2nd China-India Workshop on High Energy Astrophysics

Study of spectral properties of black hole X-ray binary GX 339-4 during its recent outburst in March 2021

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Source & Instruments

GX 339-4 is a transient Black hole X-ray binary discovered in 1971.

- **Source Distance** : 8 – 12 kpc (*10 kpc*) (Zdziarski et al. 2019, https://arxiv.org/abs/1904.07803)
- **Source Inclination Angle** : 40 – 60 degrees (*50 degree*)(Zdziarski et al. 2019, https://arxiv.org/abs/1904.07803)
- **Mass of the compact object** : 4 – 11 solar mass (*7.5 solar mass*) (Zdziarski et al. 2019, https://arxiv.org/abs/1904.07803)
- **Spin Parameter** : >0.9 (ludlam et al. 2015, https://arxiv.org/abs/1505.05449)

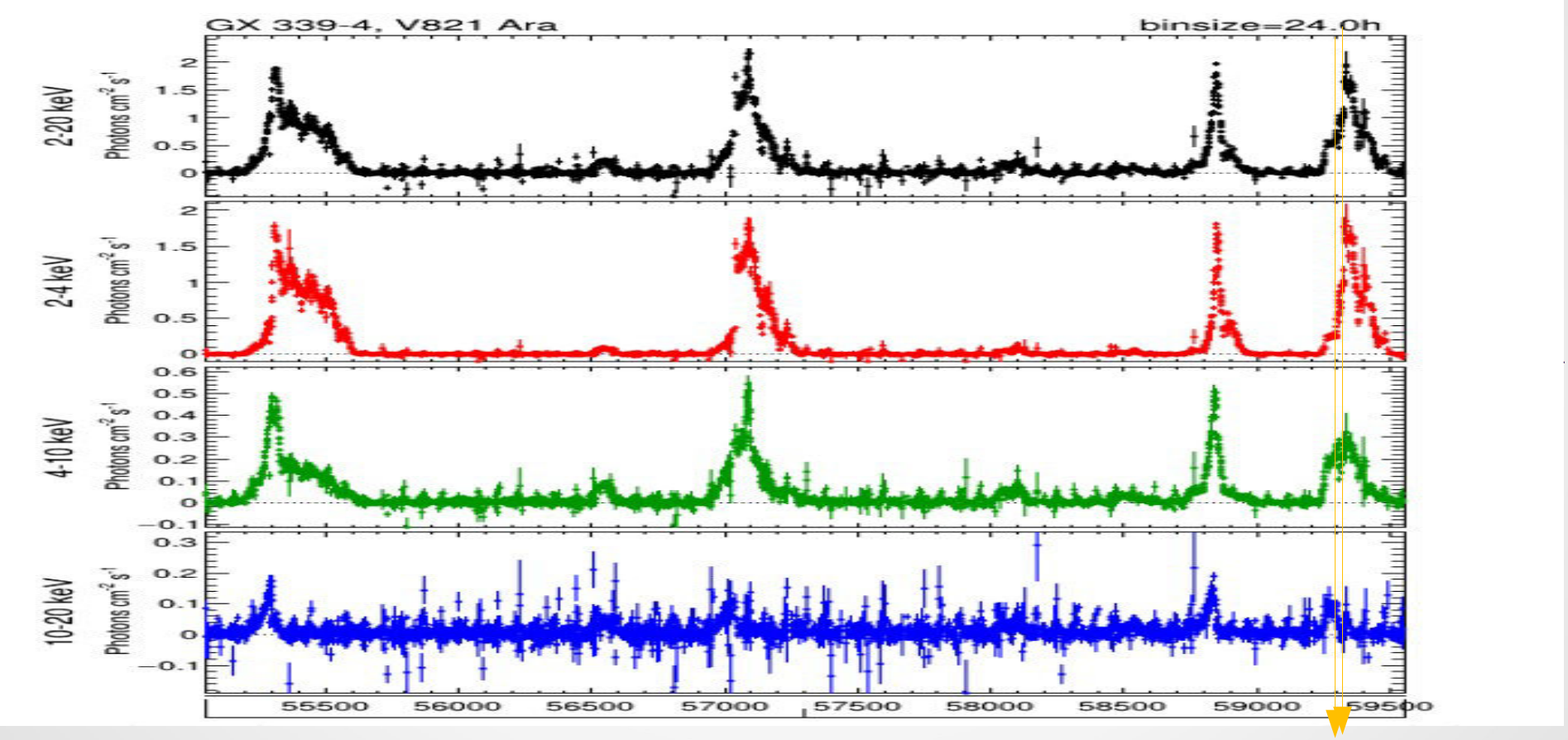
LAXPC

- Large Area X-ray Proportional Counters (LAXPC) is an instrument aboard AstroSat Satellite which consist of three identical but independent PCUs (called LAXPC10, LAXPC20 and LAXPC30) with effective area of around 6000 cm^2 at 15 keV and has the time resolution of 10 microsec in the energy range 3.0-80.0 keV.

SXT

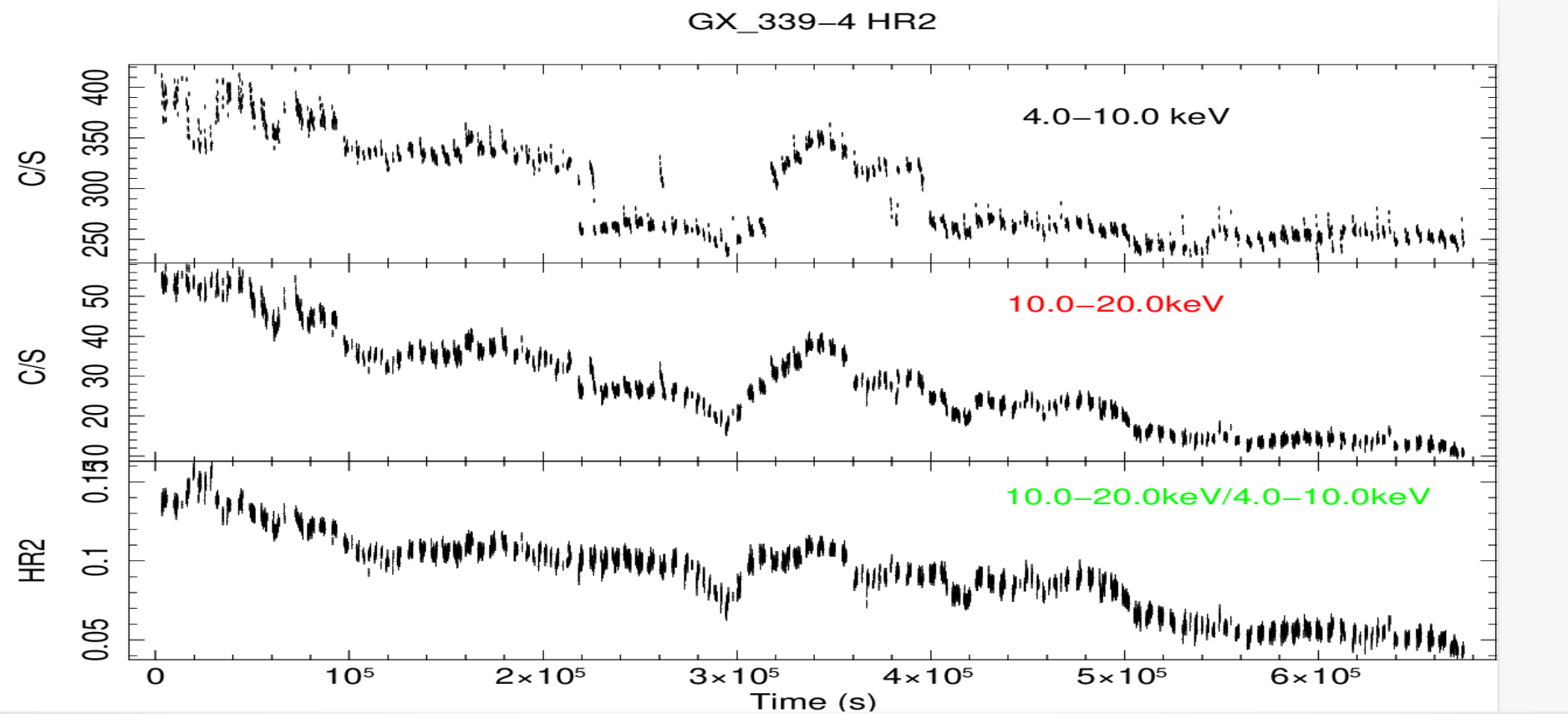
- Soft X-ray imaging Telescope (SXT) onboard AstroSat is sensitive to soft X-rays in the energy range of 0.3 − 8 keV with an effective area of 90 cm^2 at 1.5 keV and it has time resolution of ~2.4 sec in FW mode.

