A study of broadband properties of accreting X-ray pulsars with *Suzaku*

Pragati Pradhan [1,2], Biswajit Paul[3], Bikash Chandra Paul[2]

[1]St. Joseph's College, Darjeeling, India, [2]North Bengal University, West Bengal, India, [3]Raman Research Institute, Bangalore, India

Abstract

We present a comprehensive study of the hard X-ray timing and spectral properties of accreting X-ray pulsars, most of which are high mass X-ray binaries (HMXBs). Using Suzaku observations, we have examined the energy dependence of the pulsations upto highest detectable energies in these sources and compared the energy dependence with the X-ray luminosity and the magnetic field strength of these sources, if known. Similarly, the hard X-ray spectral properties of the sources are examined against the X-ray luminosity and the magnetic field strength. These measurements can provide valuable insight into physical properties of the emission region in accreting pulsars. In the lower energy band, we measured the emission lines, the absorbing column density, and the reprocessed soft X-ray emission. All of these together show the variety of the physical conditions in the accreting X-ray pulsars.

1 Introduction

High-mass X-ray binaries (HMXBs) comprise of a compact object either a neutron star or a black hole orbiting a massive OB class star. In this work, we deal with HMXBs that harbour neutron star as their compact object (Bildsten et al., 1997; Nagase, 1989; White, Swank & Holt, 1983). Such systems have strong magnetic fields, of the order of 10^{12} G and mass accretion from the stellar wind of the companion star is the main source of energy here. This accreted material on reaching the Alfven radius, gets coupled to the magnetic field lines and is channelled along these field lines leading to the formation of accretion columns. For a dipolar magnetic field, this inflowing material is directed to the magnetic poles of the neutron star and two hot spots are formed on the surface of the neutron star. The gravitational potential energy of these inflowing material is converted to X-rays (Basko & Sunyaev, 1975). If the rotation axis and the magnetic axis are not completely aligned, then to a distant observer whose line of sight to the object intersect the beam, these X-rays appear to be pulsed for each spin of the pulsar. Classical HMXBs are either Be/X-ray binaries (BeXBs; Reig 2011) or Supergiant X-ray binaries (SGXBs; Chaty 2011, and references therein). A fraction of the HMXBs with supergiant companions, called Supergiant Fast X-ray Transients (SFXTs) are characterized by short outbursts with very fast rise times ($\sim$ tens of minutes) and typical durations of a few hours (Sidoli, 2013). For this study, we have taken up both classical HMXBs and SFXTs observed with *Suzaku* (Mitsuda et al., 2007).

2 Motivation

- Timing and broadband spectroscopy (0.8-70.0 keV) of HMXBs using *Suzaku*.
- This comprehensive study includes all archival *Suzaku* data of classical HMXBs (25 pulsating and 3 non pulsating) and SFXTs (3 pulsating and 4 non pulsating)

3 Methodology

- Extracted the X-ray spectra for the individual sources
- Spectral model fitting for each source was performed using XSPEC v12.8.2.
- Each source fitted with the spectra from the XIS and PIN simultaneously with all the parameters tied except the relative instrument normalization.

4 Timing and Spectral Analysis

4.1 Timing Analysis

Highest energy upto which pulsations can be detected with *Suzaku* is investigated by comparing it's S/N in different energy bands.

