On the Different Absorption Components in the X-ray Spectra of the Intermediate Polar Systems

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SUMMARY

We present orbital phase-resolved spectroscopy of the Intermediate polars (IP) AO Psc, HT Cam, V1223 Sgr and XSS J0056+4548 using the XMM-Newton EPIC pn data. We are investigating effects of the bulges at the accretion impact zone , disk-overflow and the consequences of this on the X-ray spectra such as hardening/softening as a result of either cold or warm absorption. In general, we find two distinct components of absorption in the X-ray spectra one orignating from the disk and the other from the accretion column/curtain. In the four IP analyzed, we find $N_H$variation from 0.05×10^{22} cm^{-2} to 2.0×10^{22} cm^{-2} owing to a disk absorption component and values at $(5.0\text{-}11.0)\times10^{22}$ cm^{-2} for the constant accretion column/curtain component. These results are in accordance with the orbital phase-resolved analysis presented in Pekön & Balman (2011) and (2012) for EX Hya and FO Aqr, respectively. Absorption from the disk is a distinct component within IP X-ray spectra.

1 Introduction & Observations

A subclass of Cataclysmic Variables (CVs) is the magnetic CVs (MCVs) divided into two sub-classes according to the degree of synchronization of the binary. Polars have 230 MG$>B>$20 MG. Intermediate Polars (IPs) have less field strength of 1-20 MG compared with Polars and are thus asynchronous systems with differing orbital and spin periods of the WD (Patterson 1994; Warner 2003).Magnetic CVs constitute about 25% of the CV population. About 63% are Polars (P) and 37% are Intermediate Polars (IP). IPs have truncated accretion disks and as the accreting material is channeled to the magnetic poles accretion curtains form. The X-ray emission is from a strong standing shock near the surface of the WD (Lamb & Masters 1979, King & Lasota 1979). The post-shock region is heated to 10-95 keV where the emission band reaches out to 200 keV with $L_x \leq$ a few $\times10^{33}$ erg s^{-1} (Patterson 1994, Hellier 1996, Barlow et al. 2006, de Martino et al. 2008, Brunschweiger et al. 2009, Yuasa et al. 2010, Bernardini et al. 2012).

Table 1: Analyzed XMM-Newton EPIC pn Observations.

OBS-ID	OBS-DATE	Detector-Mode	CR c/s
AO Psc			
0009650101	2001-06-09	PN-SmallW	5.49±0.01
XSS J0056+4548			
0501230301	2007-12-31	PN-FullF	3.13±0.03
V1223 Sgr			
0145050101	2003-04-13	PN-SmallW	14.4±0.02
HT Cam			
0144840101	2003-03-24	PN-FullF	1.48±0.01

2 Previous Works EX Hya & FO Aqr

EX Hya is discovered by Kraft (1962) with an orbital period of 98 min and later 67 min rotation period was recovered (Vogt et al. 1980). The inclination is 76°-78° (Beuerman et al. 2003). We derived orbital-phase resolved spectra For both EX Hya observations with EPIC pn, 2000 and 2003, phase columns were created using the ephemerides T_0 =2437699.94179+0.068233846(4)E given by Hellier & Sproats (1992). The results are published in Pekön and Balman (2011).