MAXI Lightcurve – GX 339-4



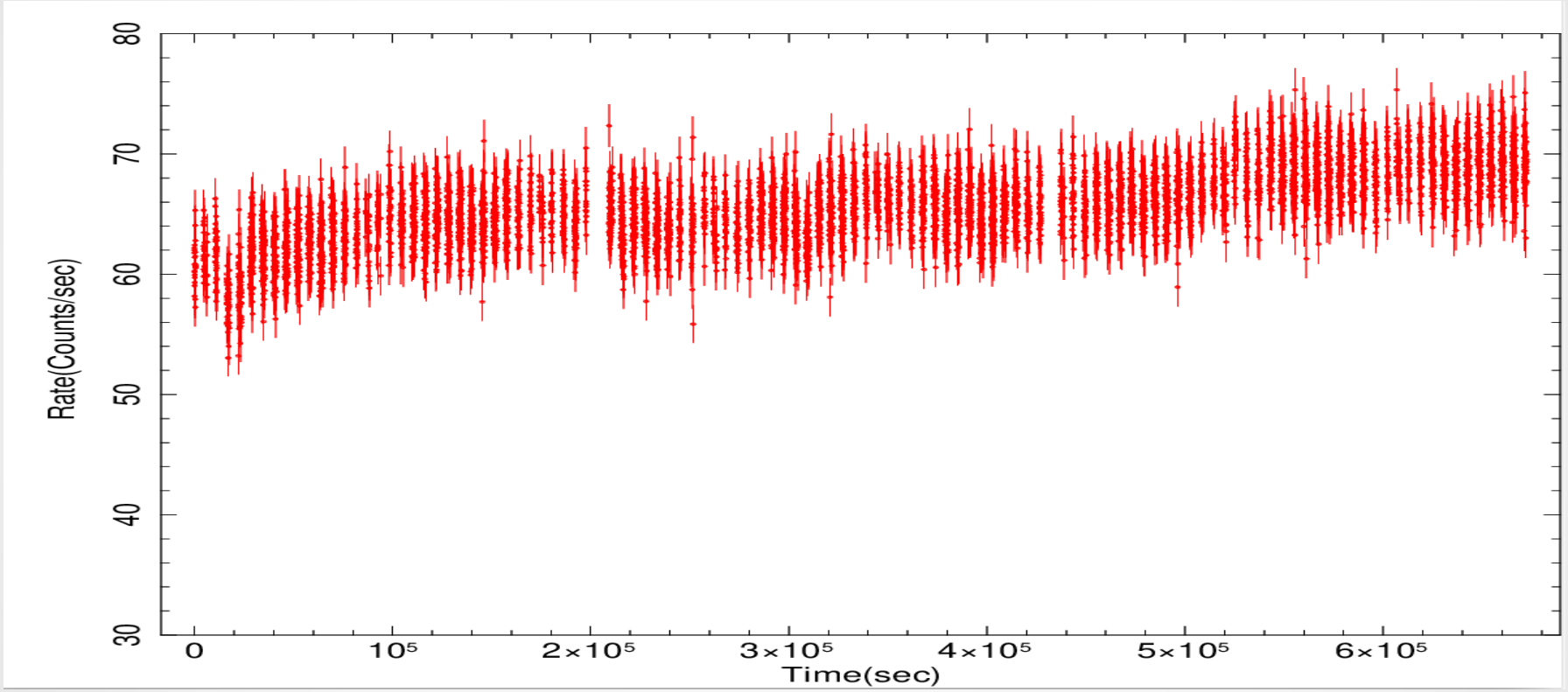
- 6 outbursts of GX 339-4 has been observed since its discovery that can be seen in the above lightcurve.
- AstroSat observed recent outburst of GX 339-4 in March 2021.

