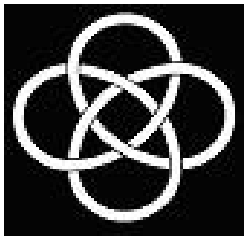
AstroSat Calibration Status/Issues



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IUCAA, Pune

AstroSat Science Support Cell (ASSC)

Thanks:

Sunil Chandra, K. P. Singh & SXT Team

H. M. Antia, R. Misra, J. Roy (ASSC) & LAXPC Team

Mithun N. P. S., D. Bhttacharya & CZTI Team

S. N. Tandon, C. S. Stalin & UVIT Team

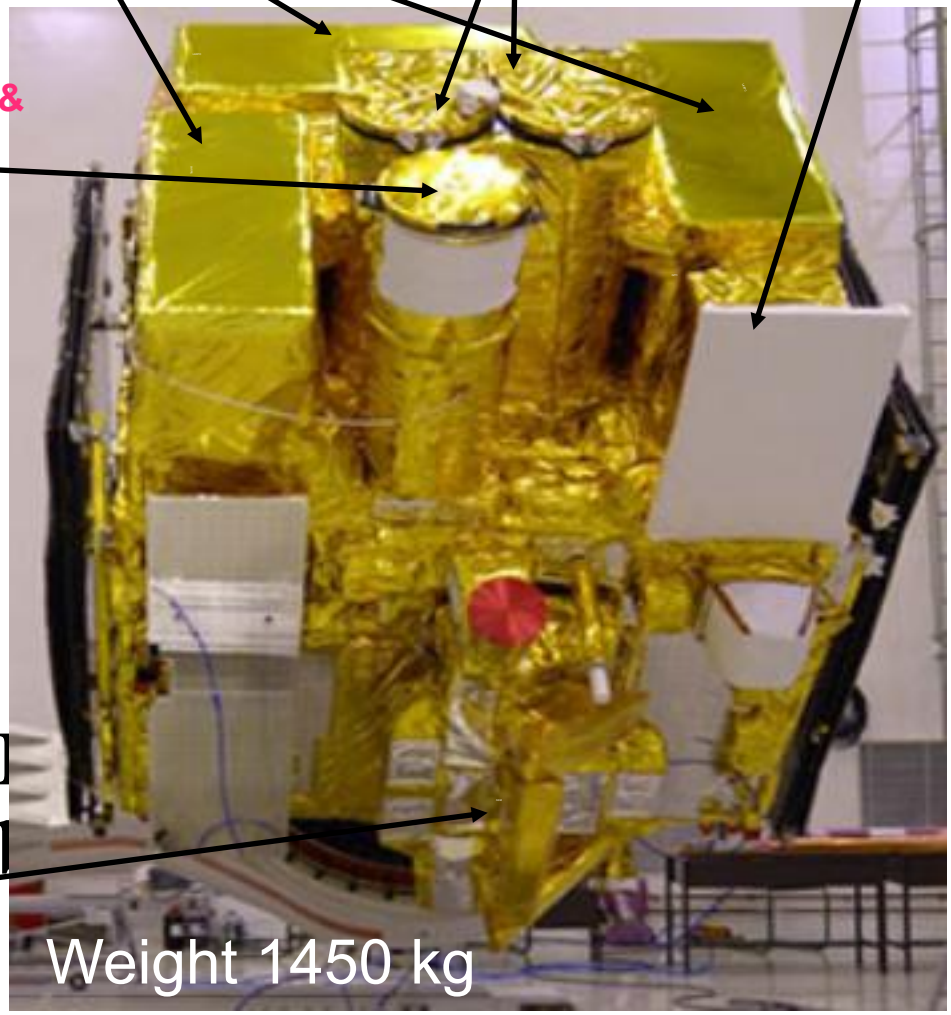
AstroSat

LAXPC
3-100 keV X-ray Timing, broadband spectroscopy

UVIT
1.4" UV imaging
1200 - 3000 A

CZTI
10-250 keV hard X-ray Imaging, timing, spectroscopy, Polarization

SXT
0.3-8 keV imaging & line spectroscopy



SSM
rotating 2-10 keV monitor

PI: S. Seetha (ISRO)
PMs: S.N. Tandon (UVIT),
H. M. Antia (LAXPC),
S. Bhattacharyya (SXT)
A.R. Rao (CZTI)
M.C. Ramadevi (SSM)

LAXPC: TIFR, RRI
SXT: TIFR, ISRO, UoL
CZTI: TIFR, ISRO, IUCAA, RRI, PRL
SSM: ISRO, IUCAA, RRI
UVIT: IIA, ISRO, IUCAA, CSA

Spacecraft: ISRO
Operations: ISRO
Ground software: ISAC, SAC, TIFR, RRI, IIA, IUCAA, NCRA, PRL

Launched 30 September 2015,
Circular orbit at an altitude of 650 km and 6deg inclination

AstroSat mission status

- 5 years in orbit, 1400 distinct targets, 2100 individual pointings, 240 ToO observations
- 1369 Users from 42 countries

Status of different instruments

UVIT: NUV no longer functioning

FUV and VIS channels functioning normally

LAXPC: Unit 3 had gas leak. Switched off on 8 March 2018

Unit 1 showed anomalous counts since 26 March 2018

- Operated with reduced HV since 29 March 2018
- Erratic behavior again started on 9 April 2019
  - data not usable.

Unit 2 functioning normally

SXT and CZTI functioning normally.

Pipeline, analysis softwares, CALDB

AstroSat Science Support Cell (ASSC) website

http://astrosat-ssc.iucaa.in/

Or Payload Operation Centre websites

- SXT (https://www.tifr.res.in/~astrosat_sxt/index.html)
- LAXPC (https://www.tifr.res.in/~astrosat_laxpc/astrosat_laxpc.html)
- CZTI (http://astrosat.iucaa.in/czti/?q=home)
- UVIT (https://uvit.iiap.res.in/Downloads)

AstroSat Data Archive

https://astrobrowse.issdc.gov.in/astro_archive/archive/Home.jsp

Quick Look Data & Data quality report

SXT: https://www.tifr.res.in/~astrosat_sxt/HTMLOUTDIR/input.html

LAXPC: https://www.tifr.res.in/~astrosat_laxpc/laxpclog/lc-hdr.html

CZTI: http://www.iucaa.in/~astrosat/czti_dqr/index.html

UVIT: http://uvit.iiap.res.in/l2stats (data status only)

SXT data processing & Analysis

Level1, Leve2 data from AstroSat archive

SXT pipeline (AS1SXTLevel2-1.4b)

run "sxtpipeline" to generate orbit-wise level2 filtered and cleaned event list

Merger Tool

Julia tool ("sxt_l2evtlist_merge") to merge orbit-wise level2 event files

HEASOFT/Xselect

Extract spectra, lightcurves, images

SXT Spectral Response

SXT RMF: sxt_pc_mat_g0to12.rmf, sxt_pc_mat_g0.rmf, sxt_pc_mat_g0to4.rmf

SXT ARF: sxt_pc_excl00_v04_20190608.arf (on axis, 15arcmin radius)

: Use sxtARFmodule (off axis, other extraction regions)