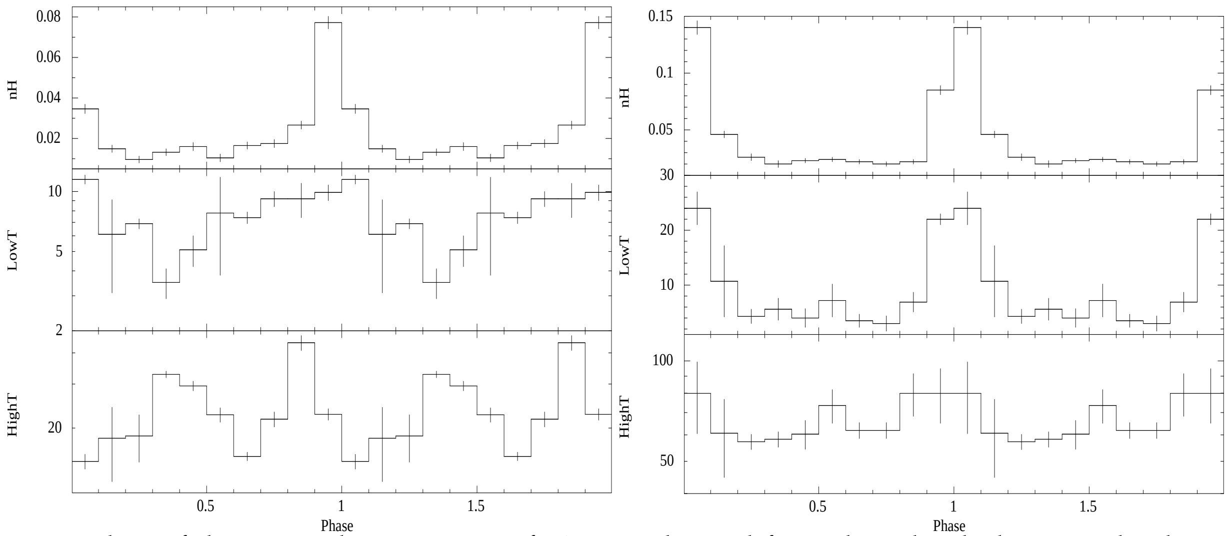

Figure 1: Plots of the spectral parameters of EX Hya derived from the orbital-phase resolved spectroscopy using the 2000 EPIC pn (top) and 2003 EPIC pn (bottom) data. Notice the peaking N_H parameter at the orbital minimum.

The IP FO AQR is a well studied IP with a spin period of 20.9 min and an orbital period of 4.85 hrs. The source is observed with several X-ray missions like EXOSAT, RXTE, ASCA, GINGA, and XMM-$Newton$ (Osborne & Mukai 1989, Hellier 1993, Mukai et al. 1994, Norton et al. 1992, Beardmore etal. 1998, Evans et al. 2004). The orbital phase-resolved spectroscopy and the modeling with warmabsorber models can be find in Pekön and Balman (2012).

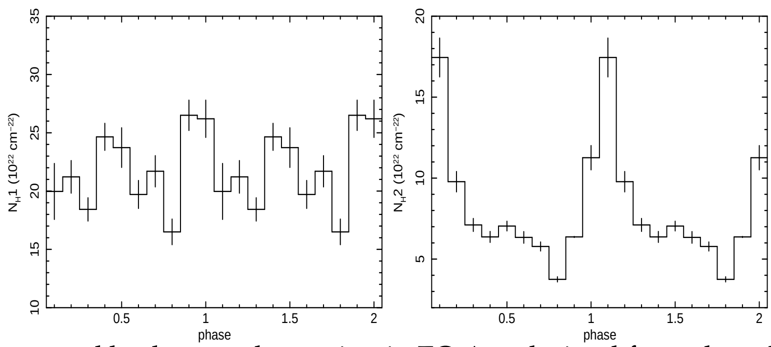

Figure 2: Plots of the neutral hydrogen absorption in FO Aqr derived from the orbital-phase resolved spectroscopy using EPIC pn data. On the left is the N_H parameter over the orbital phase due to accretion column/curtain and the second N_H componant maximizes at the orbital minimum on the right.

3 AO Psc

AO Psc is a typical IP inwhich most observable properties can be understood within the context of the standard shock model. It has a spin period of 13.4 min and orbital period of 3.59 hr (White &

Marshall 1981, Warner et al. 1981). X-ray emission fro AO Psc has been studied for 25 years with different satellites (Johnson & Imamura 2006, Suleimanov et al. 2005, Hellier & Mukai 2004, Mukai et al. 2003, Taylor et al. 1997).