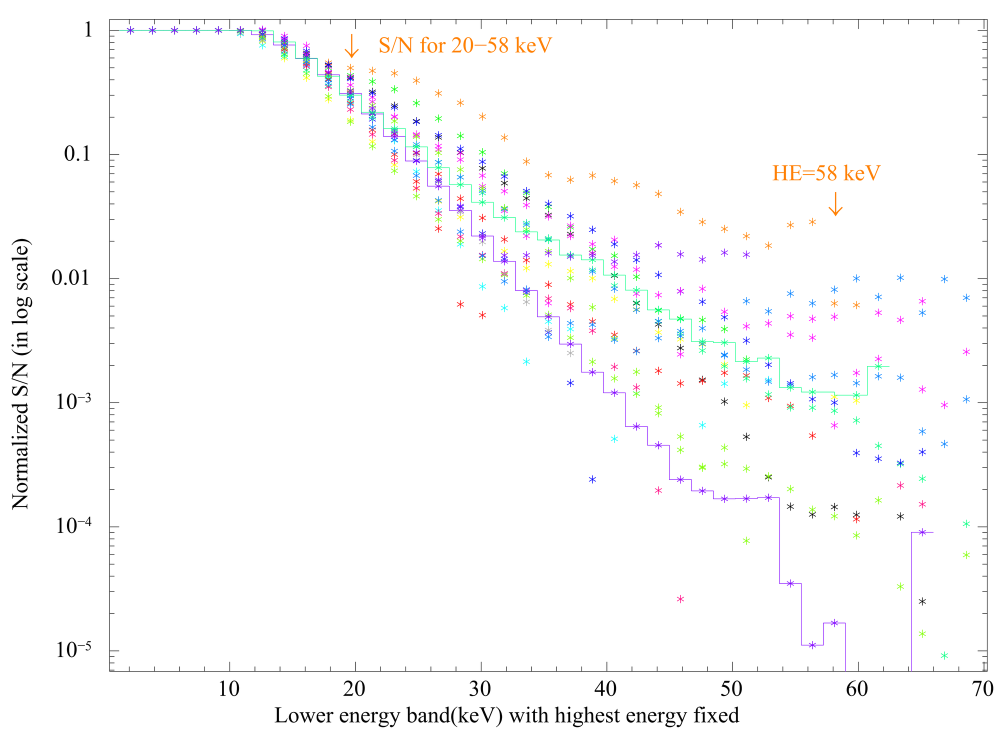

Figure 1: S/N in different energy bands

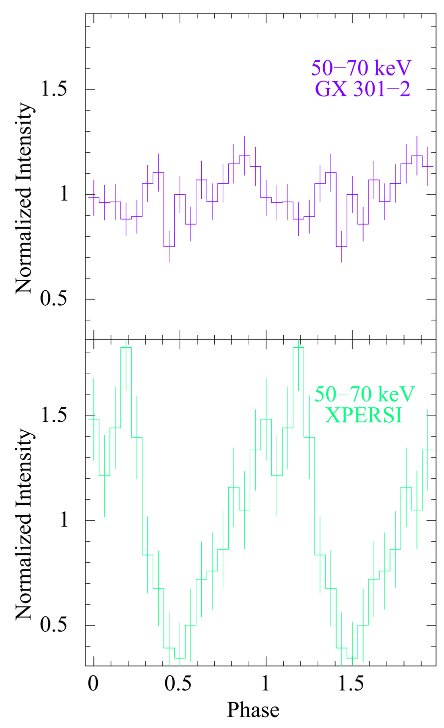

Figure 2: Pulse profiles for GX301-2 and X-PERSI in 50.0-70.0 keV

4.2 Spectral Analysis

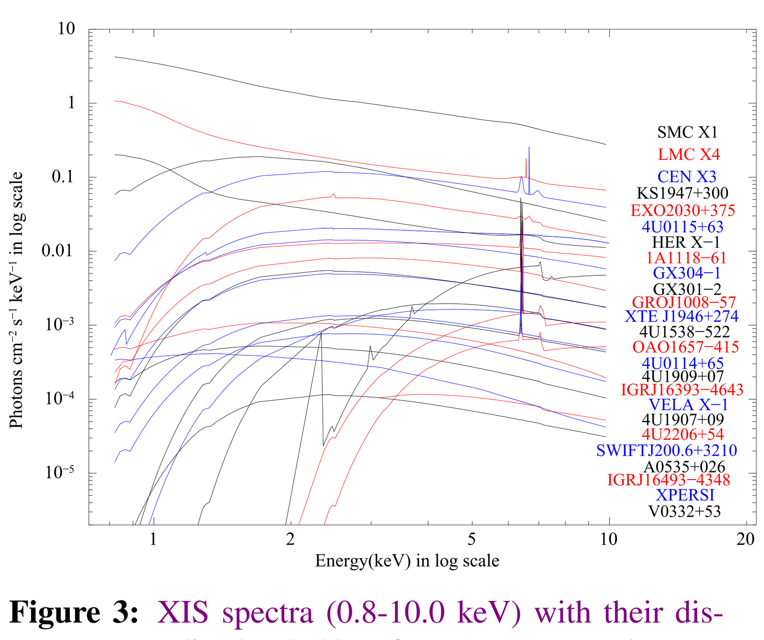

Figure 3: XIS spectra (0.8-10.0 keV) with their distances normalized at 8.5 kpc for sgHMXBs (pulsars).

