Explaining the Z-track of GX 340+0 using wideband observations with *AstroSat*★

Yash Bhargava (Infosys fellow, DAA-TIFR Mumbai)

Collaborators: Sudip Bhattacharyya, Jeroen Homan and Mayukh Pahari

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Background: Z-sources

Z-sources are a class of Neutron star (NS) low-mass X-ray binaries (LMXBs) which typically accrete close to Eddington rate. They are distinguished by the classical Z-shaped track which they trace out on their Hardness-Intensity Diagram (HID). An example of the HID of GX 340+0 is shown in Figure 1. The emission from the Z-source is typically comprised of three components, a multicolour blackbody from the accretion disk, a blackbody, assumed to be the spreading layer of matter on the NS surface and a Compromised emission from a plasma of hot electrons.

The Z-track is divided into 3 branches: Horizontal branch (HB), Normal branch (NB) and Flaring branch (FB). Across the branches these sources have also shown strong spectral variability, with prominent variations in the hard non-thermal component. Additionally all the branches have shown strong temporal variability, with horizontal branch depicting oscillations in 25-50 Hz and kilo-Hz quasi-periodic oscillations (QPOs) and low frequency broad noise component (See Figure 2 for example).

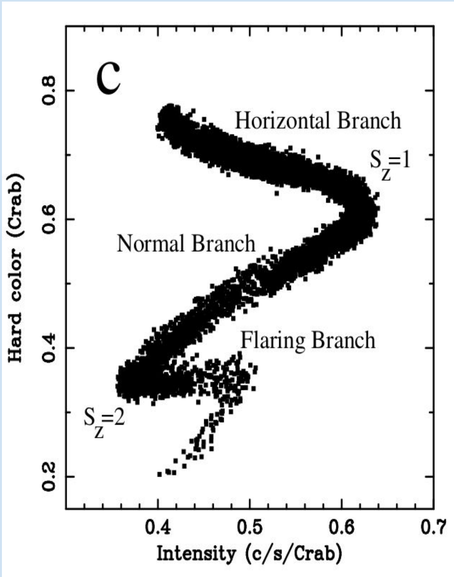


Figure 1: Hardness Intensity diagram of GX 340+0 using RXTE-PCA observations. Adapted from Jonker et al 2000.

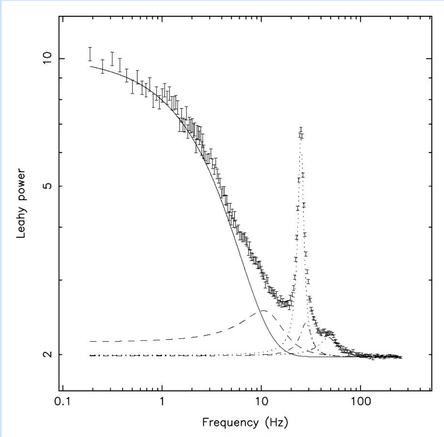
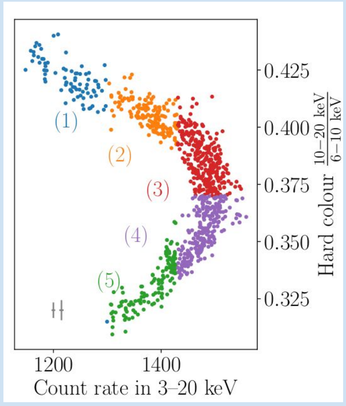


Figure 2: Power-Density spectrum (PDS) of the GX 340+0 clearly showing the HBO as seen in Jonker et al 2000.

GX 340+0 and its observation

AstroSat observed the source for a stare time of ~4 days with Soft X-ray Telescope (SXT) and Large Area X-ray Proportional Counter (LAXPC). During the observation, the source has traced the Z-track partially (see Figure 3 for the lightcurve) covering the HB and NB. To identify the which state we observed the source in, we extracted the LAXPC lightcurves in energy bands similar to van der Klis (2004) and constructed the HID (right panel of Figure 3).

We divided the observed Z-track into 5 equally spaced zones to extract the spectrum and PDS and study the evolution of the source along the track. Similar extraction was done for SXT spectrum as well to investigate the spectral properties in the source in a broad energy range. The PDS was extracted in 0.5-100 Hz for various energy bands.