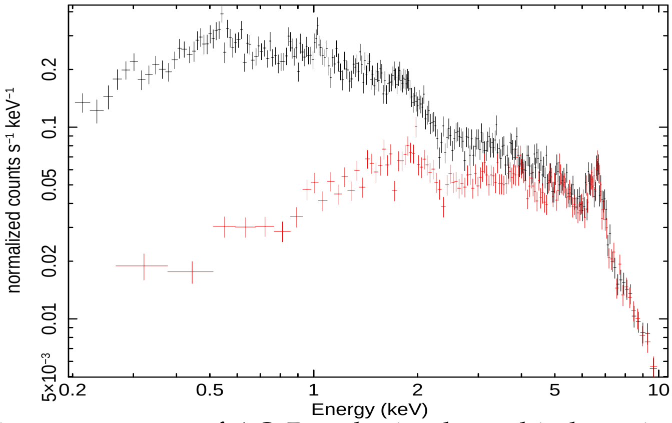

Figure 3: The *XMM-Newton* spectra of AO Psc obtained at orbital maximum (top curve in black) and the orbital minimum (bottom curve in red).

We present the spectral parameters of AO Psc obtained from *XMM-Newton* EPIN pn observation at each orbital phase of 0.1 in the 0.2-10 keV range. All the spectra were fitted with a composite model of 2 collisional equilibrium plasma emission model at different temperatures (MEKAL), 2 partial covering absorber model (PCFABS) for intrinsic absorption, a simple absorber model for interstellar absorption (WABS) fixed at 0.04×10^{22} and three Gaussians with fixed line centers at 0.57, 6.4 and 6.7 keV.