Background spectrum

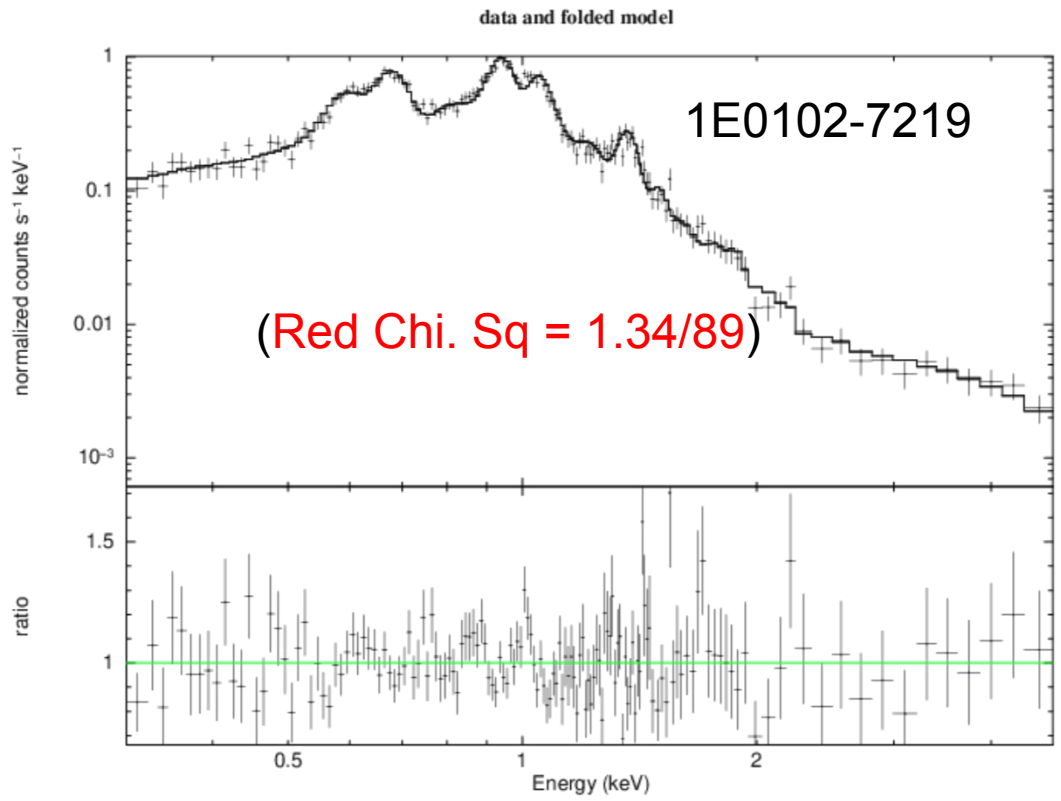
No source free-region in the CCD, background PHA spectrum from blank sky observation ("SkyBkg_comb_EL3p5_Cl_Rd16p0_v01.pha")

Use xspec gain fit with slope fixed at 1.

SXT calibration status & Issues

ARF recalibrated based on SXT observations of thermal SNRs1E0102 and simultaneous SXT+XRT observation of Blazar 1ES1959+650.

(Sunil Chandra + SXT team)



IACHEC model with following free parameters

	SXT	IACHEC
1) OVII Heα (0.56 keV) =	1.313	**1.02±0.12**
2) OVIII Lyα (0.653 keV) =	4.393	**3.941±0.28**
3) NeIX Heα (0.922 keV) =	1.381	**1.349±0.09**
4) NeX Lyα (1.127 keV) =	1.378	**1.18±0.09**

5) Const = 1.001 +/- 0.04

6) mekal norm =
(3.38 +/- 1.12) x 1E-03 ph cm^-2 s^-1

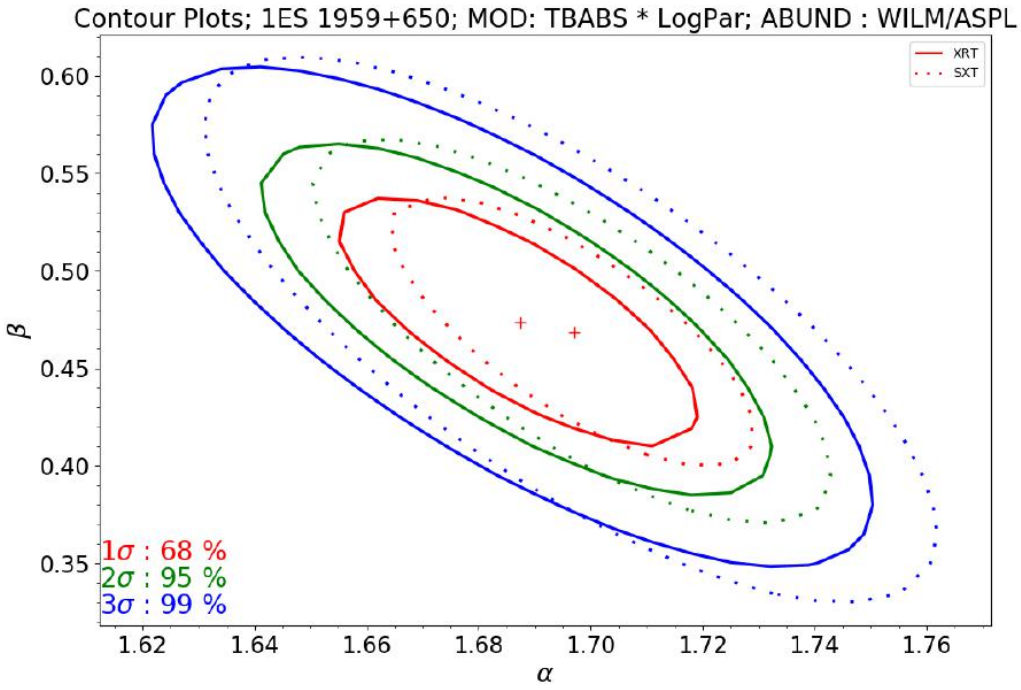
- A few % systematic error required.
- Time evolution of ARF not studied.

~10% errors on IACHEC model line fluxed are expected (Paul et al. 2017)

SXT Calibration status & Issues

Blazar: 1ES1959+650

(Sunil Chandra + SXT team)



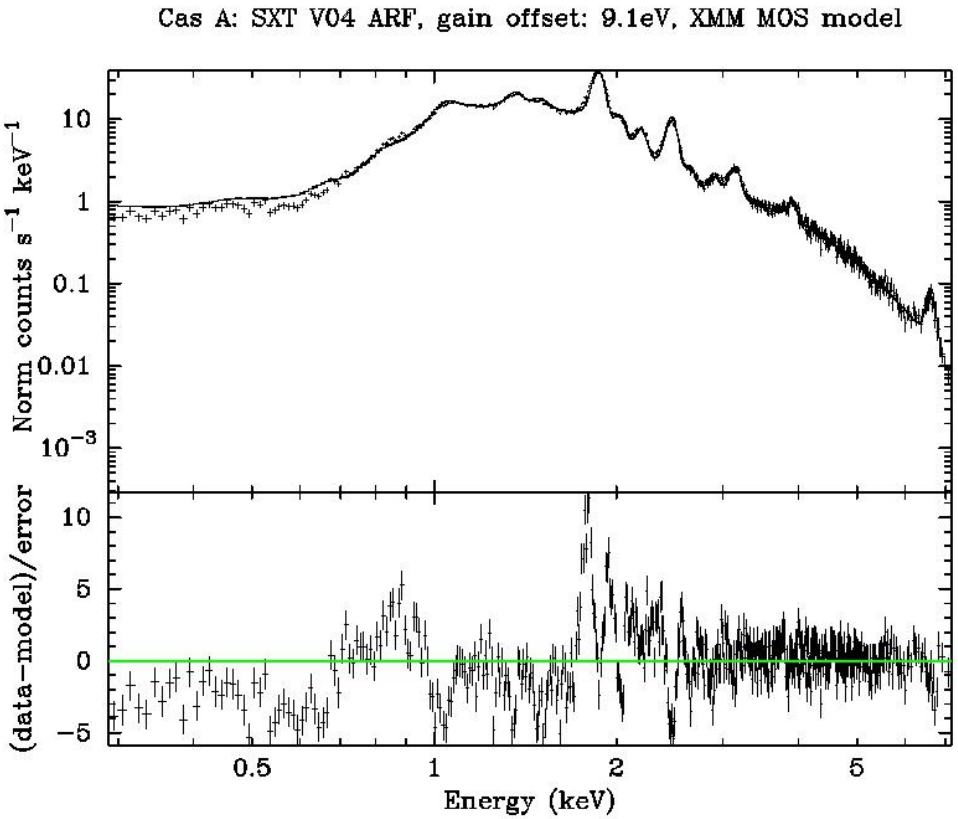
	SXT	Swift/XRT
nH = 0.1 x 10^22 (Gal. column)		
α =	1.70 ± 0.03	1.69± 0.035
β =	0.47 ±0.08	0.47±0.07
norm =	0.24±0.003	0.23 +/- 0.004
Red Sq. =	1.27/340	1.07/253

