A STUDY OF TEMPORAL CHARACTERISTICS OF SELECTED CATACLYSMIC VARIABLES : THE BROAD-BAND NOISE STRUCTURE BETWEEN 2-20 KEV

Ş. Balman[1,2], B. Külebi[2], and E. Beklen[2]

[1]ESA-ESTEC, Keplerlaan 1 P.O. Box 299 2200 AG Noordwijk ZH, Netherlands
[2]Department of Physics, Middle East Technical University, Ankara, 06531, Turkey

ABSTRACT

We present the preliminary analysis of the band-limited noise structure of Cataclysmic Variables (CVs) in the 2-20 keV energy band. We have currently analyzed Rossi X-ray Timing Explorer (RXTE) PCA data and derived time series from 30 CVs using the RXTE archive. In general, CVs of different types all show broad band noise which can be fitted with power laws, using exponential cut-offs, and Lorenzians in a similar way to power spectral (noise) characteristics of X-ray Binaries (XRBs). In general terms the power spectra show a power law index of (-)1.2-2. A rather large scale flattening of the power spectra exits in nonmagnetic systems in the low to very low frequency range. We observe that in low and high states/outbursts the noise in the high frequency range and low frequency range is changed. CVs show considerable very low frequency noise. In addition, we have recovered several possible QPOs in the X-ray wavelengths from CVs mainly from Intermediate Polar systems.

Key words: accretion: accretion disks - binaries:close - cataclysmic variables - X-rays: stars: quasi-periodic oscillations.

1. INTRODUCTION

Band limited noise from X-ray binaries (XRBs) have been studied in detail to understand the accretion process in comparison with other sources of colored noise in isolated systems (see van der Klis 2000 for a review). Recently, several QPOs, DNOs (dwarf nova oscillations) and lpDNOs (long period DNOs) have been detected from CVs (mostly in the optical wavelengths, timescales are 3-1000 sec). The favored interpretation is that they are a result of magnetospheric interaction of the accretion flow at the inner disk (DNOs) and magnetically excited traveling waves in the disk for QPOs. (Warner, Woudt & Pretorious 2003; Warner 2004). There are many parallel behaviors with the QPOs seen in X-ray binaries with high and low frequency X-ray QPOs resembling respectively DNOs and QPOs in CVs. DNOs exhibit frequency drifts, period doubling and 1:2:3 harmonic structure similar to black hole LMXBs (Kluzniak et al. 2005; see also Hameury & Lasota 2005). Our motivation is first, to understand the noise structure in CVs in order to interpret the origin and type of QPOs in CVs.

2. RESULTS

We used the Rossi X-ray Timing Explorer RXTE archive to study the broad band noise structure of CVs. RXTE has observed 55 CVs with more than one pointing on about half the sample. We analyzed the data of 30 CVs obtained with the Proportional Counter Array (PCA). We used archived background subtracted and merged light curves for the analysis in the low frequency range below 0.01 Hz. For the higher frequency range between 0.01-1 Hz, the data were screened and the light curves were created via SEEXTRCT v4.2. The power spectral analyses were carried out by FTOOLS/XRONOS v.5.21. and averaged about/over 30-100 spectra in each case yielding about 1000-2000 sec coherence timescale in the low frequencies (LFN ν<0.01). A 100-200 sec coherence time scale was used in the high frequency regime (HFN 0.01<ν<1) while 100-500 spectra were averaged. Figure 1 displays the fitted power spectra of a group of CVs with high states and low states labeled on each panel. The y axis is power normalized such that their integral gives the squared rms fractional variability (therefore the power spectrum is in units of (rms)^2/Hz). The expected (white) noise level is subtracted to obtain the rms fractional variability of the series ((rms)^2-mean/Hz). The data are fitted sucessfully (χ^2_ν in a range 1.1-1.9) with a power law plus an exponential cut off model. Occasinally, when necessary, lorentzians were added around wide QPO features to fit the data more properly. The QPOs were largely recovered from Intermediate Polars; only two Polars (AM Her and V834 Cen) and one nonmagnetic CV (SS Cyg) showed QPO like structures in the X-rays (see Table 1).