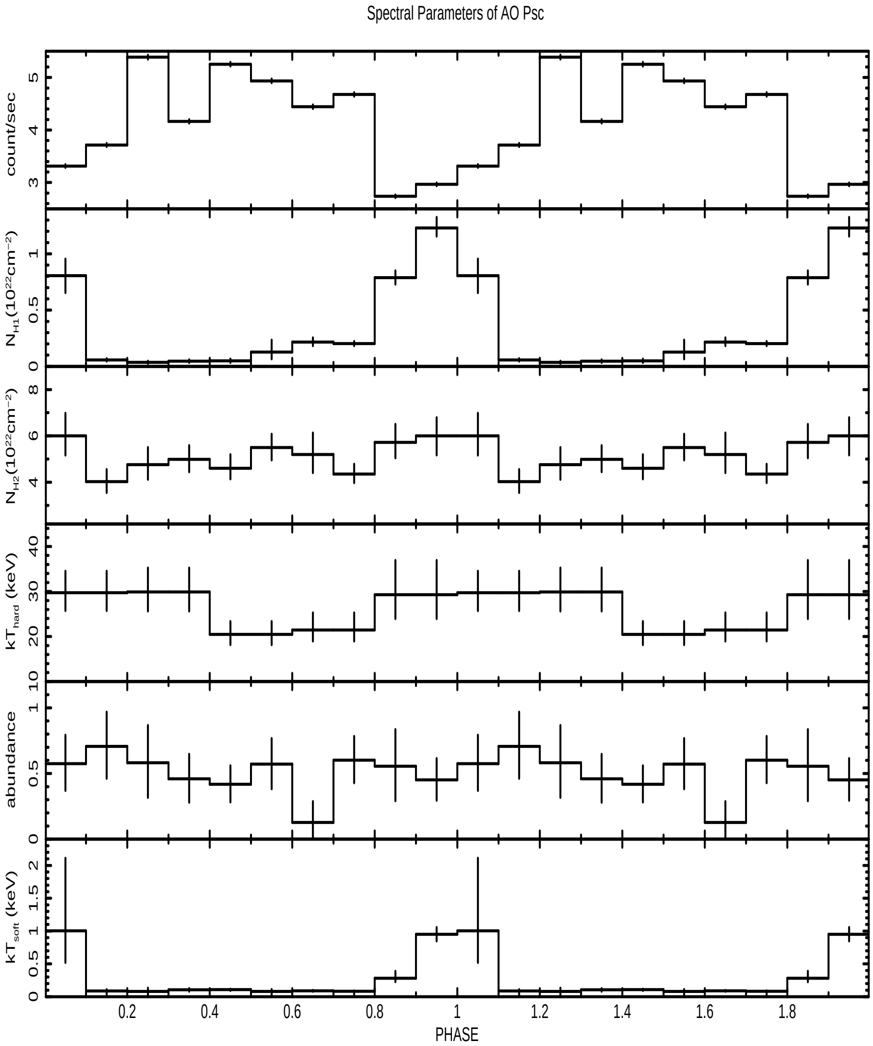

Figure 4: Plots of the spectral parameters of AO Psc derived from the orbital-phase resolved spectroscopy using the EPIC pn data. Notice the almost constant second N_H componant over the orbital phase (due to accretion column/curtain) and the first N_H componant that varies and maximizes at the orbital minimum. Note the spectral hardening at the orbital minimum of the plasma emission component with the soft X-ray temperature.

4 HT Cam

HT Cam=RXJ 0757+6306 (henceforth HT Cam) was identified as a short orbital period (81 min) CV and proposed by Tovmassian et al. (1998) as an IP . Kemp et al. (2002) found an orbital period of 85.98 min. and a spin period of 515.06 sec. HT Cam also occasionally display short outburts (Ishioka et al. 2002) with a decline rate of about 4 mmag/day similar to EX Hya. The detailed analysis of the XMM-$Newton$ data can be found in de Martino et al. (2005). We display the orbital phase-resolved spectral results not presented in de Martino et al. (2005).

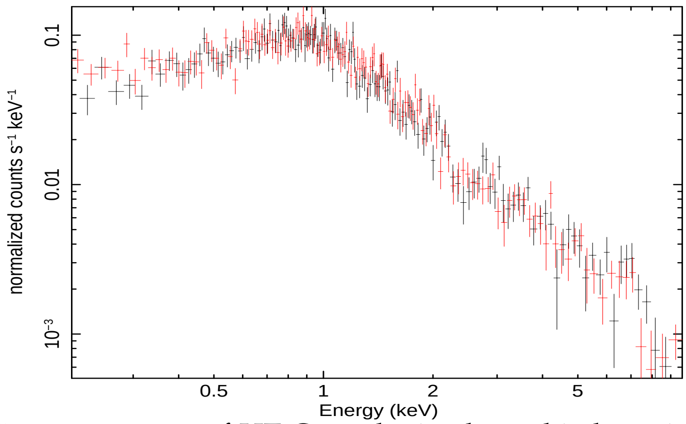

Figure 5: The *XMM-Newton* spectra of HT Cam obtained at orbital maximum (top curve in red) and the orbital minimum (bottom curve in black). Note that the above minimum and maximum spectrum is similar, this is largely because of the changing covering fraction of the absorber over the orbital phase 0.49 at the maximum to 0.24 at the minimum by a factor of two.

We present the spectral parameters derived for the year HT Cam observation at each orbital phase of 0.1 in the 0.3-10 keV range. All the spectra were fitted with a composite model of CEMEKL plasma emission model at different temperatures and a partial covering absorber model (PCFABS). The given errors correspond to 90% confidence level.

