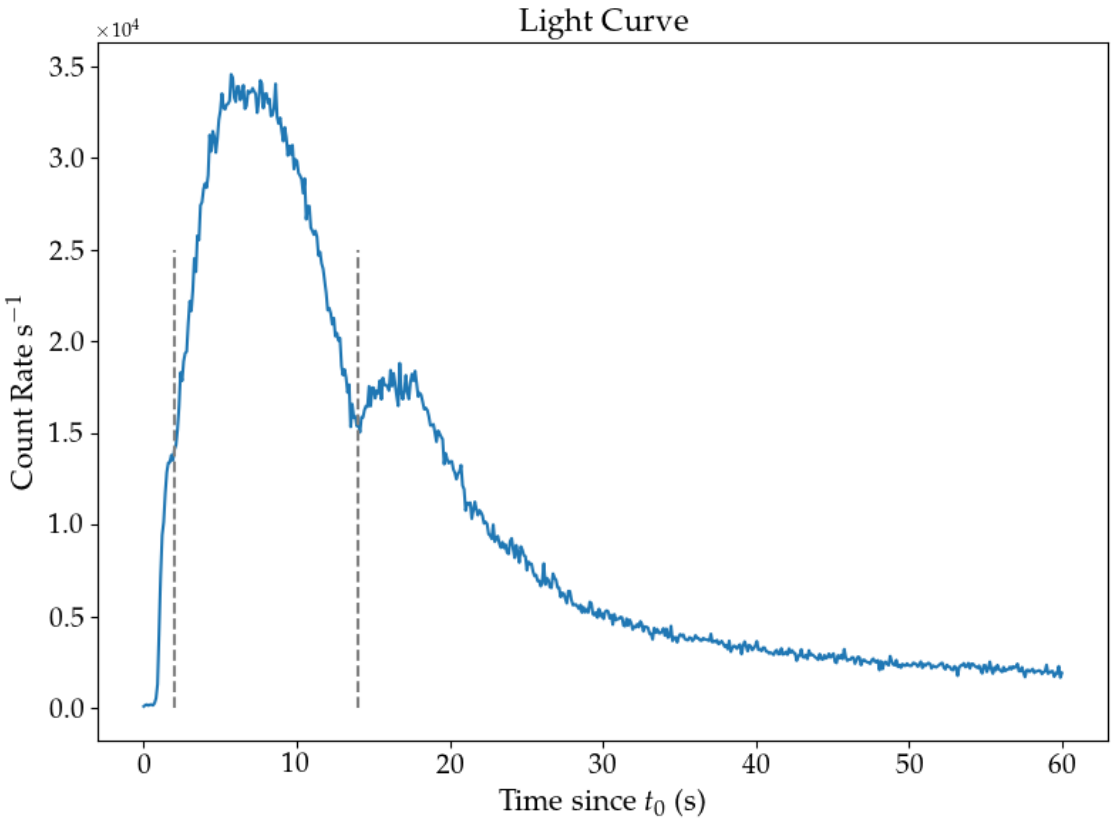
#lc rate data from each configuration
lc_config1_rate = lc_congif1_data['RATE']
lc_config2_rate = lc_congif2_data['RATE']
lc_config3_rate = lc_congif3_data['RATE']
```

Light Curve We want the flare dominated region which makes up about 60 second worth of data.

[232]:
```
#60s of data = 60s/0.1s/bin = 600bins
bin_left = 12030
bin_right = bin_left + 600  #left bin start + 60s in units of bins
t_vals = np.linspace(0, 60, 600)
print(f"$t_0$ is equal to {lc_config1_time[bin_left]}")

fontsize = 16
plt.plot(t_vals, lc_config1_rate[bin_left:bin_right])
plt.title("Light Curve", fontsize=fontsize)
plt.xlabel("Time since $t_0$ (s)", fontsize=fontsize-1)
plt.ylabel("Count Rate s$^{-1}$", fontsize=fontsize-1)
plt.ticklabel_format(axis='y', style='sci', scilimits=(0,0))
plt.tick_params(labelsize=fontsize-2)
plt.vlines(x=(2, 14) , ymin=0, ymax=2.5e4, color='grey', linestyles='--')
# plt.grid()
# plt.legend(fontsize=fontsize-1)
plt.tight_layout()
plt.show()
```