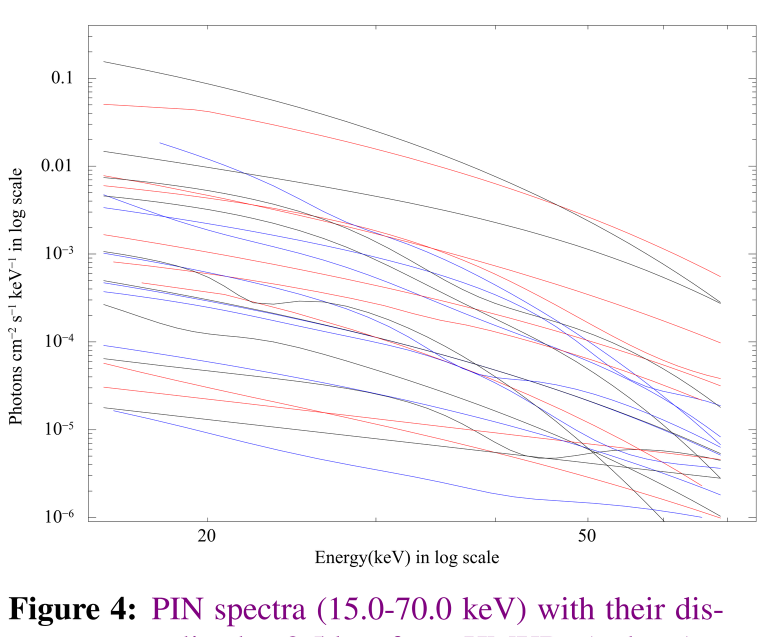

Figure 4: PIN spectra (15.0-70.0 keV) with their distances normalized at 8.5 kpc for sgHMXBs (pulsars).

5 Correlation Studies

5.1 Continuum flux, N_H and iron line flux

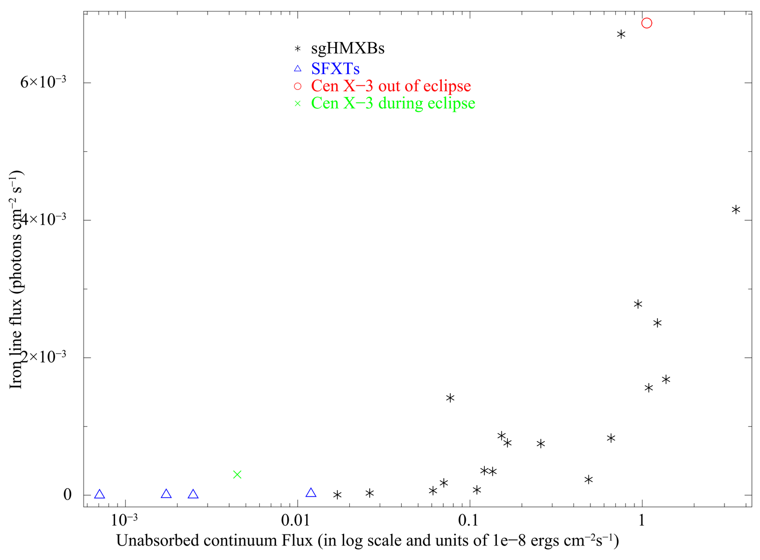

Figure 5: Non-linear correlation of the iron line flux to the unabsorbed continuum flux

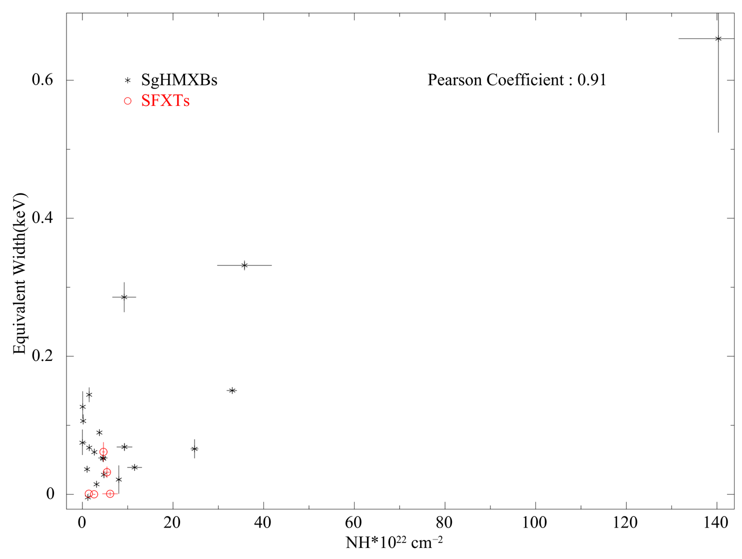

Figure 6: Co-relation between equivalent width of iron line versus N_H is not clear.

