THE NATURE OF HIGHLY-IONIZED ABSORBERS IN DIPPING LOW-MASS X-RAY BINARIES

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ABSTRACT

X-ray observations have revealed that many low-mass X-ray binaries (LMXBs) exhibit narrow absorption features identified with Fe XXV and Fe XXVI. The changes in both the X-ray continuum and the Fe absorption features during dips from the LMXB XB 1323−619 have been modeled as resulting primarily from an increase in column density and a decrease in the ionization state of a highly-ionized absorber (see Boirin et al. in these proceedings). We successfully fit the same ionized absorber model to the persistent and dipping emission from all the other bright dipping LMXBs observed by XMM-Newton (EXO 0748−676, XB 1254−690, X 1624−490, MXB 1659−298, 4U 1746−371 and XB 1916−053) and demonstrate that complex spectral changes in the X-ray continua observed from the dip sources as a class can be most simply explained primarily by changes in the highly ionized absorbers present in these systems. We observe also small changes in the equivalent hydrogen column of neutral material, which may be related to the inclination of the system. Since the ionized plasma has a cylindrical geometry with a maximum column density close to the plane of the accretion disk and dipping sources are simply normal LMXBs viewed from close to the orbital plane this implies that ionized plasmas are a common feature of LMXBs.

Key words: X-ray binaries – Accretion, accretion disks – X-rays: EXO 0748−676, XB 1254−690, X 1624−490, MXB 1659−298, 4U 1746−371, XB 1916−053.

1. INTRODUCTION

Around 10 galactic low-mass X-ray binaries (LMXBs) show periodic dips in their X-ray light curves (Fig. 1). The dips recur at the orbital period of the system and are believed to be caused by periodic obscuration by material located in a thickened outer region of the accretion disk due to its interaction with the inflowing gas stream from the companion. The presence of periodic dips and absence of eclipses from the companion indicate that dipping sources are viewed relatively close to edge-on.

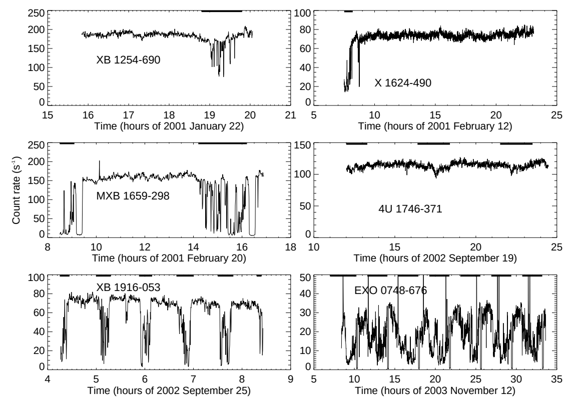

Figure 1. EPIC pn 0.6–10 keV lightcurves of the LMXBs analyzed in this work. The thick horizontal lines mark the intervals used to extract dip spectra.

The improved sensitivity and spectral resolution of *Chandra* and XMM-Newton is allowing narrow absorption features from highly-ionized Fe and other metals to be observed from a growing number of X-ray binaries. In particular, Fe XXV or Fe XXVI 1s-2p resonant absorption lines near 7 keV were reported from the micro-quasars GRO J1655−40, GRS 1915+105 and H 1743−322, and from the neutron star systems Cir X−1, GX 13+1, MXB 1659−298, X 1624−490, XB 1254−690, XB 1916−053 and XB 1323−619 (see references in Díaz Trigo et al. (2005)). Most of the sources are known to be viewed close to edge-on (many are dippers). This indicates that the highly ionized plasma probably originates in an accretion disk atmosphere or wind, which could be a common feature of accreting binaries but preferentially detected in systems viewed close to edge-on. Boirin et al. (2005) demonstrated that the changes between persistent and dipping intervals *both* in the X-ray continuum and the Fe absorption features from XB 1323−619 can be modeled as resulting primarily from an increase in column density and a decrease in