```
$t_0$ is equal to 5562.5
```



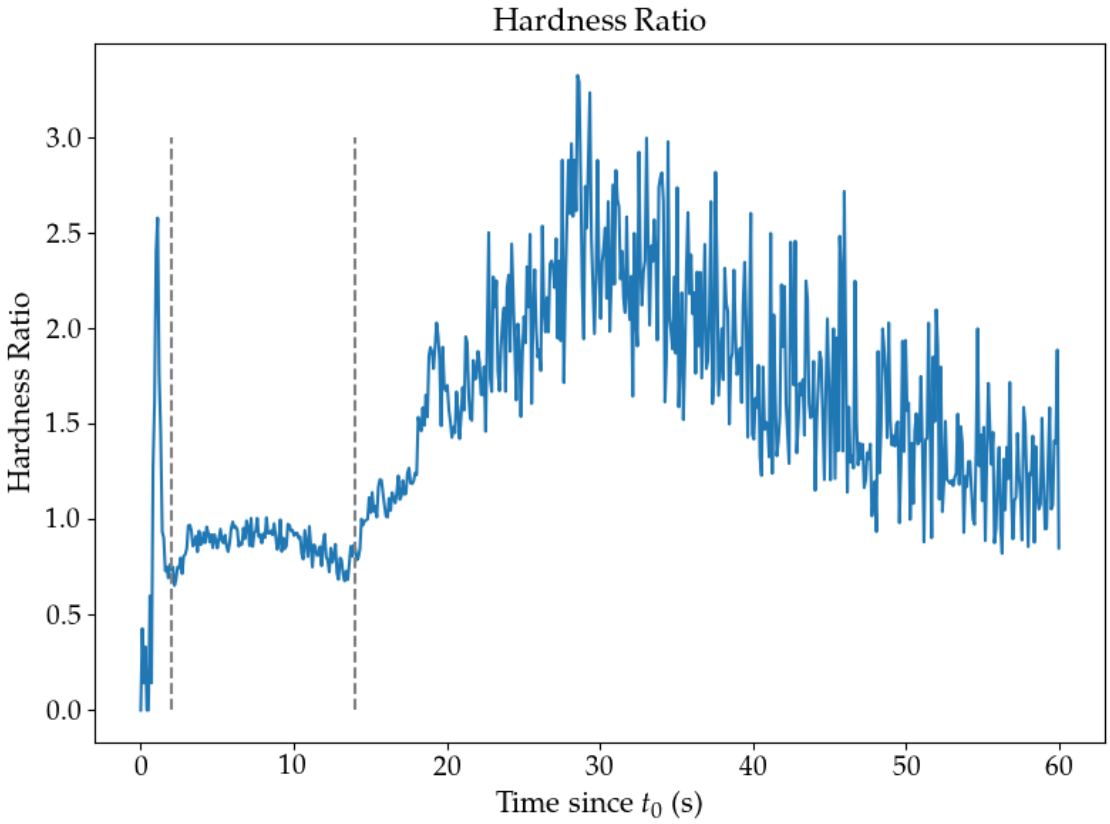
Hardness Ratio

[233]:
```
#compute the hardness ratio (high energy / low energy)
hardness_ratio = lc_config2_rate/lc_config3_rate

#plot the hardness ratio
plt.plot(t_vals, hardness_ratio[bin_left:bin_right])
plt.title("Hardness Ratio", fontsize=fontsize)
plt.xlabel("Time since $t_0$ (s)", fontsize=fontsize-1)
plt.ylabel("Hardness Ratio", fontsize=fontsize-1)
plt.ticklabel_format(axis='y', style='sci', scilimits=(0,0))
plt.tick_params(labelsize=fontsize-2)
# plt.legend(fontsize=fontsize-1)
plt.vlines(x=(2, 14) , ymin=0, ymax=3, color='grey', linestyles='--')
# plt.grid()
plt.tight_layout()
plt.show()
```