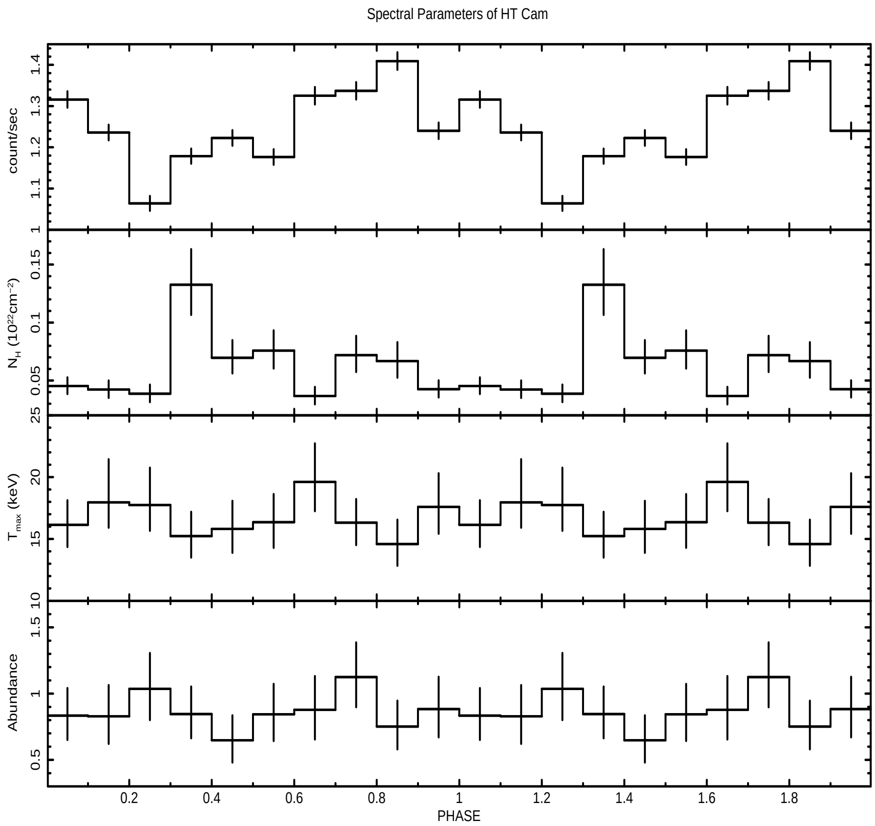

Figure 6: Plots of the spectral parameters of HT Cam derived from the orbital-phase resolved spectroscopy using the EPIC pn data. Notice the peaking N_H parameter at the orbital minimum.

5 V1223 Sgr

V1223 Sgr was identified by HEAO1 (Steiner et al. 1981). It has a spin period of 745.6 sec (Osborne et al. 1985) and intensity modulation at an orbital period of 3.37 hr (Jablonski & Steiner 1987) with also a beat period around 794.4 sec.) The distance and inclination are 527 pc and 24 degrees (Beuermann et al. 2004). The source is observed by allmost all X-ray staellites (Hayashi et al. 2011, Revnivtsev et al. 2011,2010,2004 Barlow et al. 2006, Beardmore et al. 2000, Taylor et al. 1997). Here, we display the orbital phase-resolved spectral results from an archival XMM-$Newton$ data.

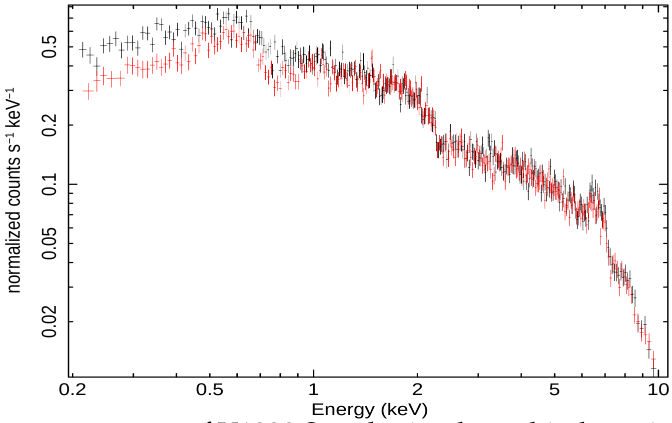

Figure 7: The XMM-$Newton$ spectra of V1223 Sgr obtained at orbital maximum (top curve in black) and the orbital minimum (bottom curve in red).