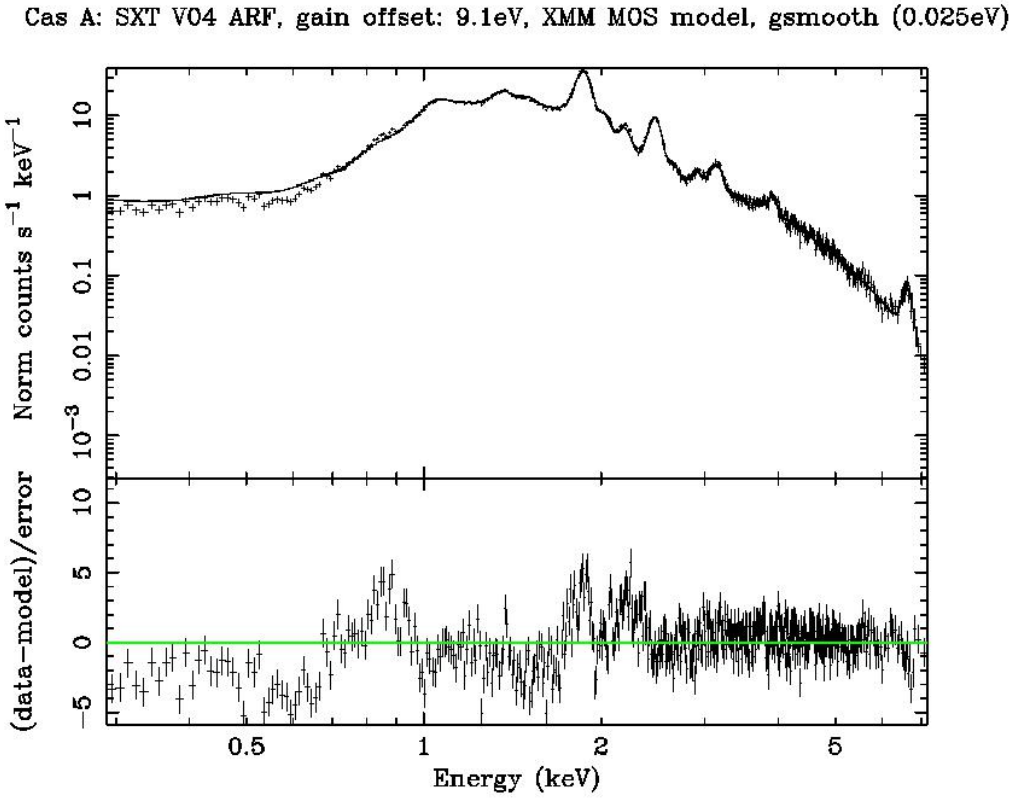
Flux SXT (0.3-8.0 keV) = 9.75e-10 (9.64e-10 - 9.89e-10)

Flux XRT 0.3-8.0 keV = 9.71e-10 (9.60e-10 – 9.81e-10)

gain: slope = 1, offset = 1.75E-02 (best fit)

SXT Calibration status & Issues : Cas A





- Line reponses have broadened. Fe55 onboard calibration shows broder lines than the current RMF. Possibly due to CTI changes or BIAS variations (under investigation)
- Time evolution of ARF/RMF not studied.
- **With a few % systematic error and gain fit, the current RMF/ARF are good enough for sources with weak or no lines.**

LAXPC: Data analysis, Calibration status and Issues

Antia et al. (2020)

- Begin with level1 data from AstroSat archive.

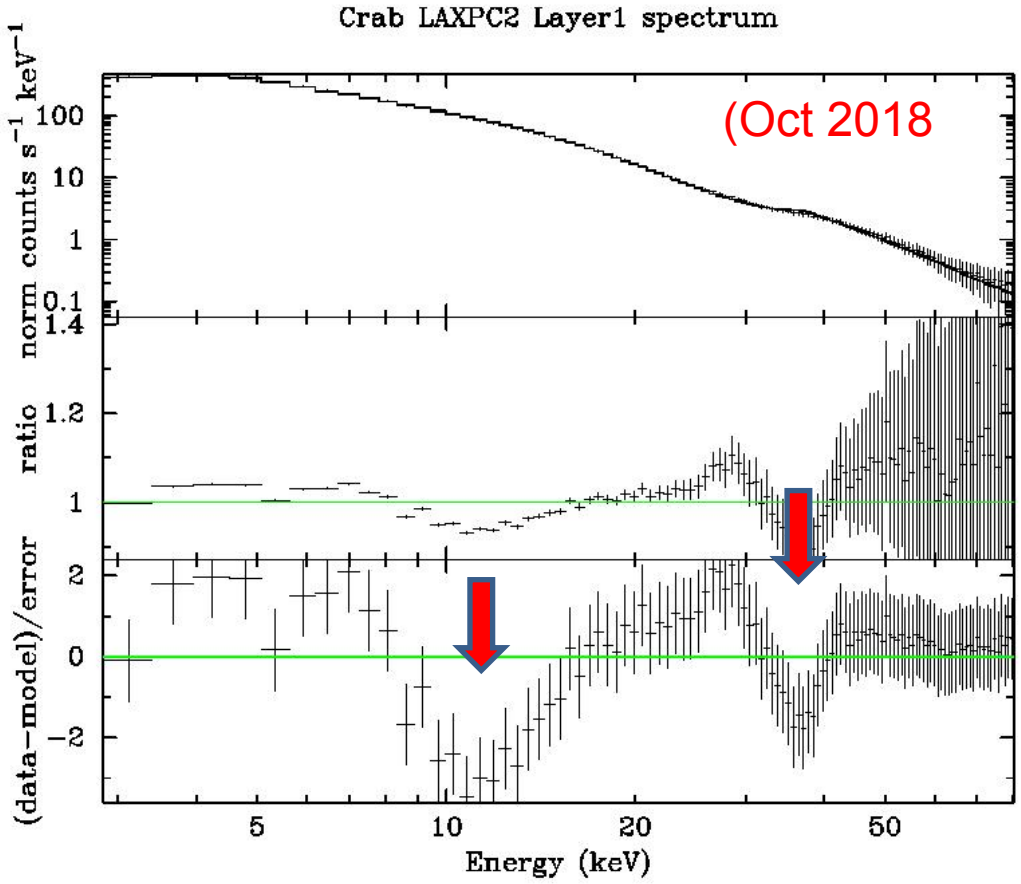
- Three ways to analyze LAXPC data
  - Level2 pipeline version 3.1 (limited support)

  - Standalone Fortran programmes laxpc1 and backshift to generate source and background spectra, lightcurves, event files, GTI, etc. The products in FITS format compatible with HEASOFT.

  - User-firendly individual routines based on the two fortran codes to generate spectra, lightcurves, event files in standard FITS format compatible with HEASOFT

LAXPC: Calibration status and Issues

Crab



Background systematic error: 3%
Model systematic error: 2%

gain slope=1 (fixed), offset=-0.22keV

Reduced chi^2=1.36

Gamma=2.069±0.009

Calibration issues near ~12keV and 30-40keV which can be confused with CRSF like absorption features.

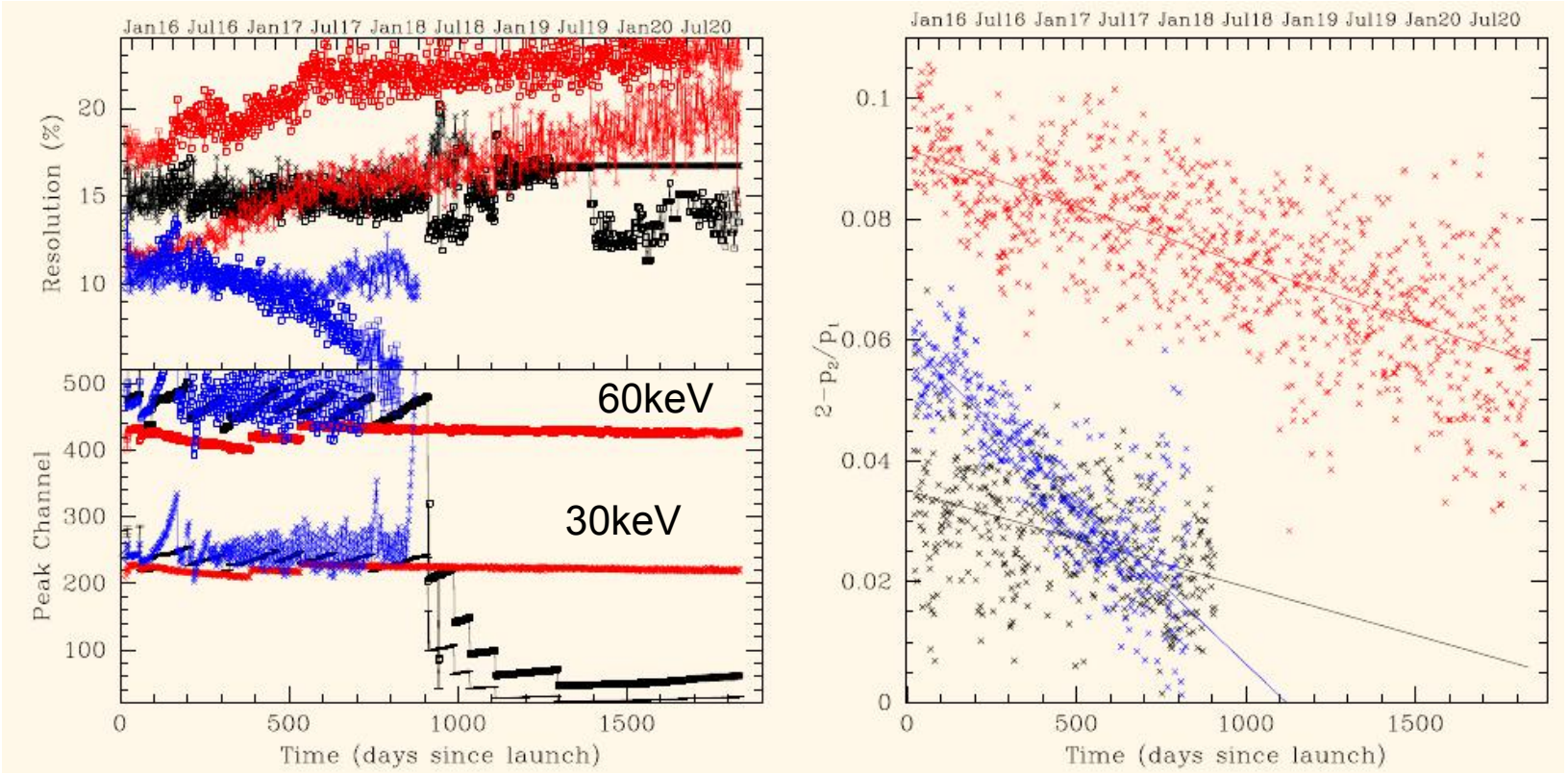
Fit residual features vary due to variation in the detector gain and uncertainty in the background model.