```
/tmp/ipykernel_83636/4266621225.py:2: RuntimeWarning: divide by zero encountered
in divide
  hardness_ratio = lc_config2_rate/lc_config3_rate
/tmp/ipykernel_83636/4266621225.py:2: RuntimeWarning: invalid value encountered
```

```
in divide
  hardness_ratio = lc_config2_rate/lc_config3_rate
```



1.4 Spectrum

Time Bins for the gti.txt file These can come directly from the light curve data in the plots from the previous section.

[234]:
```
#indices used above:
#60s of data = 60s/0.1s/bin = 600bins
bin_left = 12030
bin_right = bin_left + 600

#use these indices to extract the corresponding time data
time_array = np.zeros((600))
time_array[:] = lc_config1_time[bin_left:bin_right]

#start and stop bins
time_array_starts = time_array[::2]
time_array_stops = time_array[1::2]
```

```
#save in the correct .txt file format
bins = np.column_stack((time_array_starts, time_array_stops))
# print(bins)
np.savetxt('gti_barycorr.txt', bins, header=' # START STOP')
```

[235]:
```
#inspect the header of the .evt files
fn = 'obs_id_data/2584010501/xti/event_cl/ni2584010501mpu7_srconfig_1.lc'
f = fits.open(fn)
f.info()
```

```
Filename: obs_id_data/2584010501/xti/event_cl/ni2584010501mpu7_srconfig_1.lc
No.    Name      Ver    Type      Cards   Dimensions   Format
  0  PRIMARY       1 PrimaryHDU     215   ()
  1  RATE          1 BinTableHDU    281   183570R x 5C   [D, E, E, E, 1E]
  2  GTI           1 BinTableHDU     53   25R x 2C   [1D, 1D]
```

[236]:
```
gti_info = f[1]
gti_info.header
```

[236]:
```
XTENSION= 'BINTABLE'           / binary table extension
BITPIX  =                    8 / 8-bit bytes
NAXIS   =                    2 / 2-dimensional binary table
NAXIS1  =                   24 / width of table in bytes
NAXIS2  =               183570 / Number of bins
PCOUNT  =                    0 / size of special data area
GCOUNT  =                    1 / one data group (required keyword)
TFIELDS =                    5 / number of fields in each row
TTYPE1  = 'TIME    '           / NICER MET Timestamp
TFORM1  = 'D       '           / data format of field: 8-byte DOUBLE
TUNIT1  = 's       '           / physical unit of field
TTYPE2  = 'RATE    '           / Average rate (scaled to 52 FPMs)
TFORM2  = 'E       '           / data format of field: 4-byte REAL
TUNIT2  = 'count/s/52FPM'      / physical unit of field
TTYPE3  = 'ERROR   '           / Statistical error (scaled to 52 FPMs)
TFORM3  = 'E       '           / data format of field: 4-byte REAL
TUNIT3  = 'count/s/52FPM'      / physical unit of field
TTYPE4  = 'FRACEXP '           / Fractional exposure
TFORM4  = 'E       '           / data format of field: 4-byte REAL
EXTNAME = 'RATE    '           / name of this binary table extension
HDUCLASS= 'ogip    '           / Format conforms to OGIP/GSFC conventions
HDUCLAS1= 'LIGHTCURVE'         / Extension contains a light curve
DATAMODE= 'PHOTON  '           / Datamode
DATE    = '2025-04-03T17:34:17' / file creation date (YYYY-MM-DDThh:mm:ss UT)
EXPOSURE= 1.835700000029802E+04 / Exposure time
ONTIME  = 1.835700000029802E+04 / On-source time
TIMEPIXR= 5.000000000000000E-01 / Timestamps give center of bin
TIMEDEL = 1.000000000000000E-01 / Binning factor
```