We present the spectral parameters of V1223 Sgr obtained from 2003 EPIC pn observation at each orbital phase of 0.1 in the 0.2-10 keV range. All the spectra were fitted with a composite model of 3 collisional equilibrium plasma emission model at different temperatures (MEKAL, one with a fixed temperature at 30.0 keV), 2 partial covering absorber model (PCFABS) for intrinsic absorption, a simple absorber model for interstellar absorption (WABS) and two Gaussians with fixed line centers at 6.4 and 6.7 keV and σ at 0.001 keV.

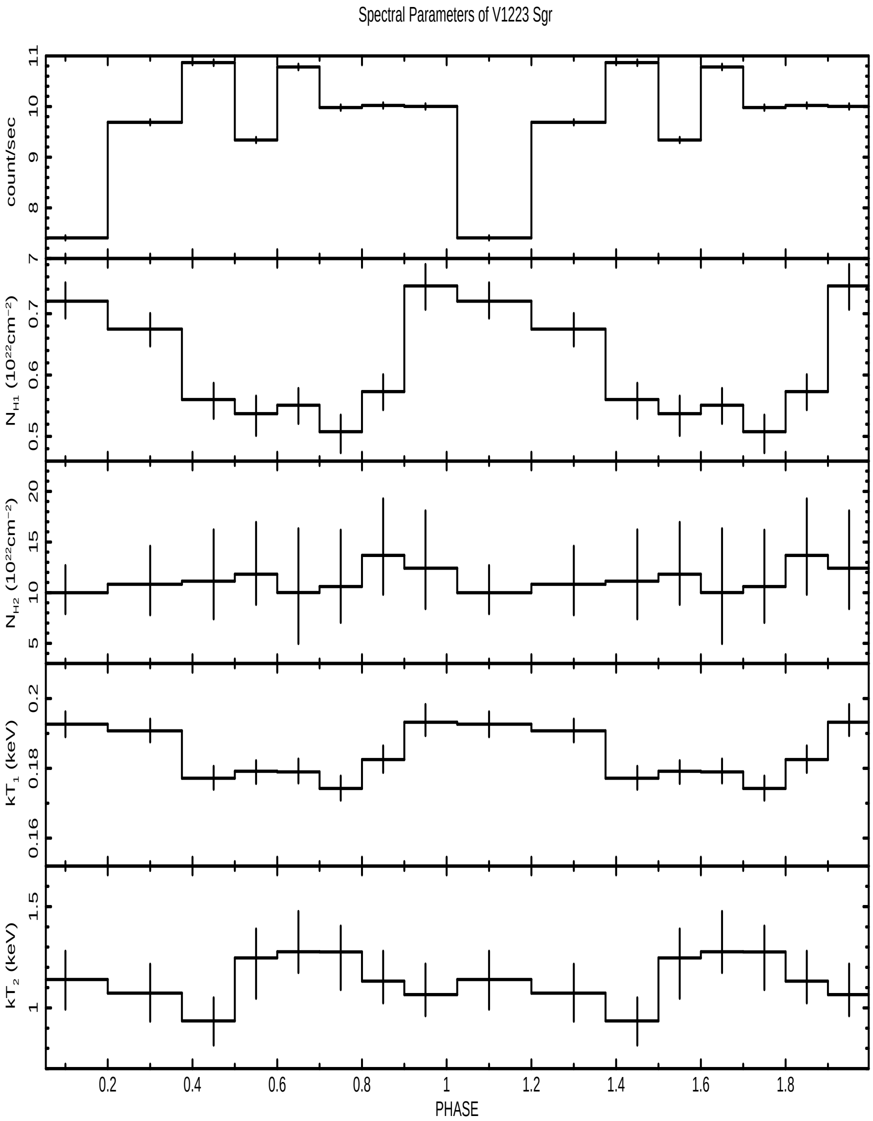

Figure 8: Plots of the spectral parameters of AO Psc derived from the orbital-phase resolved spectroscopy using the EPIC pn data. Notice the almost constant second N_H componant over the orbital phase (due to accretion column/curtain) and the first N_H componant that varies and maximizes at the orbital minimum.