LAXPC Lightcurve & HR2



- To create this lightcurve we used bin time of 100 sec and LAXPC20 unit out of the three.
- First panel shows LAXPC lightcurve in the energy range of 4.0 – 6.0 keV.
- Middle panel shows LAXPC lightcurve in the energy range 6.0 – 10.0 keV.
- Last panel shows HR2 diagram which is just ratio of non-thermal to thermal component of radiation.

SXT Lightcurve



- Lightcurve shows X-ray variability with time.
- To merge this lightcurve, we use julia software.
- Time bin used for this lightcurve is 23.775 sec.
- We took care of piling effect to create the lightcurve.

Methodology

- AstroSat observed recent outburst of GX 339-4 in March 2021.
- We have 116 orbits data of LAXPC and SXT to analyse.
- We analyse few individual orbit data to select the best fit model to the energy spectrum.
- LAXPC energy spectrum range selection; we selected 4.0-20.0 keV energy range for LAXPC energy spectrum
- SXT annular region selection to take care of piling effect ; we take annular region with inner radii 7 armins and outer radii 15 arcmins for further spectral analysis.
- XSPEC model selection for energy spectrum;

  First we combined energy spectrum of LAXPC and SXT and then apply these models and compare red. Chi sq. , and model parameter for different orbits,

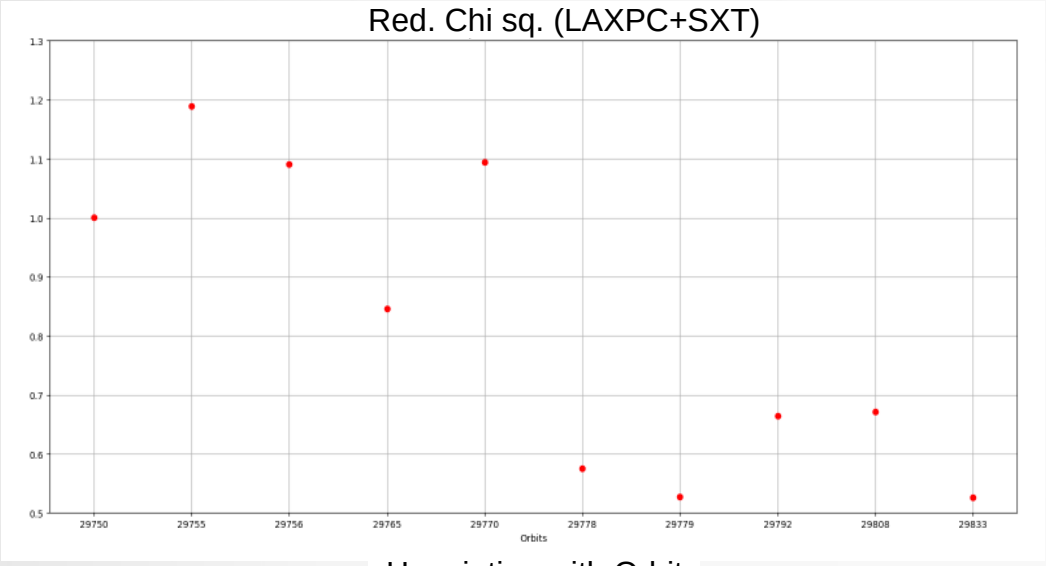
  1. constant *x* tbabs *x* (gaussian + powerlaw + diskbb)