LAXPC: Calibration status and Issues

Detector gain variation

Peak channels of 30keV (crosses) Xe K peak and Am241 peak (sqaures), spectral resolution (LAXPC10, LAXPC20, LAXPC30)

Non-linearity of the gain: 2 − p2 /p1
p2: peak channel for 60keV line
p1: peak channel for 30keV line

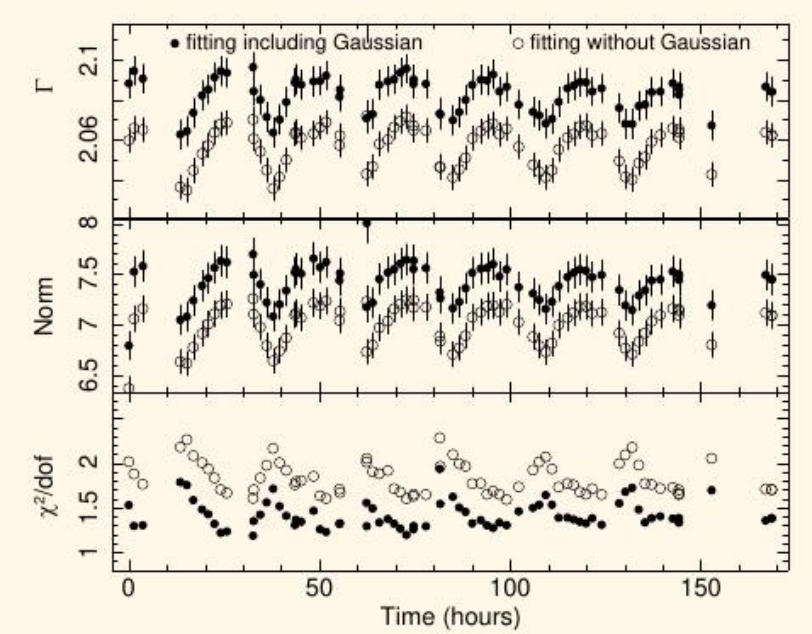


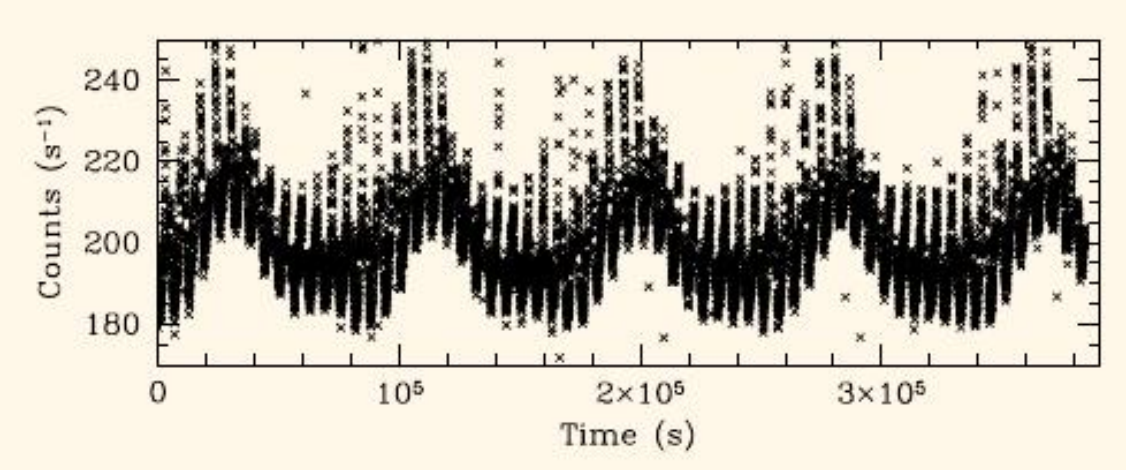
Channel to energy conversion quadratic.

Three coefficients of quadratic relation between Energy and channel cannot be determined with two peaks. Only linear term is assumed to change with time, and accordingly RMF is provided for different values of 30keV peak. LAXPC software selects the appropriate RMF. Need to use XSPEC gain fit with slope fixed at 1.

LAXPC: Calibration status and Issues

Background Variation - Short-term variations





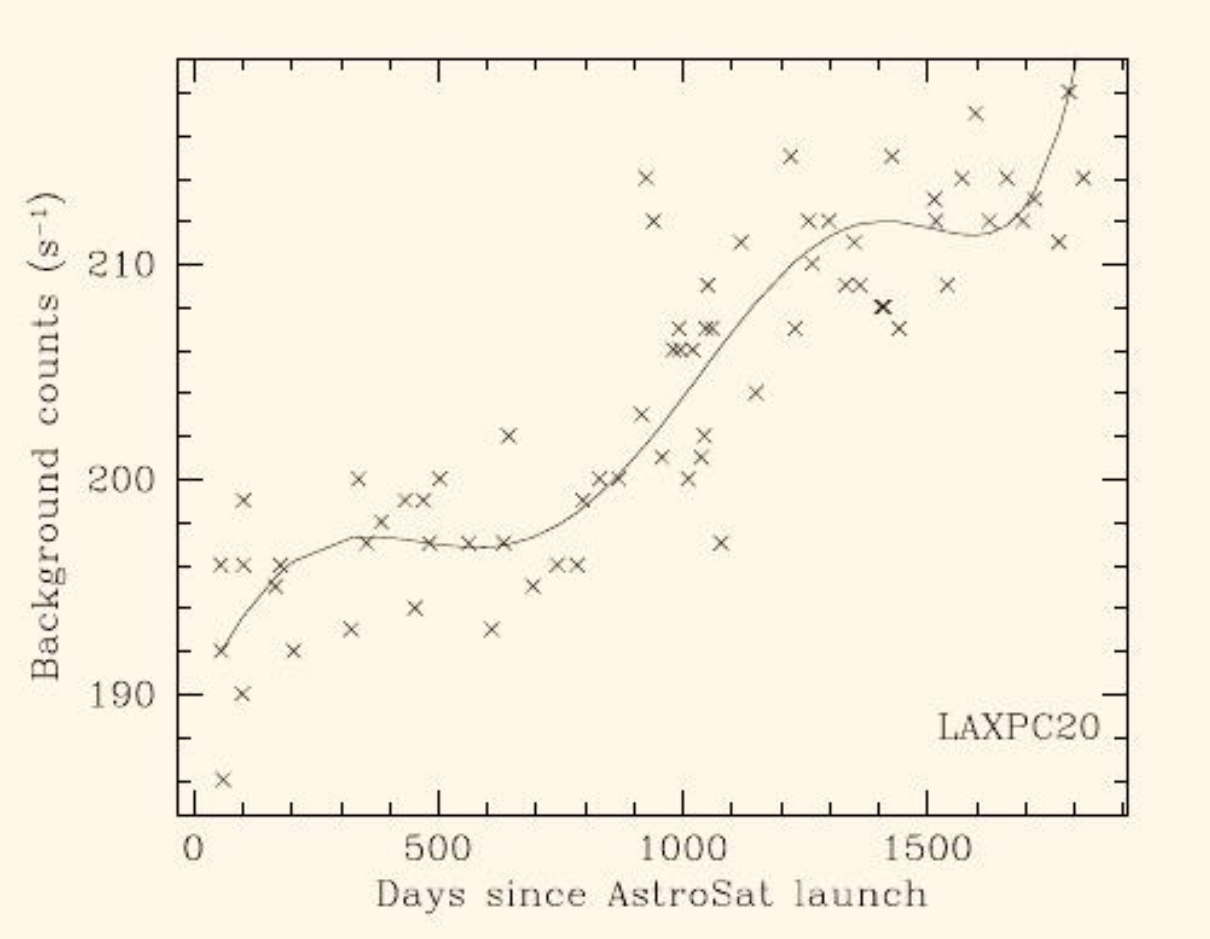
Diuranal variations in background count rate, some evidence for increasing amplitude overs the last 5 years.

