Example of AstroSat SXT Data Analysis

SXT POC: http://www.tifr.res.in/~astrosat_sxt/home.php

Please read the SXT portions of the AstroSat handbook before starting the data analysis: http://www.iucaa.in/~astrosat/AstroSat_handbook.pdf

Getting Clean Event Files

1. Get the level-2 *tar.gz* files (of the latest version; now processed by SXT pipeline version 1.4).

2. Untar the files using the command: *tar xzvf filename.tar.gz*

3. To untar all the files together, list the files in a directory using: *ls *tar.gz > filename.sh*

4. To open the file containing the list: *gedit filename.sh*

5. A clean event file "AS1A04_055T01_9000001574sxtPC00_level2_cl.evt" could be found in a directory "~/20171002_A04_055T01_9000001574_level2_10881_V1.0/sxt/10881/sxt.01". This is an example and here "10881" is the satellite orbit number.

Merging the clean event files: (if data from more than one orbit are to be combined):

1. Download SXTEVTMERGERTOOL from the SXT website:
http://www.tifr.res.in/~astrosat_sxt/page1_data_analysis.php

2. Follow the instruction of the "readme.pdf" file.

Analysing the data

Making the image, light curve and spectrum:

Use XSELECT to get the image, light curve and spectrum of the source.

The following link provides the information on using XSELECT to make the image, light curve and spectrum of the source.
For using XSELECT: http://www.swift.ac.uk/analysis/xrt/xselect.php
and https://heasarc.gsfc.nasa.gov/docs/software/lheasoft/ftools/xselect/xselect.html

1. First, one needs to enter the name of the directory in which the merged/single clean event file is placed. After entering the directory name, the merged/single clean event file has to be entered.

2. To get the image of the source, use the commands >**extract image** >**plot image.**

- Region filters can applied after the image gets plotted in ds9 (*http://ds9.si.edu/doc/user/index.html*). This can be done by selecting the required region using the Region option from the Menu bar.

- The region filters have to saved. The command for applying region filters is **filter region**

nameofsavedregionfile.reg. The image has to be re-extracted and re-plotted.

- The image can be saved using the command >**save image** and it gets saved with an extension .img.

3. To make the light curve, use the commands >**extract curve** >**plot curve**. The curve can be saved using the command >**save curve** and it gets saved with an extension .lc.

4. To get the spectrum, use commands >**extract spectrum** >**plot spectrum**. The spectrum can be saved using the command >**save spectrum** and it gets saved with an extension .pha.

5. The image, the curve and the spectrum can also be saved using the command **>save all**.

Getting the RAWX, RAWY coordinates of the image centroid:

1. Remove the region filter which is applied using the command **> clear region filter**.

2. Use the command > **set xyname rawx rawy > extract image > plot image**. Choose region (circle) and find and note down the RAW centroid coordinates.

Analysing the spectrum:

1. For analysing the spectrum, the *XSPEC* tool can be used.

2. *XSPEC* requires the spectrum data file (.pha), the background file (.pha), the response file (.rmf) and the area file (.arf).

3. The following link describes the XSPEC. The chapter *"Walks through XSPEC"* explains the analysis with an example.

https://heasarc.gsfc.nasa.gov/xanadu/xspec/XspecManual.pdf

ARF, Background and RMF used:
(One can get these files from http://www.tifr.res.in/~astrosat_sxt/page1_data_analysis.php)

On -axis ARF files:
FW – central 1 arcmin removal – extraction radius 5 arc min: sxt_fw_excl01_v02.arf
FW – without removal - extraction radius 5 arc min: sxt_fw_v02.arf
PC – central 1 arcmin removal - extraction radius 16 arc min: sxt_pc_excl01_v03.arf
PC – central 2 arcmin removal - extraction radius 16 arc min: sxt_pc_excl02_v03.arf
PC – central 3 arcmin removal - extraction radius 16 arc min: sxt_pc_excl03_v03.arf

Background File: SkyBkg_comb_EL3p5_Cl_Rd16p0_v01.pha *(same for PC and FW mode)*

RMF File: sxt_pc_mat_g0to12.rmf *(same for PC and FW mode)*

Creating off-axis ARFs from on-axis ARFs using SXTMKARF tool:

1. Download the SXTMKARF tool from
http://www.tifr.res.in/~astrosat_sxt/page1_data_analysis.php .

2. To run the tool, one needs the .pha file created using XSELECT, the name for the output ARF file

which will be created after running the code, the RMF and the on-axis ARF files. Type chmod 755 sxtmkarf.sh, which gives the permission to run the script. Then run ./sxtmkarf.sh . It will ask for RAWX, RAWY co-ordinates, which are the previously noted down RAW centroid co-ordinates.

- Example:
  sxtmkarf phafile=crab_pc_1arcmin_spec.pha outfile=sxt_pc_excl01_v03_offax.arf rmffile=sxt_pc_mat_g0to12.rmf inarffile=sxt_pc_excl01_v03.arf expofile=NONE psfflag=N vigfile=CALDB srcx=-1 srcy=-1 chatter=4 clobber=Y history=Y
  cphead sxt_pc_excl01_v03.arf+1 sxt_pc_excl01_v03_offax.arf+1

Commands used to analyse Crab data:
(Data can be downloaded from http://www.tifr.res.in/~astrosat_sxt/page1_data_analysis.php).

The following commands were used in XSPEC to analyse the data:

Energy range selected: 0.7 keV – 7.0 keV

1. grppha command: > grppha
   a. Enter the original .pha spectrum file (***filename.pha***)
   b. Change the name of original .pha file and enter the new name. (***filename_grp.pha)***
   c. Enter the background file name. (> command **chkkey backfile *filename.pha)***
   d. Enter the response filename. (> command **chkkey respfile *filename.rmf)***
   e. Enter the arf filename. (> command **chkkey ancrfile *filename.arf)***
   f. Enter the number of channels to be grouped. (command > **group min 60**)
   e. Enter exit.

2. First, the data file i.e. the .pha spectrum file has to be entered.
   > data *filename.pha*.
Subsequently, the background file, the response file and the ancillary response file
   > **back SkyBkg_comb_EL3p5_Cl_Rd16p0_v01.pha** ,
   > **response sxt_pc_mat_g0to12.rmf**
   > **arf *filename.arf*** (corresponding to the data file)

3. The spectral model used: **tbabs*powerlaw**.
   - Command **> model tbabs*powerlaw**
   - Enter the initial values of nH, PhoIndex, norm, and fit.

4. gain fit command: > gain fit
   The slope should be kept frozen at 1 with “1, -1”, and the offset should be a free parameter.