```
TIMEZERO= 1.778130870500000E+08 / Time Zero
COMMENT   DEADTIME is approximate MPU deadtime on a per-event basis. Each MPU
COMMENT   is independent of the others.  MPU dead-time is quantized in steps
COMMENT   of 620.2 ns.  True dead time may be anywhere within this step, but
COMMENT   this FITS file records the center of the range. The dead-time value is
COMMENT   truncated at 79075.5 ns; the true dead-time may be larger.
COMMENT   EVENT_FLAGS is a bit pattern with MPU-derived information flags
COMMENT   (EVENT_FLAGS == bxx1xxxxx) First X-ray event in an MPU photon packet
COMMENT   (EVENT_FLAGS == bxxx1xxxx) Slow channel triggered
COMMENT   (EVENT_FLAGS == bxxxx1xxx) Fast channel triggered
COMMENT   (EVENT_FLAGS == bxxxxx1xx) Externally triggered pulse height sample
COMMENT   (EVENT_FLAGS == bxxxxxx1x) Hardware-detected overshoot
COMMENT   (EVENT_FLAGS == bxxxxxxx1) Hardware-detected undershoot
COMMENT   $Id: 4b324dae198c907e696418e47b9f3010ef3c9986 $
TELESCOP= 'NICER   '           / Telescope (mission) name
INSTRUME= 'XTI     '           / Instrument name
TARG_ID =                 6124 / NICER target catalog ID number
OBSERVER= 'BULT, PETER'        / Observer or Principal Investigator
TITLE   = 'MONITORING THE ACCRETING MILLISECOND PULSAR SAX J1808.4-3658' / Scien
OBS_ID  = '2584010501'         / Observation ID
ORIGIN  = 'NASA/GSFC'          / origin of fits file
CREATOR = 'extractor v6.17'    / Extractor
TLM2FITS= 'NICER2FITSv1.25_FSWv20170404a' / Telemetry converter version number
PROCVER = 'l0-master_20190620' / Processing script version number
SOFTVER = 'Hea_26Mar2025_V6.35.1_NICER_2025-03-11_V013a' / NICER Software Versio
CALDBVER= 'xti20190516'        / CALDB index versions used
SEQPNUM =                    3 / Number of times the dataset processed
OBJECT  = 'SAX_J1808.4-3658'   / Name of observed object
EQUINOX =            2.000E+03 / Equinox of celestial coord system
RADECSYS= 'FK5     '           / celestial coord system
RA_NOM  =             272.1151 / [deg] R.A. of nominal aspect point [J2000]
DEC_NOM =            -36.97873 / [deg] Dec. of nominal aspect point [J2000]
RA_OBJ  =             272.1151 / [deg] R.A. of target [J2000]
DEC_OBJ =            -36.97869 / [deg] Dec. of target [J2000]
TIMESYS = 'TT      '           / time measured from
MJDREFI =                56658 / MJD reference day
MJDREFF = 7.775925925925930E-04 / MJD reference (fraction of day)
TIMEREF = 'LOCAL   '           / reference time
TASSIGN = 'SATELLITE'          / Time assigned by clock
TIMEUNIT= 's       '           / unit for time keywords
TIERRELA=               1.0E-8 / [s/s] relative errors expressed as rate
TIERABSO=                  1.0 / [s] timing  precision  in seconds
TSTART  = 1.778130891000000E+08 / time start
TSTOP   = 1.778931989000000E+08 / time stop
DATE-OBS= '2019-08-21T00:32:09.2840' / Start date of observations
DATE-END= '2019-08-21T22:47:19.0840' / End date of observations
CLOCKAPP=                    T / Clock correction has been applied
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DEADAPP =                    F / Has DEADC been applied to data?
LEAPINIT=                    2 / [s] Leap seconds between MJDREF and TSTART
MPUTICKR=            25803540. / [Hz] Nominal MPU tick rate (custom)
MPUTICKM= 'PREVIOUS'           / Use previous PPS to adjust MPU tick rate
MPUTIMEM= 'PREVIOUS'           / Extraplate MPU time from previous PPS
MPU_ID  =                    0 /  Selected MPU number
UNDRTIME=              0.00011 / [usec] Undertime filter for noise ringers
GAINAPP =                    T / Gain correction has been applied
LONGSTRN= 'OGIP 1.0'           / The HEASARC Long String Convention may be used.
COMMENT   This FITS file may contain long string keyword values that are
COMMENT   continued over multiple keywords.  The HEASARC convention uses the &
COMMENT   character at the end of each substring which is then continued
COMMENT   on the next keyword which has the name CONTINUE.
GAINMETH= 'FT_OFF+MPU(PULSE_GRID)+MPUPIN(MPU_A_TEMP(POLY),MPU_UNDER_COUNT(DARK&'
CONTINUE  '_MV),MV_TREND)+ECORR(UNDER_GAIN)&'
CONTINUE  ''                   / MPU pulse grid lookup + FPM linear
GCALFILE= 'nixtiflightpi20170601v008.fits[1]' / Gain calibration file name
PIFSTCOR=                    T / Event file corrected for PI_FAST=1200?
TIMEMETH= 'MPU(CONST)+TIMEZERO(-1)' / Constant MPU bias + Broadreach
TCALFILE= 'nixtitimebias20150901v003.fits[1]' / TIME calibration file name
TELAPSE = 8.010980000001192E+04 / elapsed time
FILIN001= 'ni2584010501_0mpu7_cl.evt' / Input file name
HISTORY
HISTORY START PARAMETER list for niextract-events_2.6 at 2025-04-02T20:21:40
HISTORY
HISTORY P1 filename = 2584010501/xti/event_cl/ni2584010501_0mpu7_ufa.evt[PI=20:1
HISTORY P1 500,(DEFNULL(PI_RATIO,,1)<1.100000+120.000000/PI+0.000000e+00*PI**4),
HISTORY P1 (((MPU_UNDER_COUNT<80)||(EVENT_FLAGS==bx0x1x000)))]
HISTORY P2 eventsout = 2584010501/xti/event_cl/ni2584010501_0mpu7_cl.evt
HISTORY P3 regionfile = NONE
HISTORY P4 obsid = NONE
HISTORY P5 timefile = 2584010501/xti/event_cl/nimaketime.gti
HISTORY P6 xcolf = DETX
HISTORY P7 ycolf = DETY
HISTORY P8 tcol = TIME
HISTORY P9 events = EVENTS
HISTORY P10 fpmsel = YES
HISTORY P11 gti = GTI
HISTORY P12 gtimerge = OR
HISTORY P13 colexpr = NONE
HISTORY P14 minselectmb = 2000
HISTORY P15 copyall = no
HISTORY P16 cleanup = YES
HISTORY P17 history = YES
HISTORY P18 clobber = NO
HISTORY P19 chatter = 1
HISTORY P20 mode = ql
```