Background count rate varies in an orbit of ~98 minutes, count rate minumum in between two SAA passages and tends to increase when approaching and after the SAA.

Genrally spike in background count rate after the SAA exit during diurnal maximum.

LAXPC: Calibration status and Issues

Long-term Background variations based on monthly monitoring observations



Generally increasing trend - induced radio activity?

Significant scatter about the best-fit curve.

LAXPC software generates model background lightcurve with an accuracy of ~3% for any given observation.

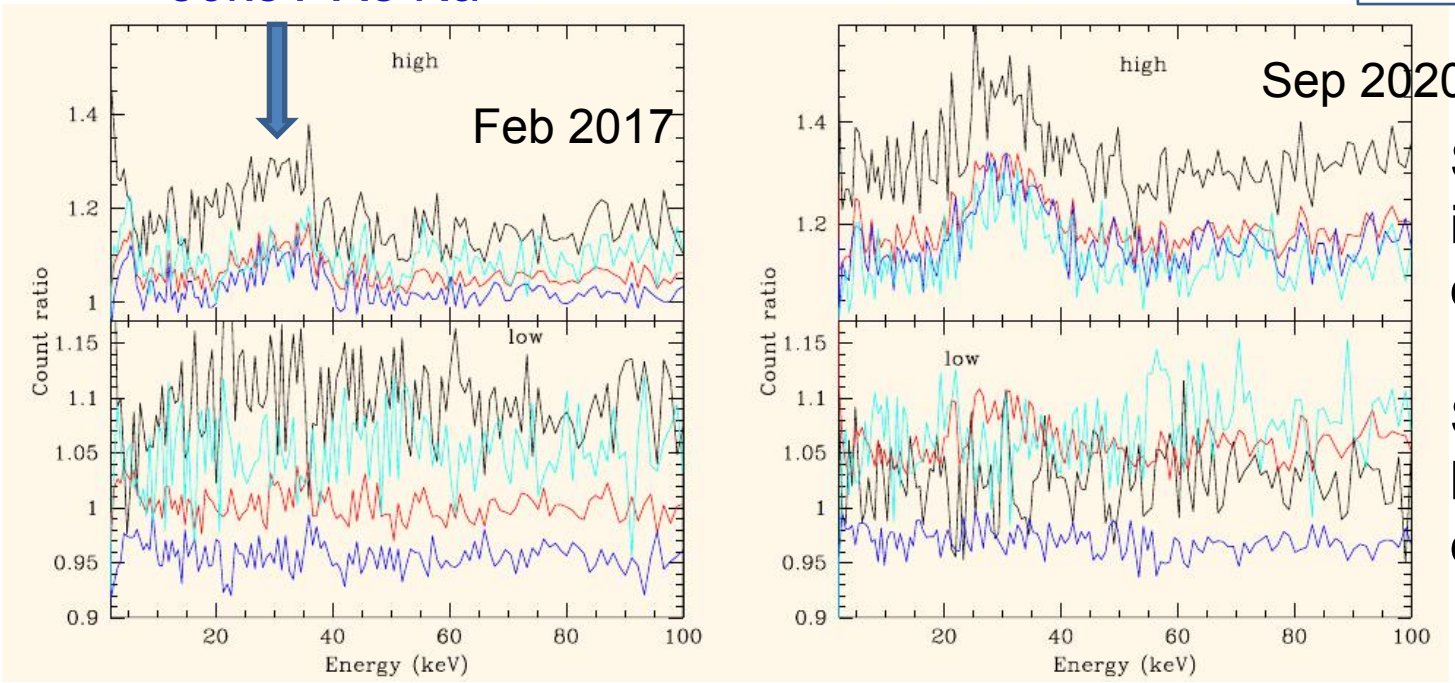
LAXPC: Calibration status and Issues

Background spectral variations

- orbit - period between consecutive SAA passage
- “low” - an orbit with low count rate
- “high” - an orbit with high count rate

- 1st 600 after SAA
- last 600 after SAA
- middle part of the orbit
- average over orbit

30keV Xe Kα

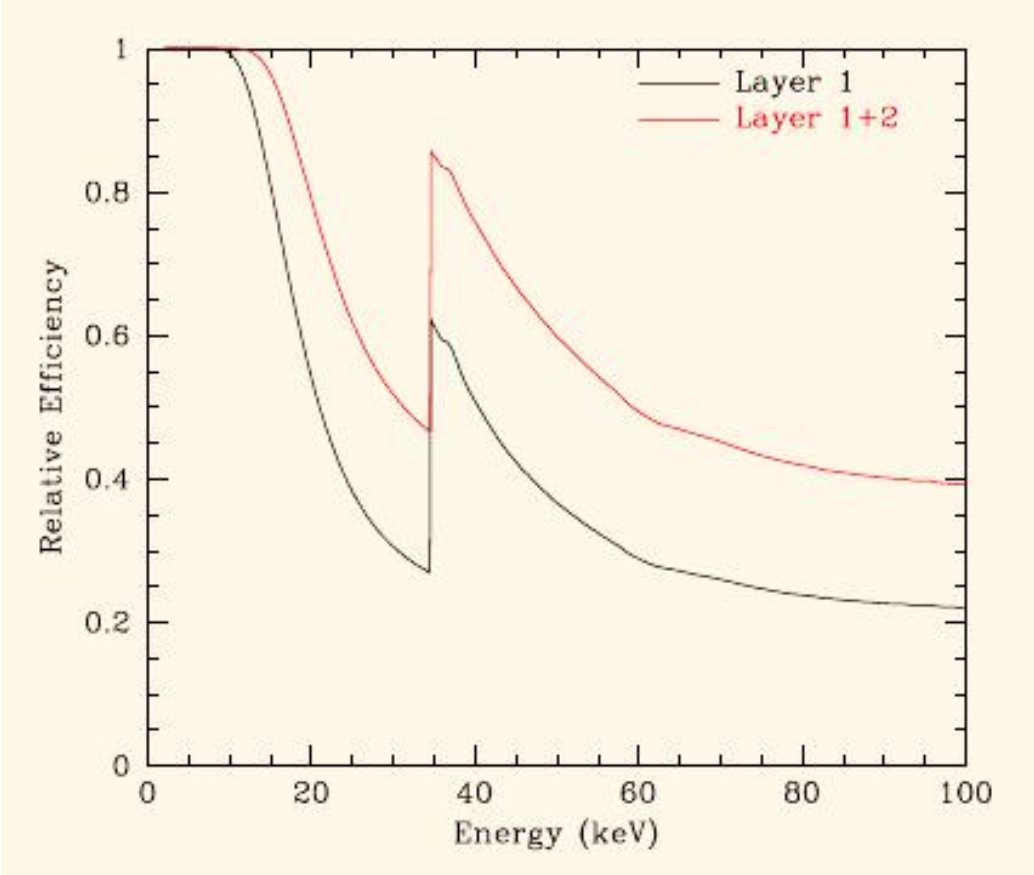


Similar ratios for individual layers of the detectors

Significant change in background spectrum during “high” orbits

The model background spectrum accounts for the increase in the count rate during the high orbit but the spectrum is scaled to average counts. This likely introduces the 30keV bump seen in the spectral fit residuals.