5. Abundance: > abund wilm

6. Xsect : > xsect bcmc

7. Systematic command:
   The systematic used was 0.02: > systematic 0.02

8. Fit command:
   > fit

9. Error command:
   Determines the error in the three parameters.
   > error 1 2 3

1. PC mode:

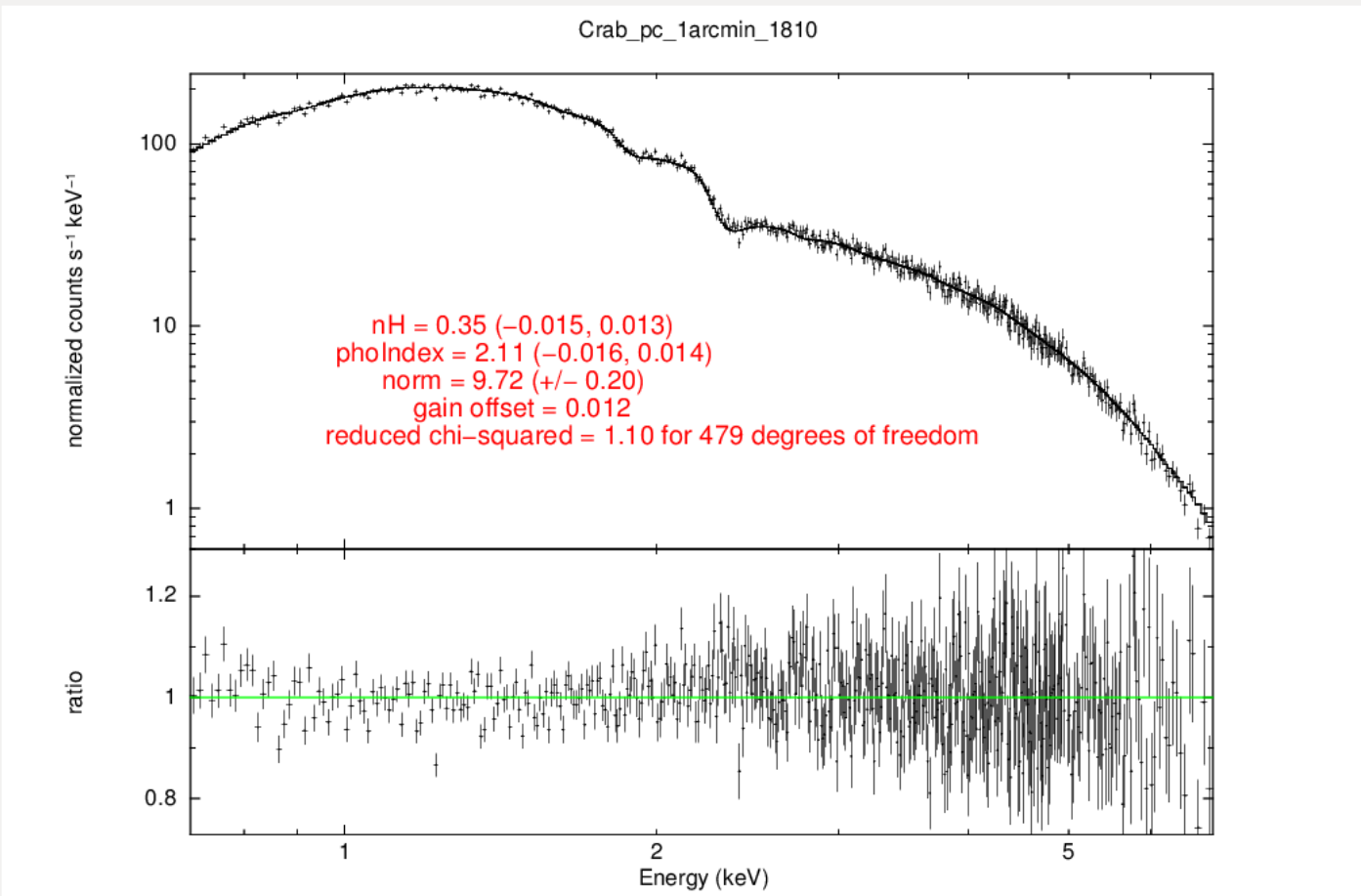
Observation date: 31.03.2016

Orbit Used: 02741

1 arcmin removal, extraction radius 16 arcmin:

On-axis ARF used: sxt_pc_excl01_v03.arf

The plot below was obtained using the commands mentioned above.



Similar plots can be obtained for:

PC – central 2 arcmin removal - extraction radius 16 arc min: sxt_pc_excl02_v03.arf
PC – central 3 arcmin removal - extraction radius 16 arc min: sxt_pc_excl03_v03.arf

2. FW Mode:

Observation dates: 31.03.2016
Orbits to be Merged: 02762, 02766, 02767, 02768

ARFs to be used:

1. FW - central 1 arcmin removal – extraction radius 5 arc min: sxt_fw_excl01_v02.arf
2. FW – without removal - extraction radius 5 arc min: sxt_fw_v02.arf

Similar procedure and commands are to be followed for the FW mode.

Note:
Central circular exclusion of PSFs can be done to mitigate the pile-up effect for bright sources. One has to use a suitable ARF depending on the exclusion area radius. For faint sources, exclusion is not required. In such PC mode data, one can use sxt_pc_excl01_v03.arf, and correct the normalizations of spectral fitting by estimating the fraction of counts in the central 1 arcmin radius circular region. For faint sources, the spectrum extraction region can have a radius smaller than 16 arcmin.