```
HISTORY END PARAMETER list for niextract-events_2.6
HISTORY
HISTORY
HISTORY START PARAMETER list for nicerclean_1.12 at 2025-04-02T20:21:44
HISTORY
HISTORY P1 infile = 2584010501/xti/event_cl/ni2584010501_0mpu7_ufa.evt
HISTORY P2 outfile = 2584010501/xti/event_cl/ni2584010501_0mpu7_cl.evt
HISTORY P3 gtifile = 2584010501/xti/event_cl/nimaketime.gti
HISTORY P4 detlist = launch,@2584010501/xti/event_cl/ni2584010501_0mpu7_ufa.evt_
HISTORY P4 detlist.txt
HISTORY P5 mkfile = 2584010501/auxil/ni2584010501.mkf
HISTORY P6 pirange = 20:1500
HISTORY P7 trumpetfilt = YES
HISTORY P8 trumpetkeep = GOOD
HISTORY P9 datamode = SO+S+F
HISTORY P10 keep_forced = NO
HISTORY P11 keep_undershoots = NO
HISTORY P12 keep_overshoots = NO
HISTORY P13 keep_noisering = NO
HISTORY P14 noisering_under = 80
HISTORY P15 fastconst = 1.1
HISTORY P16 fastsig = 1200.0
HISTORY P17 fastquart = 0
HISTORY P18 filtexpr = NONE
HISTORY P19 fpmsel = YES
HISTORY P20 cleanup = YES
HISTORY P21 clobber = NO
HISTORY P22 chatter = 2
HISTORY P23 history = YES
HISTORY P24 mode = ql
HISTORY END PARAMETER list for nicerclean_1.12
HISTORY
HISTORY
HISTORY START PARAMETER list for nifpmsel_1.9 at 2025-04-02T20:21:45
HISTORY
HISTORY P1 infile = 2584010501/xti/event_cl/ni2584010501_0mpu7_cl.evt
HISTORY P2 outfile = INFILE
HISTORY P3 detlist = launch,@2584010501/xti/event_cl/ni2584010501_0mpu7_ufa.evt_
HISTORY P3 detlist.txt
HISTORY P4 mkfile = 2584010501/auxil/ni2584010501.mkf
HISTORY P5 gti = GTI
HISTORY P6 filter = YES
HISTORY P7 cleanup = YES
HISTORY P8 clobber = YES
HISTORY P9 chatter = 2
HISTORY P10 history = YES
HISTORY P11 mode = ql
```