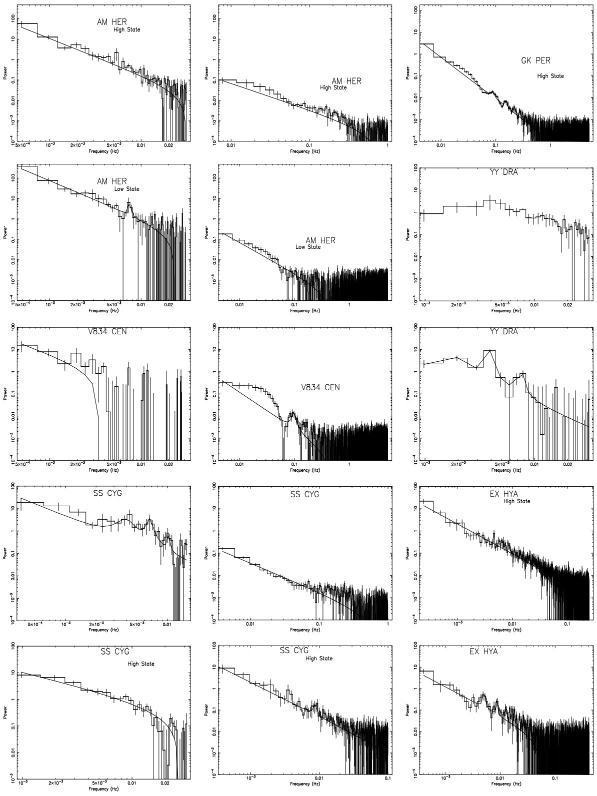

Figure 1. Noise power spectra of selected CVs in 2-20 keV energy band. The objects and their states are labeled on each panel.

3. DISCUSSION

In general CVs show lower broad band noise compared to X-ray binaries (XRBs). Even the highest noise spectrum cuts off below 0.5 Hz during outbursts/high states (like GK Per, Am Her); in quiescence the cut-offs are below 0.1 Hz. The cut-off frequency of nonmagnetic CVs is largely lower than 0.007-0.001 Hz. In general CVs constitute the low end of the Atoll, Z sources and BHCs. The HFN of XRBs do not exits for CVs. The LFN of XRBs is the like HFN for CVs and the VLFN for XRBs is LFN for CVs. Then, the very low frequency below 0.0005 Hz that is very abundant in CVs can be considered as ELFN (extreemly low frequency noise). The power law indices of the CV power spectra range between -(1.2-2.0) in general with a few exceptions. Intermediate Polars have steep spectra without flattening (except for YY Dra). Some Polars and particularly nonmagnetic CVs show considerable flattening below 0.001 Hz. There seems to be little variability in the LFN range during high states/outburts. QPOs during high states are in the HFN regime, like in GK Per, V834 Cen and SS Cyg. Coherent QPOs exits only in the LFN range during low or quiescent states (and no significant QPO exits in HFN regime, also) as in EX Hya, SS Cyg, AM Her and YY Dra. These possible LFN QPOs detected in the magnetic CVs should be the equivalent of HBOs in LMXBs. See

Table 1 : The Table of QPOs and Cut-off Frequencies

OBJECT	CUTOFF FR (Hz)	QPO (Hz)	COMMENT
AM Her	0.5		high state
AM Her	0.1	$0.0074^{+0.0008}_{-0.0003}$	low state
V834 Cen	0.26	$0.097^{+0.012}_{-0.007}$	high state
EX Hya	0.015	$0.0051^{+0.0002}_{-0.0001}$	quiescence
		0.0087	quiescence
GK Per	1	$0.089^{+0.003}_{-0.003}$	outburst
		$0.153^{+0.005}_{-0.003}$	outburst
PQ Gem	0.5	$0.086^{+0.003}_{-0.004}$	quiescence
YY Dra		$0.0074^{+0.0008}_{-0.0003}$	quiesence
YY Dra	0.3		outburst
SS Cyg	0.02	$0.0039^{+0.0030}_{-0.0014}$	quiescence
		$0.0067^{+0.0007}_{-0.0007}$	quiescence
		0.011	quiescence
SS Cyg	0.4	$0.0087^{+0.0007}_{-0.0007}$	outburst

Table 1 for QPO details. The CVs in high and low states or in outburst have their LFN and HFN reallocated. During high states and outbursts HFN increases. In quiesence and the low states LFN is dominant and, HFN gets less. The LFN during quiescent/low states is more than in the outburst/high states. This is analogous to XRBs where the broad-band noise is controlled by accretion rate. This scenario strongly supports that the high and low states in CVs are due to changes in the accretion rate.

The nonmagnetic CV T Leo shows extreemly high band limited power (4000-6000 rms mean subtracted power) below 0.001 Hz. in the RXTE observation taken during a superoutburst (Howell et al. 1999). The increase in mass accretion rate increases the VLFN (ELFN) range as detected in other Atoll sources. SS Cyg is known to show several QPOs (Mauche 2002; Wheatley et al. 2003). We find similar QPOs in the quiescent state.

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