  2. constant *x* tbabs *x* (gaussian + simpl *x* diskbb)

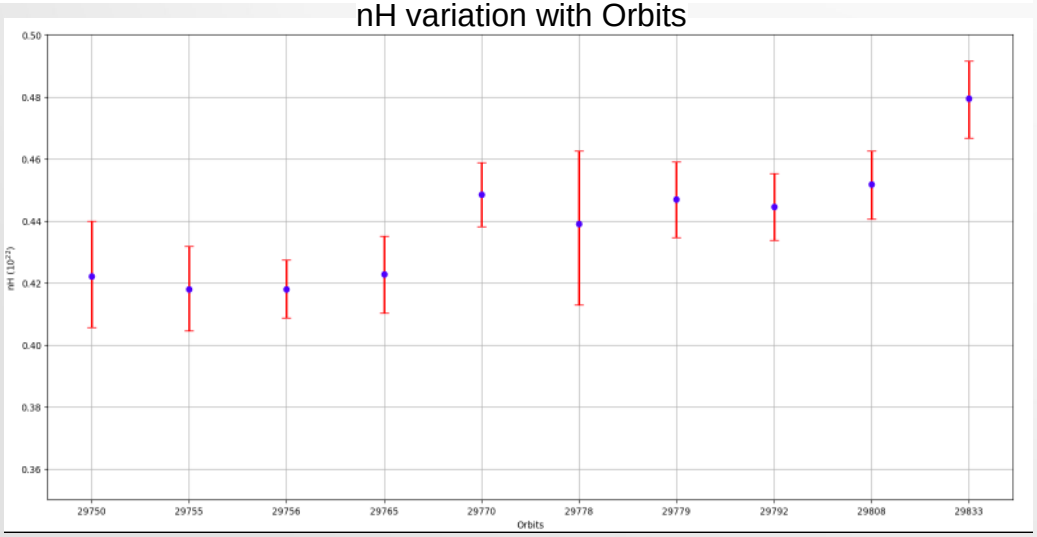
  3. constant *x* tbabs *x* (kerrdisk + simpl *x* diskbb)

  4. **constant *x* tbabs *x* (kerrdisk + simpl *x* kerrbb)** ; we select this model for further analysis
- Work is still in progress.
-