LAXPC: Calibration status and Issues



Relative fraction of events in different layers

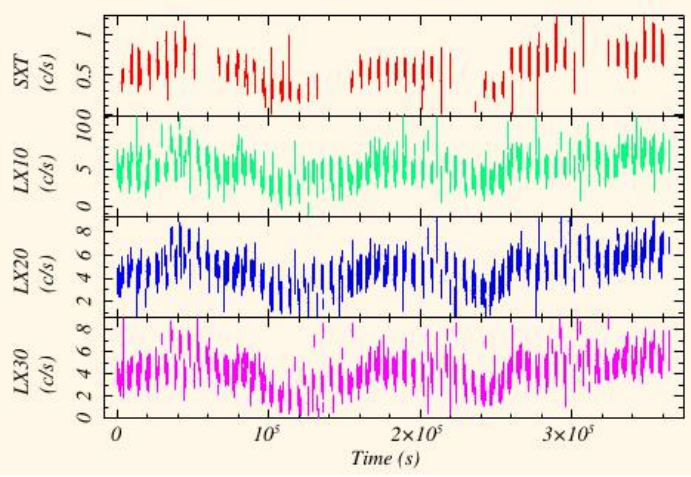
Below 10keV all events in the top layer. At 20 keV ~50% events in the top layer and ~75% in the top two layers.

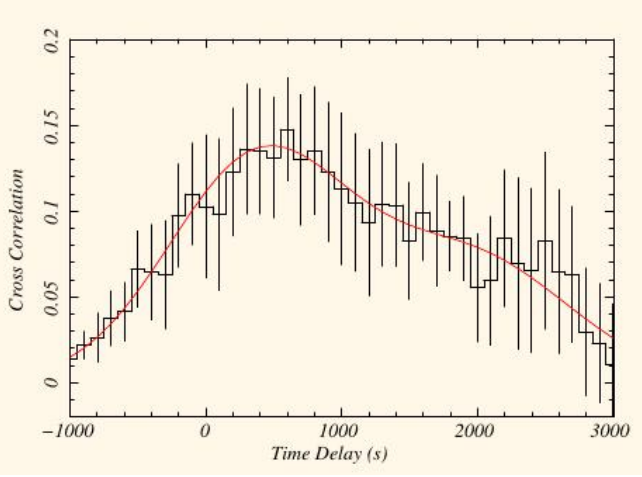
Recommendations:

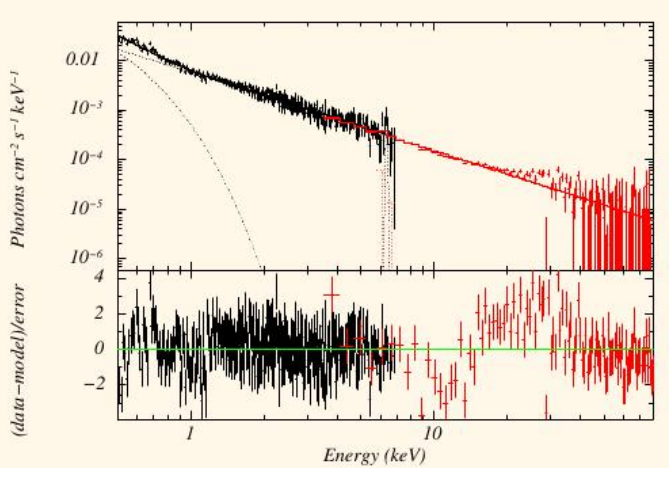
- Use top layers for studies at low energies or studies of faint sources.
- Excluding the data during “high” orbits may help reducing the background contribution.
- Use 3% systematic error in the background, and 2-3% systematic error in the model for spectral fitting.

Study of Faint sources with LAXPC

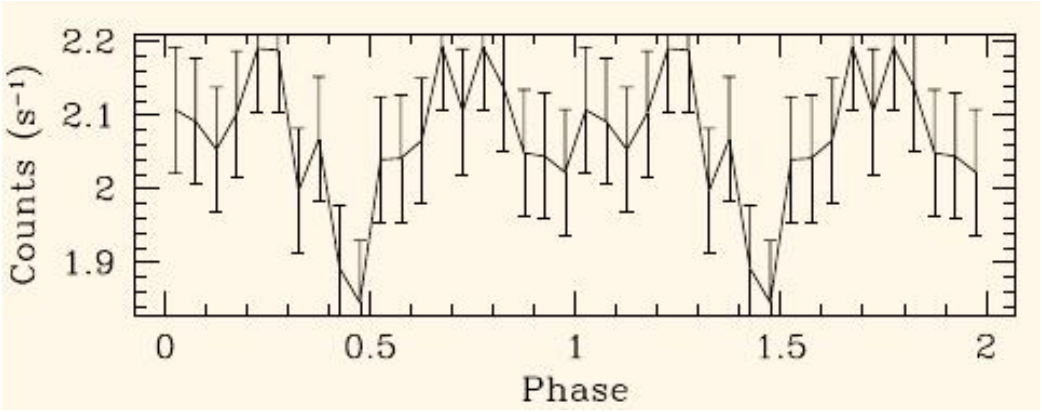
NGC4593 - an average AGN (LAXPC20 count rate ~5 counts/s)







SMC X-2 with LAXPC20 (2.1 counts/s)



LAXPC20 Pulse profile of SMC X-2 in the 3–20 keV band.

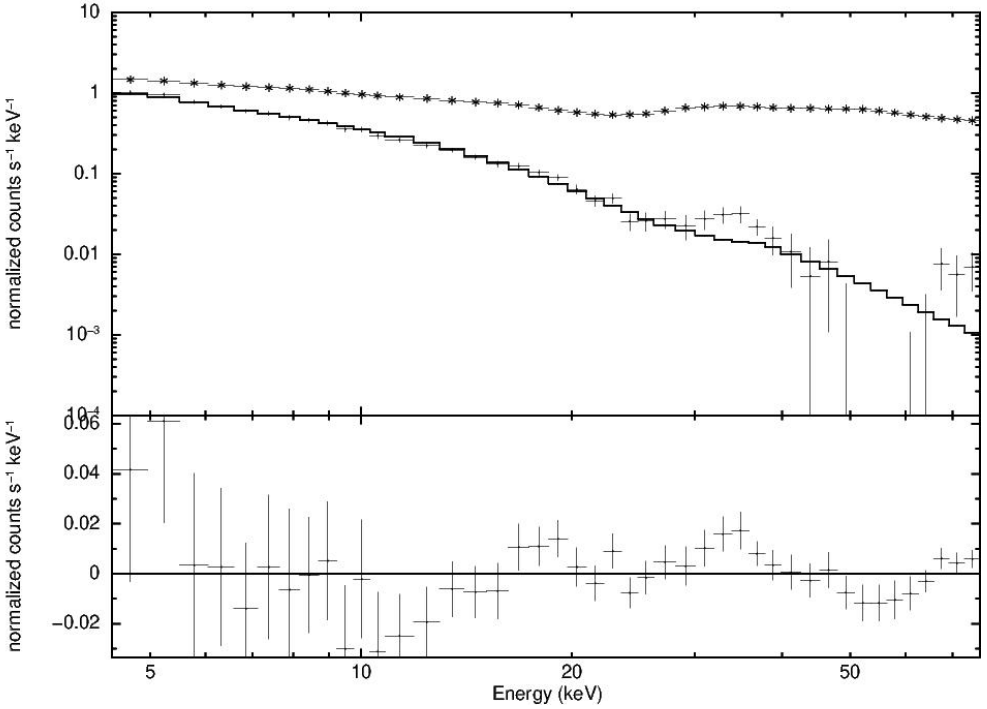
Spin period: 2.377441 ± 0.000016 s

Spin up rate (3.9 ± 1.1) × 10−11 Hz s−1

LAXPC can study faint sources with a few counts/s.

LAXPC FAINT BACKGROUND (Mrk 110)

- An alternative scheme to estimate the layer1 LAXPC 20 background for faint sources where the source contribution in the 50-80 keV band is less than 0.25 counts/sec.