```
HISTORY END PARAMETER list for nifpmsel_1.9
HISTORY
HISTORY
HISTORY START PARAMETER list for nicermergeclean_1.12 at 2025-04-02T20:21:45
HISTORY
HISTORY P1 (infiles = @2584010501/xti/event_cl/nicercal_outfiles.lis)
HISTORY
HISTORY START FILE listing: nicercal_outfiles.lis
HISTORY
HISTORY F1 2584010501/xti/event_cl/ni2584010501_0mpu0_ufa.evt
HISTORY F2 2584010501/xti/event_cl/ni2584010501_0mpu1_ufa.evt
HISTORY F3 2584010501/xti/event_cl/ni2584010501_0mpu2_ufa.evt
HISTORY F4 2584010501/xti/event_cl/ni2584010501_0mpu3_ufa.evt
HISTORY F5 2584010501/xti/event_cl/ni2584010501_0mpu4_ufa.evt
HISTORY F6 2584010501/xti/event_cl/ni2584010501_0mpu5_ufa.evt
HISTORY F7 2584010501/xti/event_cl/ni2584010501_0mpu6_ufa.evt
HISTORY END FILE listing: nicercal_outfiles.lis
HISTORY
HISTORY P2 ufafile = 2584010501/xti/event_cl/ni2584010501_0mpu7_ufa.evt
HISTORY P3 clfile = 2584010501/xti/event_cl/ni2584010501_0mpu7_cl.evt
HISTORY P4 detlist = launch
HISTORY P5 mkfile = 2584010501/auxil/ni2584010501.mkf
HISTORY P6 mpulist = 0,1,2,3,4,5,6
HISTORY P7 gtifile = 2584010501/xti/event_cl/nimaketime.gti
HISTORY P8 pirange = 20:1500
HISTORY P9 trumpetfilt = YES
HISTORY P10 trumpetkeep = GOOD
HISTORY P11 datamode = DEFAULT
HISTORY P12 keep_forced = DEFAULT
HISTORY P13 keep_undershoots = DEFAULT
HISTORY P14 keep_overshoots = DEFAULT
HISTORY P15 keep_noisering = DEFAULT
HISTORY P16 noisering_under = DEFAULT
HISTORY P17 mpugtimerge = OR
HISTORY P18 nicerclean_args = NONE
HISTORY P19 autoscreen = YES
HISTORY P20 underonlyscr = DEFAULT
HISTORY P21 overonlyscr = DEFAULT
HISTORY P22 noise25scr = DEFAULT
HISTORY P23 noiseextscr = DEFAULT
HISTORY P24 mpugtiscr = DEFAULT
HISTORY P25 roundrobbinscr = DEFAULT
HISTORY P26 lowmemscr = DEFAULT
HISTORY P27 cleaninfiles = NO
HISTORY P28 nomerge = YES
HISTORY P29 fpmsel = YES
HISTORY P30 cleanup = YES
```