Observations and Results

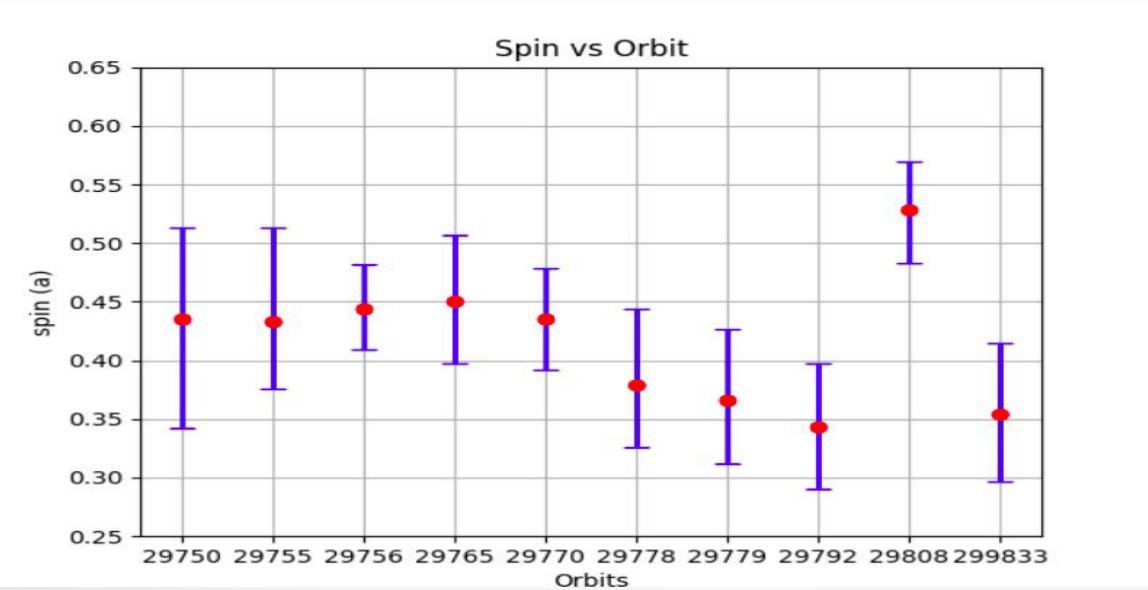


- It is red chi sq. for energy spectrum (LAXPC+SXT) of different orbits after applying xspec model constant*tbabs*(kerrdisk+simpl*kerrbb).
- It can be seen from fig. that red. Chi sq. is acceptable for all orbits for energy spectrum fitted with above model.
- We can see red. χ 2 is varying from 0.5 to 1.2 for different orbits which is quite good



- Fig. shows hydrogen column density parameter variation with different orbits for energy spectrum (LAXPC+SXT) fitted with xspec model constant*tbabs*(kerrdisk+simpl*kerrbb)
- We can see nH value is varying from $0.41 - 0.49 * 10\text{^}22$ atoms/cm^2