- Mrk110 spectrum with faint background

(Misra et al. 2020)

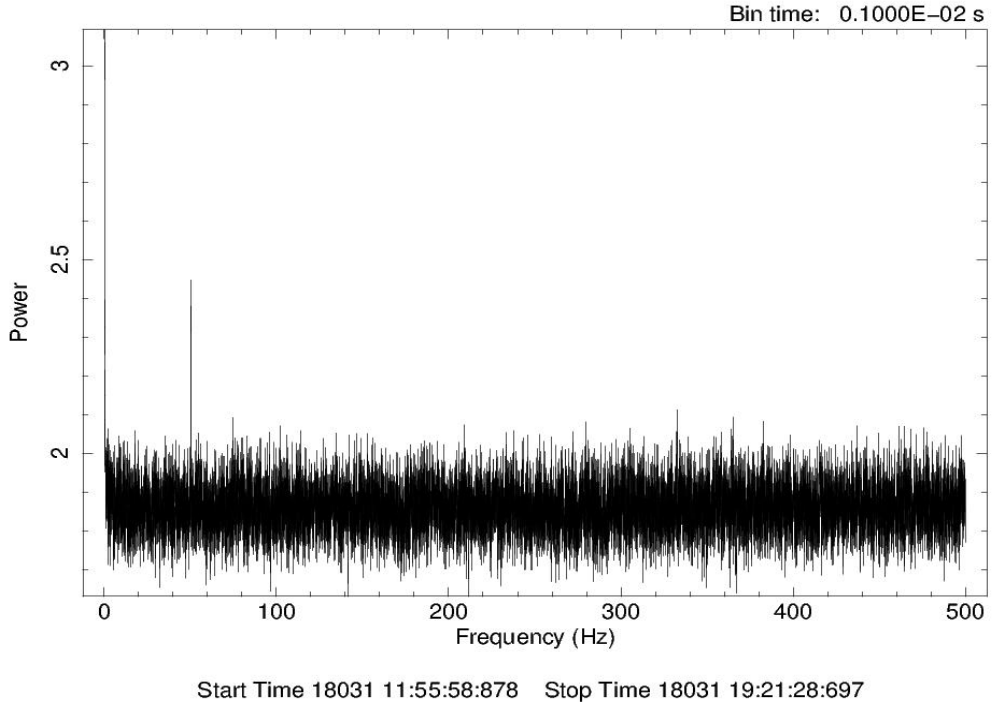
LAXPC Time calibration & Issues

Based on Crab pulsar

- Time resolution: 10μsec
- Clock stability: 4μsec rms
- fixed offset +316 ±70μs w.r.t. Fermi-LAT (Basu et al. 2020)

- Timing noise

50Hz peak in the PSD of LAXPC 20 data



LAXPC timing performance

- Verdhan et. al. 2017 for kHz QPO and burst oscillation
- Yadav et al. 2016: HF timing analysis of GRS1915

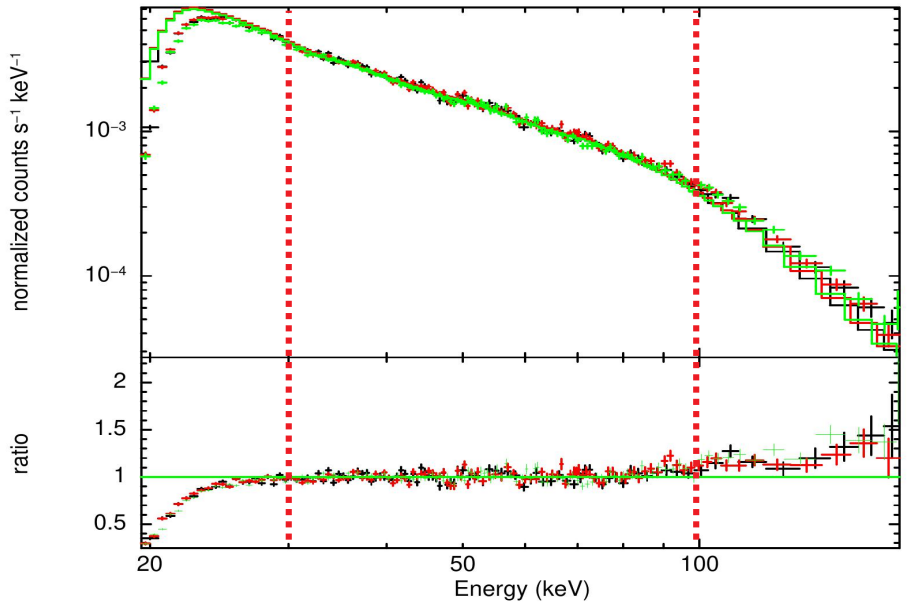
- **PSD generated from 2017 LAXPC 20 light curve of GX 3+1 shows 50 Hz peak.**
- **This feature is seen in the anode A1 data and has been traced to amplifier noise.**

Antia et al. (2017)

CZTI calibration status: Issues and potential solutions

Senstive to bright sources (>50mCrab for day long observations)

Use level2 data or process level1 data using the CZTI pipeline



- CZTI crab spectra during 2018-2020 ratio with powerlaw of index 2.1
- Good agreement in 30 – 100 keV, flux within ~10% of NuStar: Presently usuable for spectroscopy
- Deviations in 20-30 keV and in 100-180 keV

Timing Performance

- Time resolution: 20μsec
- Clock stability: 3μsec rms
- fixed offset : -650 ±70μs w.r.t. Fermi-LAT

(Basu et al. 2020)

UVIT Calibration Status/Issues

Data Processing & Analysis

Level1 or Level2 data from AstroSat archive

Processing pipeline

1. UVIT pipeline
2. CCDLAB (windows only) Postma et al. 2017

Level2 images for photometry, spectroscopy (orbit-wise or merged)

Calibration

Updated photometric calibration (Tandon et al. 2017, Tandon et al. 2020)

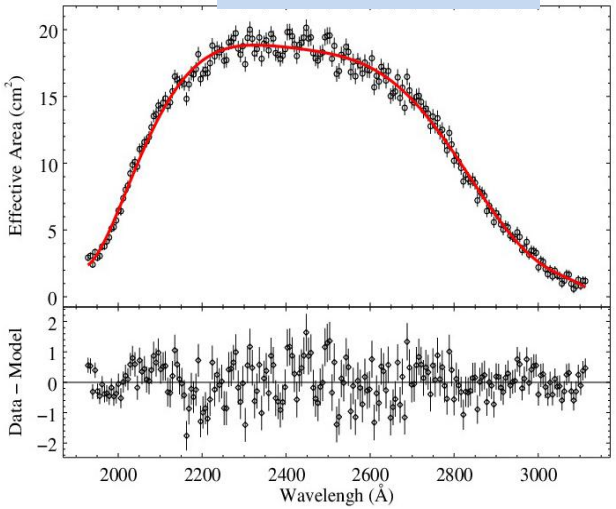
- ZP and UC to convert broadband filter count rates to magnitudes and flux density
- Convert to single channel PHA files using FTOOLS

Updated grating calibration (Dewangan 2020, submitted)

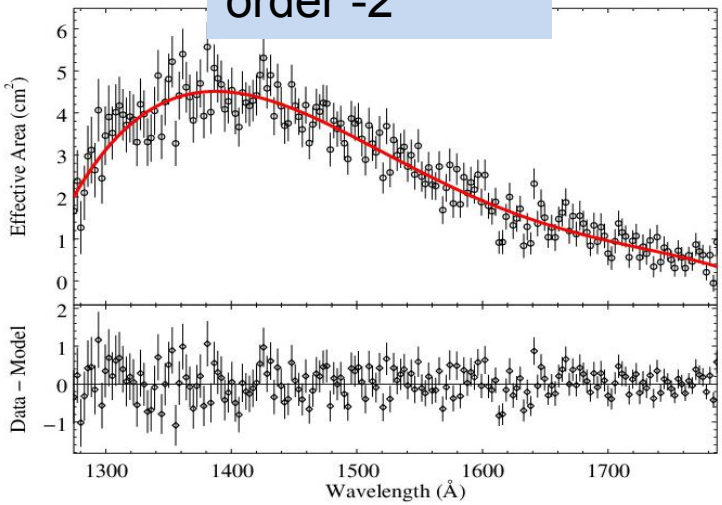
- 1D grating spectrum extraction
- Relations for wavelength calibration and flux calibration
- FTOOLS to convert into PHA spectrum, also separate tools for generating PHA count spectra and appropriate RMF/ARF.