5.2 Cutoff energy and spectral index versus luminosity

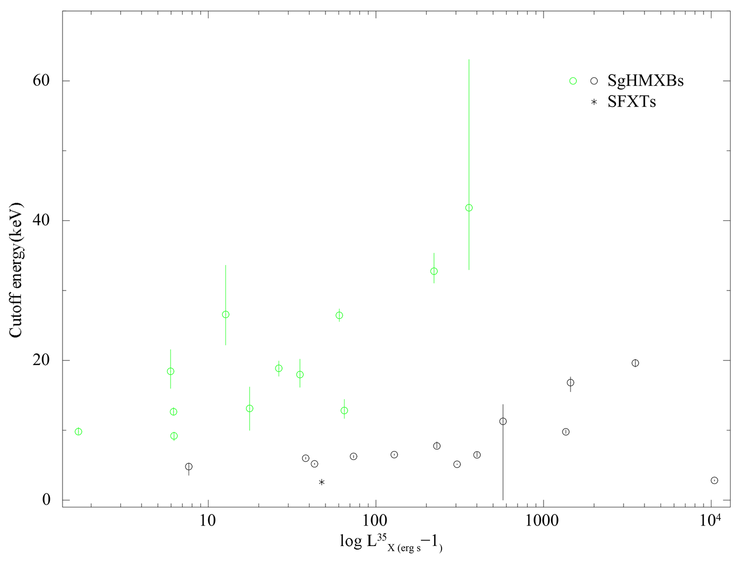

Figure 7: Cut-off energies versus luminosity show two different sets of relations, shown in green and black.

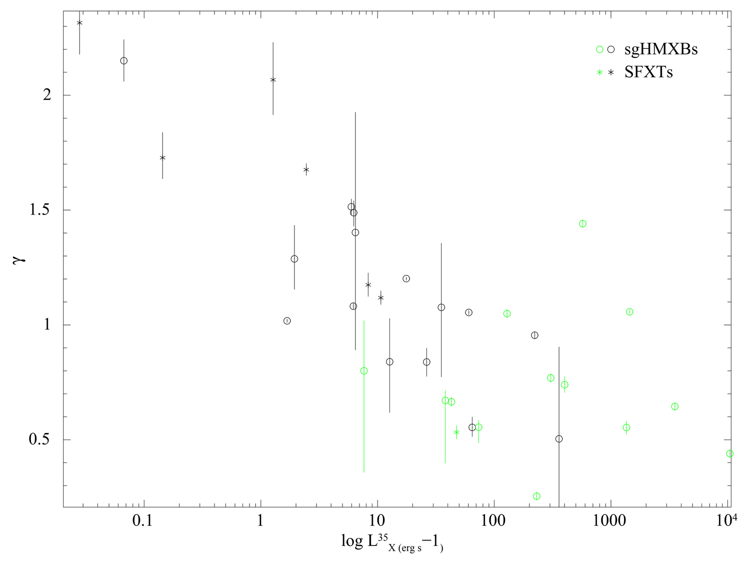

Figure 8: Anti-corelation between spectral index and luminosity

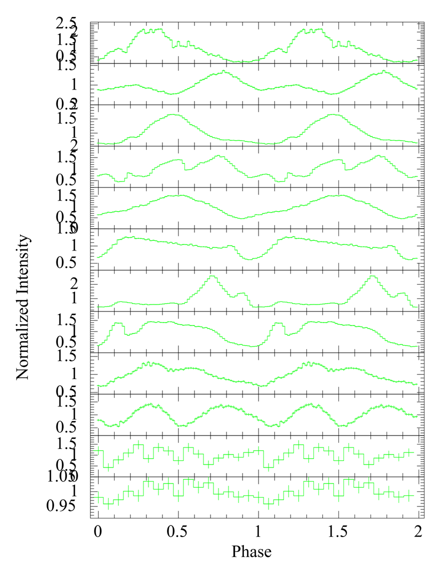

Figure 9: Pulse profile for first group (shown in green in Figures 7 and 8)

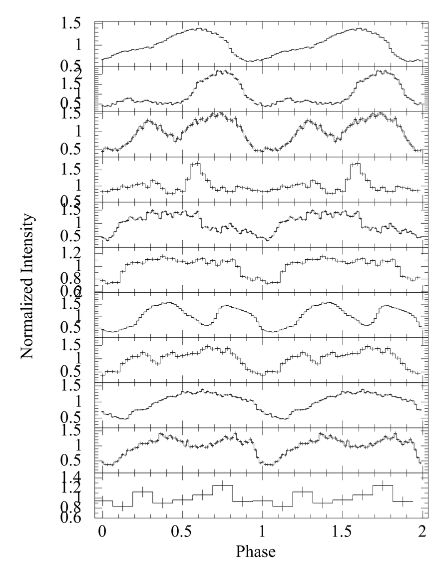

Figure 10: Pulse profile for second group (shown in black in Figures 7 and 8)