Observations and Results

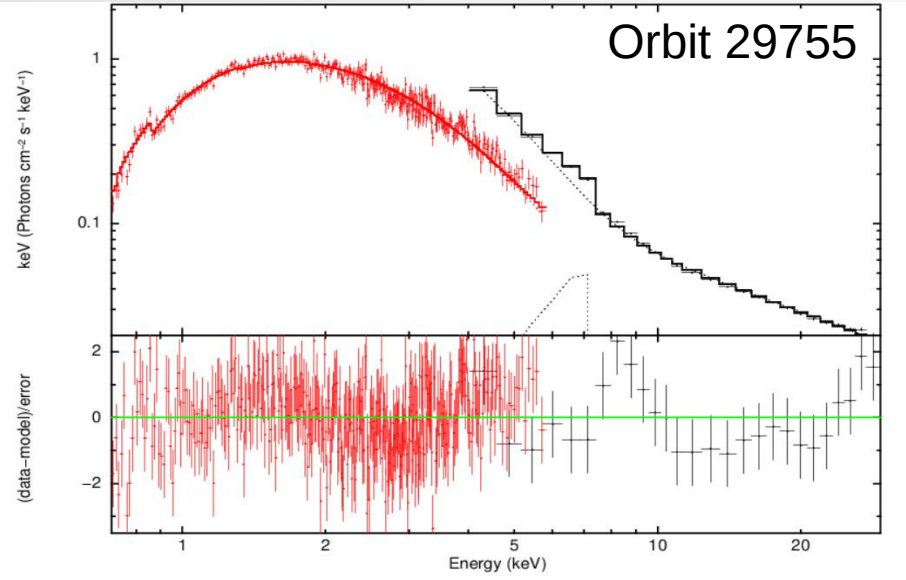


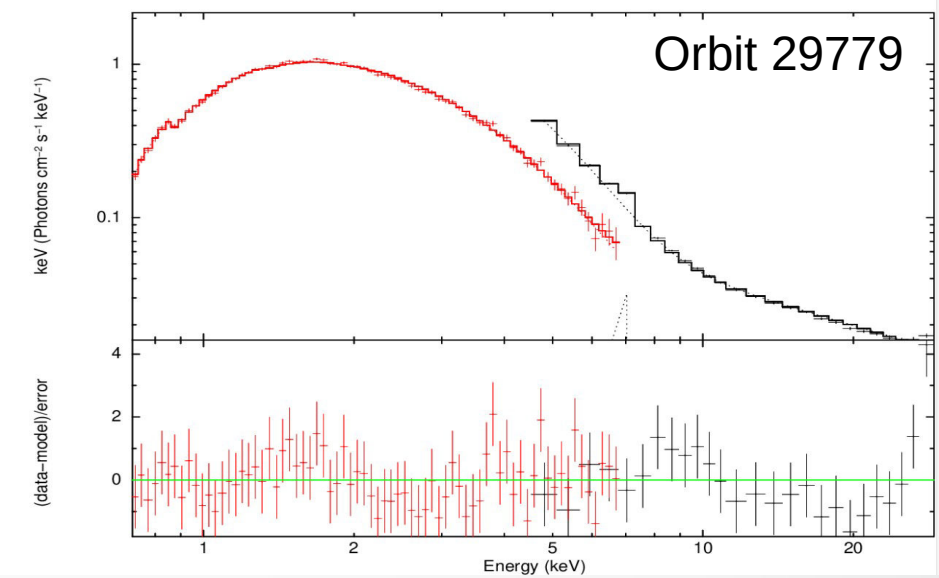
- Fig. shows spin parameter parameter variation with different orbits for energy spectrum(LAXPC+ SXT) fitted with xspec model constant*tbabs*(kerrdisk+simpl*kerrbb)

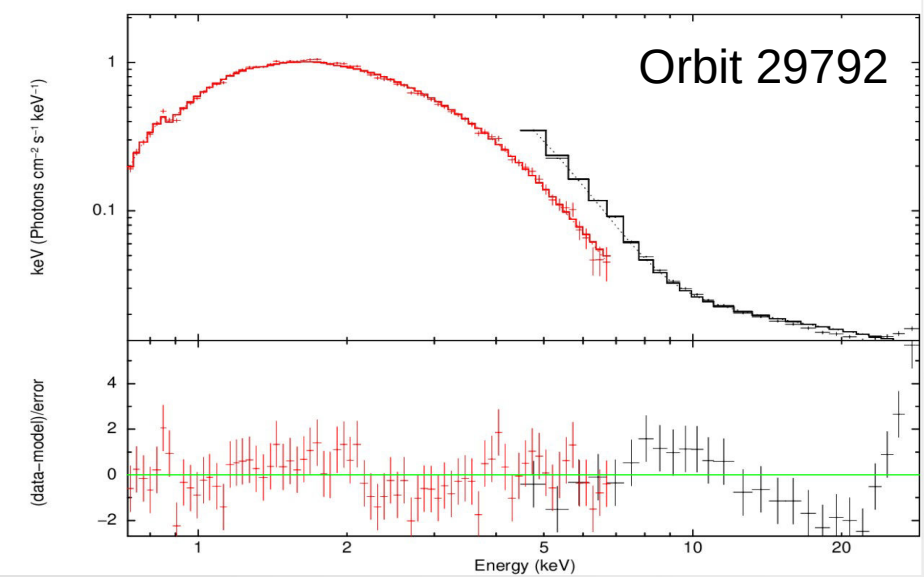
Energy Spectrum :