NUV/FUV Grating effective area

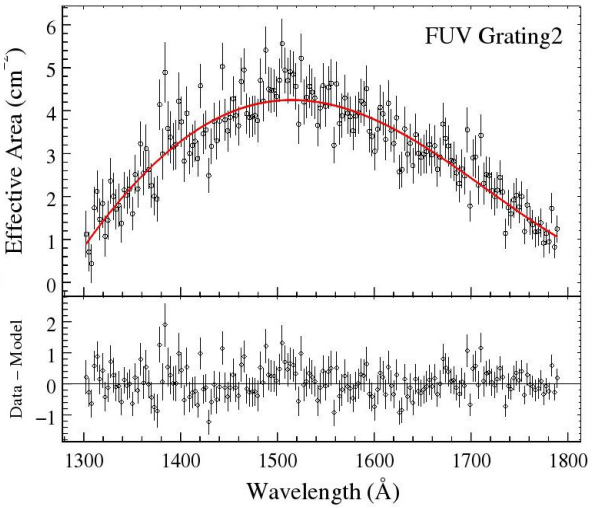
NUV Grating order -1



FUV Grating1 order -2



FUV Grating2 order -2

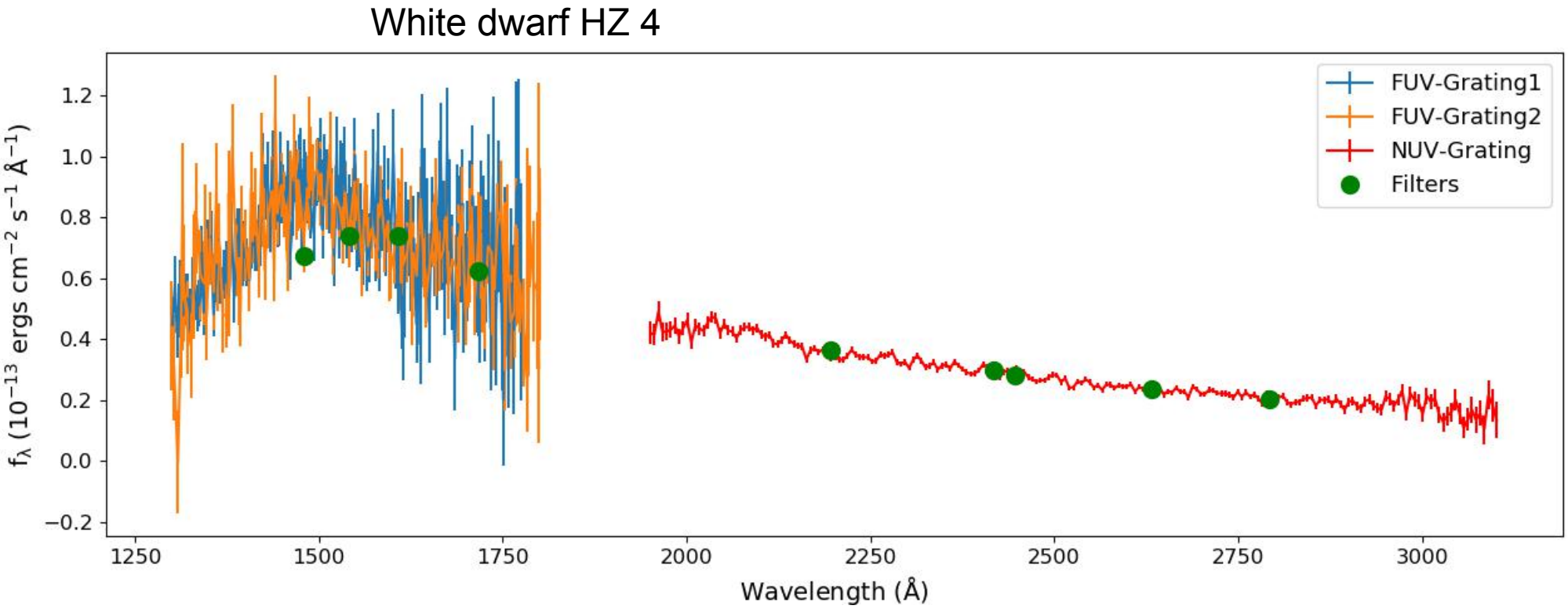


Peak effective area: 18.7cm2 (NUV grating), 4.5cm2 (FUV gratings)

FWHM: 38.4A (NUV-grating), 16A(FUV-grating1), 14A(FUV-grating2)

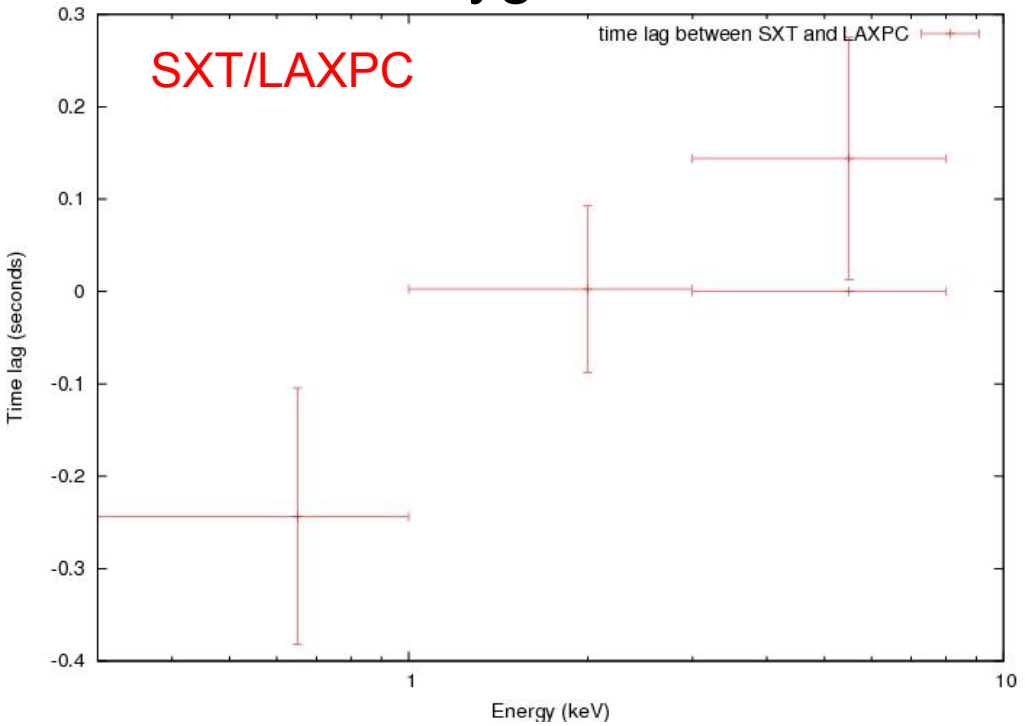
UVIT calibration status

Gratings and broadband filters



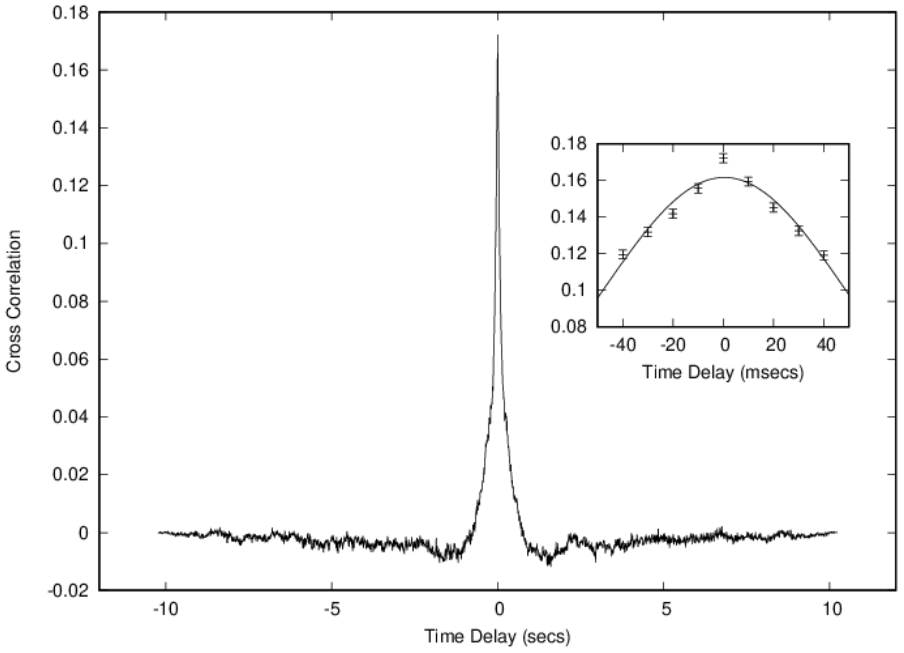
Timing cross-calibration

Based on Cygnus X-1 observations



LAXPC/NICER

time lag in the 4-8keV band



Absolute time difference between LAXPC and CZTI

966.0 ± 99.0μs

R. Misra

Thank You