```
HISTORY P31 clobber = NO
HISTORY P32 chatter = 2
HISTORY P33 history = YES
HISTORY P34 mode = ql
HISTORY END PARAMETER list for nicermergeclean_1.12
HISTORY
HDUCLAS2= 'TOTAL   '
HDUCLAS3= 'RATE    '
DETNAM  = 'NONE    '           / Detector
LIVETIME= 1.835700000029802E+04 / On-source time
DATE-BEG= '2019-08-21T00:32:09.2840' / Start date of observations
MJD-BEG = 5.871602264217592E+04 / MJD of data start time
MJD-END = 5.871694983893519E+04 / MJD of data start time
MJD-OBS = 5.871602264217592E+04 / MJD of data start time
USER    = 'mike    '           / User name of creator
PHALCUT =                   30 / Minimum PI channel
PHAHCUT =                 1000 / Maximum PI channel
NPIXSOU =     5.6000000000E+01 / Numbers of Pixels
MINFREXP=     1.0000000000E-01 / Minimum value of FRACEXP included
HISTORY extractor v6.17
CHECKSUM= '9HeMA9eL9EeLA9eL'   / HDU checksum updated 2025-04-03T17:34:17
DATASUM = '3365210597'         / data unit checksum updated 2025-04-03T17:34:17
HISTORY
HISTORY START PARAMETER list for nicerl3-lc_2.2 at 2025-04-03T17:34:17
HISTORY
HISTORY P1 indir = 2584010501
HISTORY P2 pirange = 30-1000
HISTORY P3 timebin = 0.1
HISTORY P4 cldir = $INDIR/xti/event_cl,$INDIR
HISTORY P5 clfile = $CLDIR/ni$OBSID_0mpu7_cl.evt
HISTORY P6 ufafile = $CLDIR/ni$OBSID_0mpu7_ufa.evt
HISTORY P7 mkfile = $CLDIR/ni$OBSID.mkf,$INDIR/auxil/ni$OBSID.mkf
HISTORY P8 lcfile = $INROOTmpu7_sr$SUFFIX.lc
HISTORY P9 bkgfile = $INROOTmpu7_bg$SUFFIX.lc
HISTORY P10 skyarffile = $INROOTmpu7_sk$SUFFIX.arf
HISTORY P11 rmffile = $INROOTmpu7$SUFFIX.rmf
HISTORY P12 bkgrmffile = $INROOTmpu7_bg$SUFFIX.rmf
HISTORY P13 lcthresh = 0.1
HISTORY P14 detnormtype = ARR52
HISTORY P15 detnormbuff = 1.6
HISTORY P16 detnormchg = 10
HISTORY P17 doplot = YES
HISTORY P18 plotfiles = $INROOTmpu7_lc$SUFFIX.png/png
HISTORY P19 plottime = TIME
HISTORY P20 bkgmodeltype = NONE
HISTORY P21 bkgformat = file
HISTORY P22 bkgcomponents = INDEF
```

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HISTORY P23 bkgvariant = INDEF
HISTORY P24 bkgver = INDEF
HISTORY P25 bkgconfigs = NONE
HISTORY P26 hbgcut = 0.5
HISTORY P27 s0cut = 30.0
HISTORY P28 swauxilfile = CALDB
HISTORY P29 detlist = launch
HISTORY P30 suffix = config_1
HISTORY P31 gtifile = NONE
HISTORY P32 obsid = AUTO
HISTORY P33 incremental = NO
HISTORY P34 cleanup = YES
HISTORY P35 clobber = YES
HISTORY P36 chatter = 2
HISTORY P37 history = YES
HISTORY P38 mode = ql
HISTORY END PARAMETER list for nicerl3-lc_2.2
HISTORY
TTYPE5  = 'NUM_FPM_SEL'        / label for field
TFORM5  = '1E      '           / format of field
```