6 XSS J0056+4548

The source XSSJ0056 was found in the RXTE all sky survey and identified with the X-ray ROSAT source 1RXS J005528.0+461143. Bikmaev et al. (2006) discoverd it as an IP with a period of 480 sec. Butters et al. (2008) detected an X-ray spin period of 465.68± 0.07 sec with orbital sidebands. Bonnet-Bidaud et al. (2009) fond an orbital period of 2.6244±0.0007 hrs both in X-rays and the optical. Some analysis and phase average spectrum of the *XMM-Newton* data presented here can be found in Bernardini et al. (2012). Extensive photometric results and the temporal behaviour in the optical wavelengths exist in Kozhevnikov (2012).

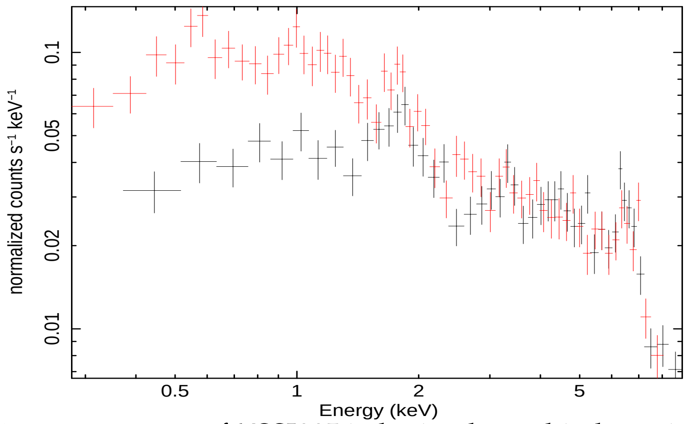

Figure 9: The *XMM-Newton* spectra of XSSJ0056 obtained at orbital maximum (top curve in red) and the orbital minimum (bottom curve in black).

We present the pectral parameters of XSS J0056+4548 obtained from the 2007 *XMM-Newton* EPIC pn observation at each orbital phase of 0.1 in the 0.2-8 keV range. All the spectra were fitted with a composite model of 2 collisional equilibrium plasma emission model at different temperatures (MEKAL), 2 partial covering absorber model (PCFABS) for intrinsic absorption, a simple absorber model for interstellar absorption (WABS) fixed at 0.1×10^{22} and a Gaussian with a fixed line center at 6.45 keV and σ at 0.01 keV. The given errors correspond to 2σ confidence level for a single parameter.

5 Discussion

In general, we find two distinct components of absorption in the X-ray spectra one orignating from the disk and the other from the accretion column/curtain.

- We find increase of absorption to a value of $N_H$of about 1.2×10^{22} cm^{-2} in AO Psc around the orbital minimum with spectral hardening in the temperatures from 0.2 to 1 keV in the soft plasma emission component. AO Psc shows a second constant absorption over the orbital phase at a value of 5-6×10^{22} cm^{-2} which can be attributed to the accretion column/curtain.
- The low absorption system HT Cam, also shows increase of $N_H$at the orbital minimum from 0.05×10^{22} cm^{-2} to 0.13×10^{22} cm^{-2} without a detectable spectral hardening. This is also true for V1223 Sgr which increases absorption from 0.5×10^{22} cm^{-2} to 0.9×10^{22} cm^{-2} at the orbital minimum covering a large solid angle from phase 0.9 to 1.35. This source also reveals a different constant absorption component of $N_H 11\times10^{22}$ cm^{-2}.
- Finally, we find two main absorption components for XSS J0056+4548, as well, one being constant and about 10×10^{22} cm^{-2} which we attribute to the absorption from the accretion column/curtain. The second component varies over the orbital phase and is maximized at the orbital minimum around phase 0.0/1.0 with a value of 1.1×10^{22} cm^{-2} and we detect some spectral hardening in the high temperature plasma component.