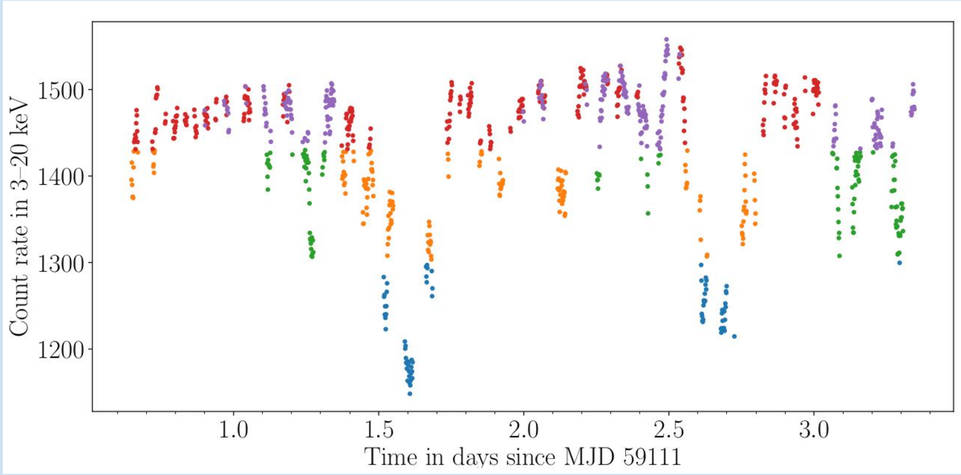


Figure 3: Light curve (left) and the HID (above) of GX 340+0. The points are colour-coded to trace the evolution of the source on the light curve as it moves along the HID. *AstroSat* observation covers two traces of the partial HB and short segments of the NB (also compare it with the Figure 1 in the poster)

Spectra, flux and PDS: What do they tell us?

To investigate the broadband spectra, we model it with a combination of a thermal accretion disk, a blackbody and Comptonised emission which covers the accretion disk and up-scatters its photons. The unabsorbed contribution to the spectrum is shown in Figure 4.

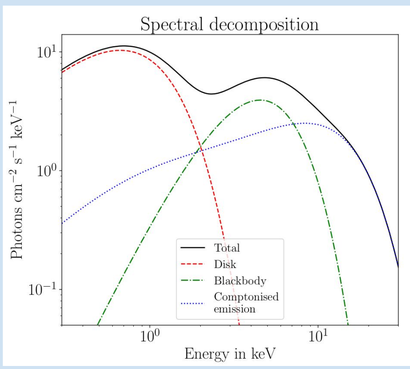


Figure 4: Spectral decomposition of one of the HID zones of GX 340+0. The HID is dominated by contributions from Comptonised emission and blackbody

The emission in 3-20 keV is dominated by the blackbody and the Comptonised emission. The interplay of these two components leads to the Z-track on the HID as we show in Figure 6. The PDS of all the zones show a strong variability. The energy dependent PDS show an evolution of the QPO strength (measured by its fractional RMS in Figure 5). The stronger QPO at higher energies can only arise from the Comptonising medium as it is the dominant component at those energies.

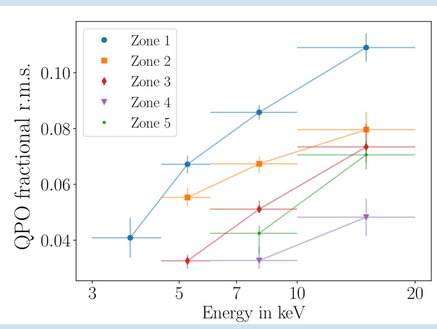


Figure 5: Variation of the QPO fractional RMS as a function of the energy. QPO in Zone 1 (i.e. the HB) is strongest and has the highest strength in 10-20 keV, which is dominated by Comptonised emission.