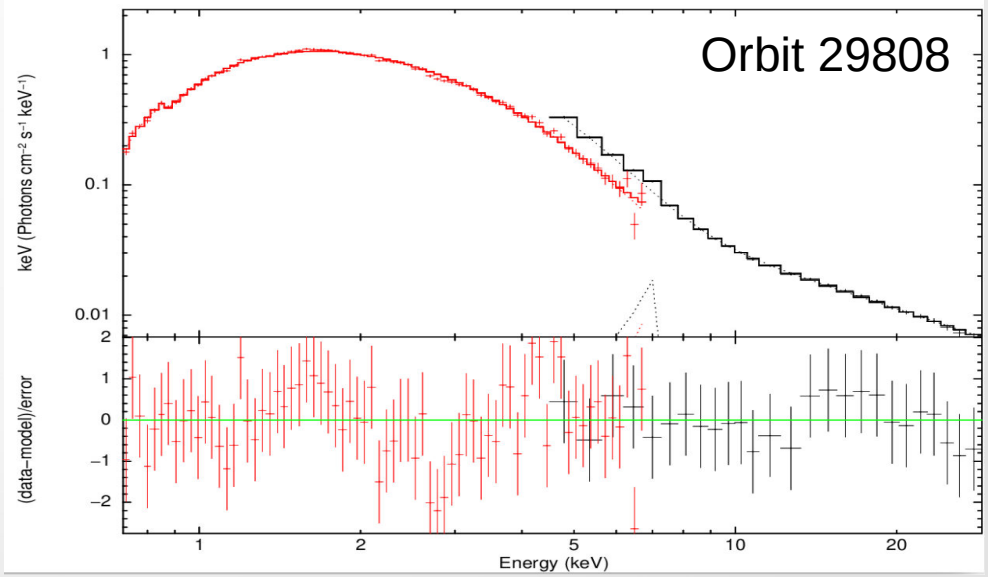
- Energy spectrum shows the number of particle as a function of particle energy.
- Energy spectrum (LAXPC+ SXT) fitted with xspec model constant*tbabs*(kerrdisk+simpl*kerrbb) of orbits 29755, 29779, 29792 and 29808 are shown in the next slide.

Energy Spectra : constant*tbabs*(kerrdisk+simpl*kerrbb)









Paramters：constant*tbabs*(kerrdisk+simpl*kerrbb)

Orbits	nH Value (10^{22} atoms-cm^{-2})	Gamma	FracSctr	Spin (a)	χ^2_{red}
29755	$0.435^{-0.011}_{+0.011}$	$2.083^{-0.037}_{+0.037}$	$0.061^{-0.005}_{+0.005}$	$0.354^{-0.045}_{+0.058}$	1.08
29779	$0.441^{-0.011}_{+0.006}$	$1.965^{-0.031}_{+0.029}$	$0.035^{-0.002}_{+0.001}$	$0.392^{-0.043}_{+0.052}$	0.84
29792	$0.436^{-0.013}_{+0.009}$	$1.610^{-0.066}_{+0.043}$	$0.016^{-0.001}_{+0.001}$	$0.364^{-0.038}_{+0.071}$	1.45
29808	$0.455^{-0.011}_{+0.012}$	$2.361^{-0.054}_{+0.082}$	$0.052^{-0.005}_{+0.005}$	$0.514^{-0.049}_{+0.039}$	0.74

Conclusion and Future Work

- We have studied flux variability of 116 orbits of AstroSat data (LAXPC+SXT).
- We selected few random orbits and studied energy spectra for LAXPC and SXT.
- We studied combined energy spectra of LAXPC and SXT and decided to fit it with xspec model “constant *x* tbabs *x* (kerrdisk + simpl *x* kerrbb).
- After fitting the energy spectra, we get spin parameter of the black hole ~ 0.37.
- We will study the spectral properties of the source segmentwise with nearly same hardnesss ratio.

Acknowledgement

- I would like to express my special thanks of gratitude to my advisors Prof. Pankaj Jain, Prof. J S Yadav and Prof. Ranjeev Misra for their guidance.

- I would also like to thank my collegues Abhishek Kumar Jha and Ruchika Dhaka for their help in work.

Thank You

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