5.3 No dependence of cut-off energies on magnetic field and spectral index

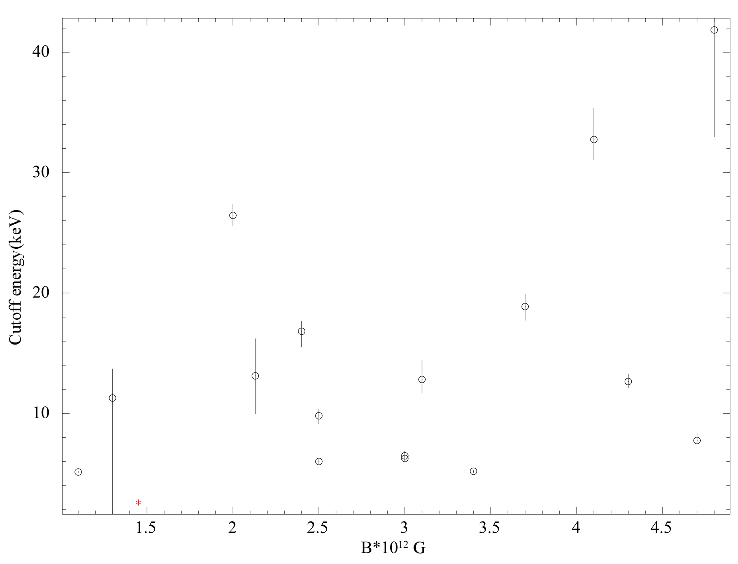

Figure 11: Cut-off energies versus magnetic field

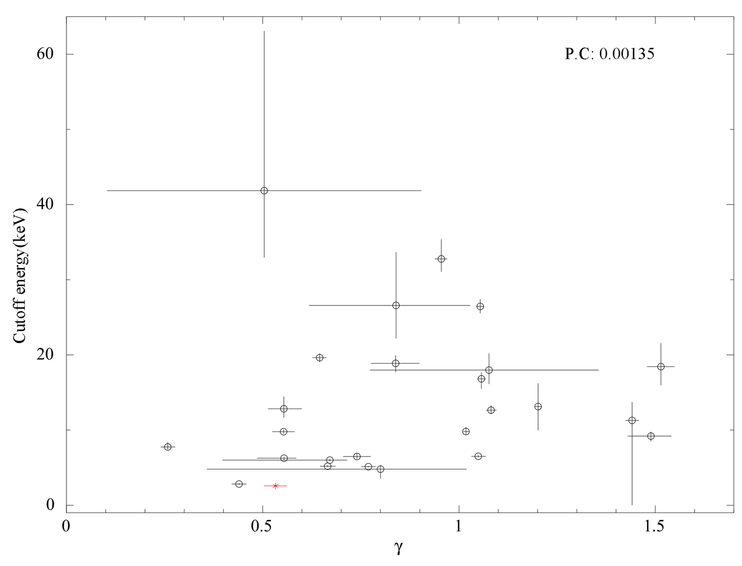

Figure 12: Cut-off energies versus spectral index

6 Discussion

- Figures 1 and 2: Timing analysis reveal that the highest energy upto which pulsations can be detected are different among different sources of this class.
- Figures 3 and 4: Broadband spectral analysis show the spectral normalisation to differ by six orders of magnitude.
- Figures 5 and 6: Non linear correlation unusual, since the iron line emission is due to the reprocessing of the continuum by iron atoms in the matter surrounding it.
- Figures 7 and 8: HMXBs seem to be divided into two classes following two different trends.
- Figures 9 and 10: To check if these two groups shown in green and red in Figures 7 and 8 have different beaming mechanism, (for example pencil beam vs fan beam) we examined the pulse profiles of the two sets of sources and found no dependency on the beaming pattern.
- Figures 11 and 12: No co-relation of cut-off energies on magnetic field and spectral index.

References

Basko M. M., Sunyaev R. A., 1975, A&A, 42, 311
Bildsten L. et al., 1997, ApJS, 113, 367
Chaty S., 2011, in Astronomical Society of the Pacific Conference Series, Vol. 447, Evolution of Compact Binaries, Schmidtobreick L., Schreiber M. R., Tappert C., eds., p. 29
Mitsuda K. et al., 2007, PASJ, 59, 1
Nagase F., 1989, PASJ, 41, 1
Reig P., 2011, Ap&SS, 332, 1
Sidoli L., 2013, ArXiv e-prints
White N. E., Swank J. H., Holt S. S., 1983, ApJ, 270, 711