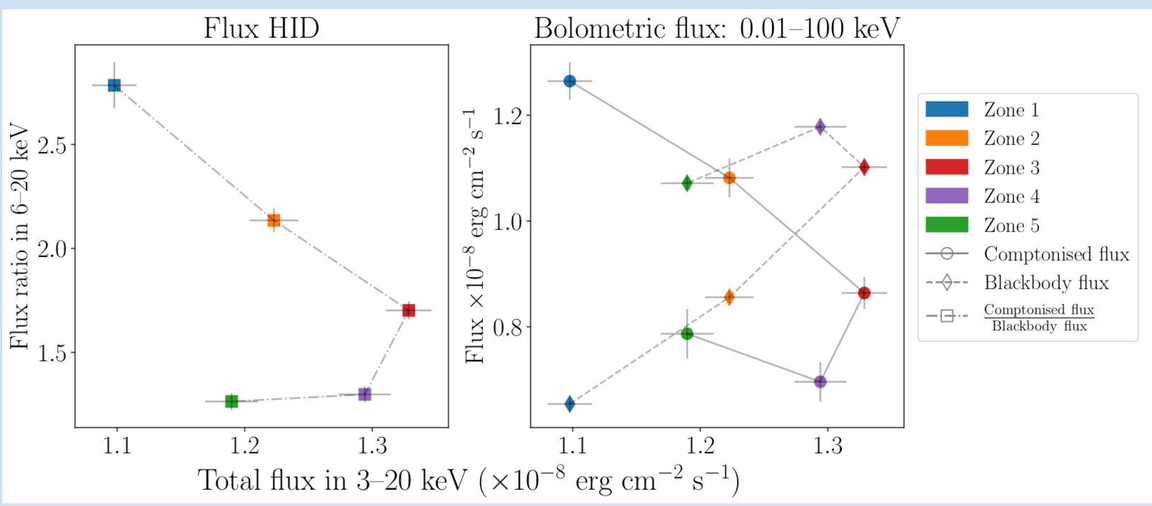
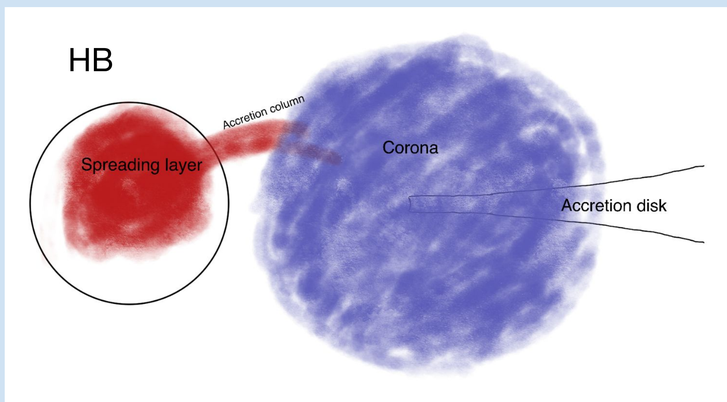


Figure 6: Flux evolution of the blackbody and Comptonised component as a function of the HID Zone. In the left panel the ratio of the component clearly reproduces the Z-track while in the right panel, we observe that the bolometric flux of the component are roughly anticorrelated.

Results & Interpretation

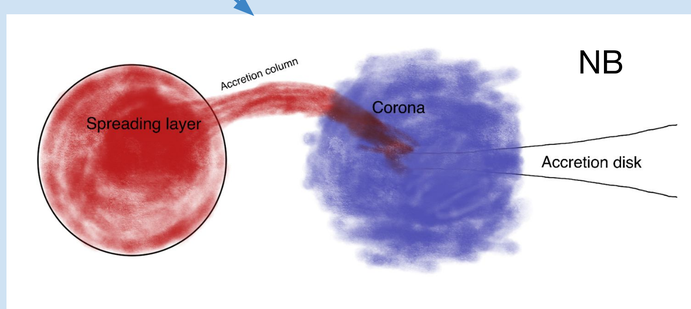
The evolution of the spectral components suggest that the as the source traverses the HID, there is a strong variation in the blackbody component and the Comptonised emission. When the source is in HB, the contribution of the Comptonising medium is higher, while during the NB the blackbody emission dominates the 3--20 keV band. This results in a similar total flux but strong differences in the hardness.



During HB the matter from accretion disk feeds to the Comptonising medium instead of the spreading layer. This leads to a stronger contribution of the Comptonised emission, a larger electron cloud (which then covers a larger fraction of the disk leading to a QPO at a lower frequency but at a considerable strength.

During NB, the matter is fed to the spreading layer instead, which is marked by the higher area of the blackbody (i.e. its normalisation).

The Comptonised emission is weaker as compared to the HB and even the observed QPO is at a lower frequency and of a different kind (weaker RMS and without associated broad noise)



References

- Jonker et al 2000, ApJ, 537, 374.
- van der Klis 2004, Compact stellar X-ray sources, Cambridge University Press.

★ The article on which this poster is based is currently under review.