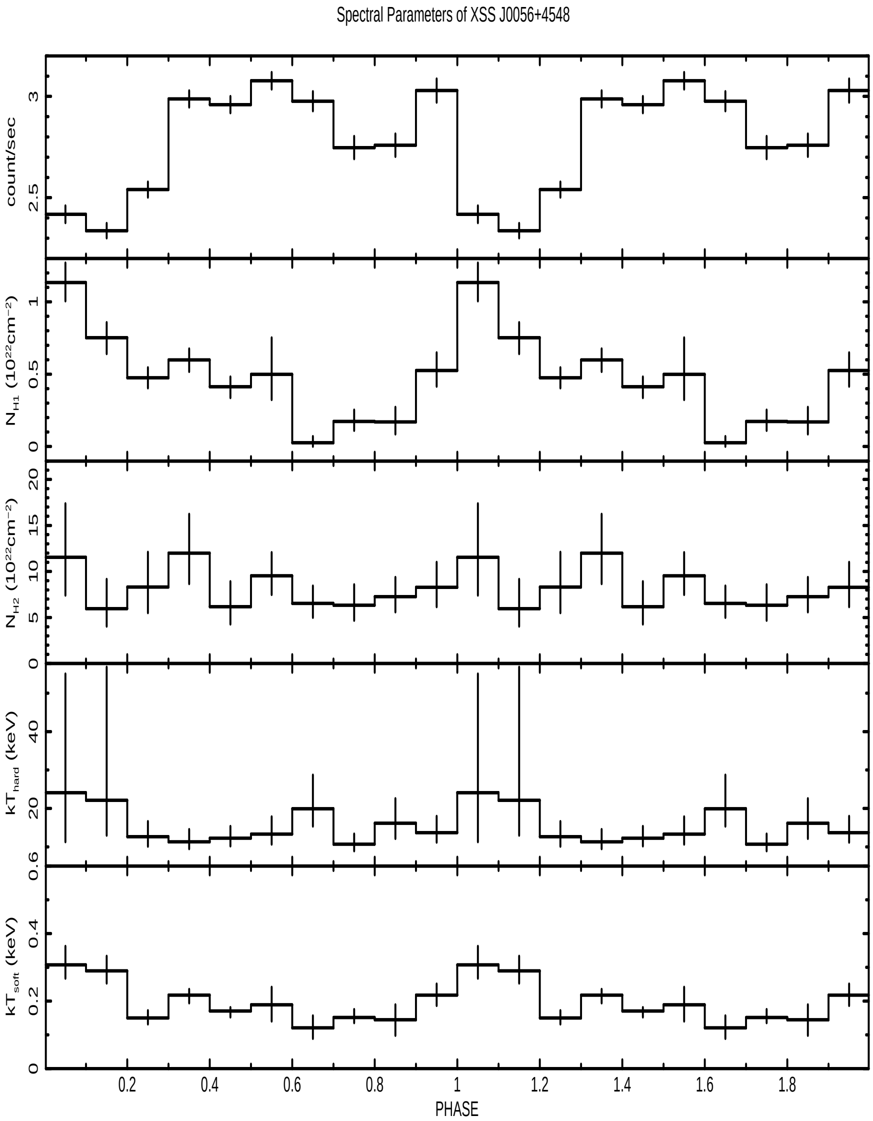

Figure 10: Plots of the spectral parameters of XSS J0056+4548 derived from the orbital-phase resolved spectroscopy using the EPIC pn data. Notice the almost constant second N_H componant over the orbital phase (due to accretion column/curtain) and the first N_H componant that varies and maximizes at the orbital minimum. The high plasma temperature componant of the spectrum also shows spectral hardening.