Table 1. The persistent (Dip 1 for X 1624−490) values of $N_{\rm H}$ *(col. 2),* $N_{\rm H}^{\rm xabs}$ *(col. 6) and* $\log(\xi)$ *(col. 8) and the changes in* $N_{\rm H}$ *(col. 3) and* $N_{\rm H}^{\rm xabs}$ *(col. 7) from persistent to the deepest dip intervals observed for each source.* $N_{\rm Hgal}$ *is the averaged interstellar value for the 0°.5 region in the sky containing the source.* $\Delta N_{\rm H}/(N_{\rm Hpers}-N_{\rm Hgal})$ *is the relative change in* $N_{\rm H}$ *local to the source from persistent to the deepest dip interval. Col. 9 shows the value of* $\log(\xi)$ *during the deepest dip for each source.* $N_{\rm H}$ *for EXO 0748−676 is constrained to be* $\geq 1.1 \times 10^{21}$ *atom cm*$^{-2}$*. All values of* $N_{\rm H}$*,* $N_{\rm H}^{\rm xabs}$ *and their changes are expressed in units of* 10^{22} *atom cm*$^{-2}$*.*

LMXB	$N_{\rm Hpers}$	$\Delta N_{\rm H}$	$N_{\rm Hgal}$	$\Delta N_{\rm H}$/ ($N_{\rm Hpers}$-$N_{\rm Hgal}$)	$N_{\rm H}^{\rm xabs}{}_{\rm pers}$	$\Delta N_{\rm H}^{\rm xabs}$	$\log(\xi)_{\rm pers}$	$\log(\xi)_{\rm dip}$	Dip depth
XB 1916−053	0.432 ± 0.002	0.46 ± 0.07	0.27	2.8 ± 0.4	4.2 ± 0.5	50 ± 3	3.05 ± 0.04	$2.52\ ^{+0.02}_{-0.06}$	80%
XB 1323−619[a]	3.50 ± 0.02	0.7 ± 0.2	1.57	0.4 ± 0.1	3.8 ± 0.4	33 ± 2	3.9 ± 0.1	3.13 ± 0.07	75%
EXO 0748−676	0.11	$0.13\ ^{+0.09}_{-0.05}$	0.11	∞	3.5 ± 0.2	12.0 ± 0.5	2.45 ± 0.02	2.26 ± 0.03	>85%
XB 1254−690	0.346 ± 0.002	0.04 ± 0.01	0.31	1.0 ± 0.3	8.4 ± 0.3	39 ± 3	4.3 ± 0.1	2.94 ± 0.05	50%
MXB 1659−298	0.306 ± 0.003	0.40 ± 0.04	0.19	3.5 ± 0.4	11.1 ± 0.6	42 ± 3	3.8 ± 0.1	$2.42\ ^{+0.02}_{-0.06}$	>85%
X 1624−490[b]	10.7 ± 0.5	$48\ ^{+6}_{-3}$	2.22	$5.7\ ^{+0.7}_{-0.4}$	13 ± 2	55 ± 9	3.6 ± 0.2	≥ 3.3	80%

[a] Values for XB 1323−619 are derived from the spectral fits in Boirin et al. (2005).
[b] The changes for X 1624−490 are calculated between the Dip 1 and Dip 5 stages.

the ionization state of a highly-ionized absorber. At the lower ionization levels seen during dips, lower-Z abundant ions such as H-like Ne, Si, and S and intermediate ionization states of Fe are present and their absorption features blend together at CCD energy resolution. This and the appearance of strong edges from the same ions result in an apparent change in the continuum, which is consistent with that actually observed during dips.

Here we demonstrate that the model applied by Boirin et al. (2005) to XB 1323−619 explains the spectral changes, *both* in the continuum and in the narrow absorption features, between persistent and dipping intervals of all the bright dipping LMXBs observed by XMM-Newton. Details may be found in Díaz Trigo et al. (2005).

2. DATA ANALYSIS AND RESULTS

We re-analysed all the XMM-Newton observations of bright dipping LMXBs in a similar way as it was done for XB 1323−619. Their EPIC pn 0.6-10 keV lightcurves are shown in Fig. 1. We fit the spectra of all the sources with a continuum consisting of a power-law, and a blackbody modified by absorption from neutral material (the `abs*(bb+pl)` model in SPEX). For each source we fit simultaneously all the EPIC pn spectra of the persistent and dipping intervals with the continuum parameters tied together, while we allowed to vary all the other parameters. We included Gaussian emission profiles when emission features were evident near 1 keV and/or 6 keV. To account for the absorption features around 7 keV we included absorption from a photo-ionized plasma (`xabs`) in the spectral model. The `xabs` model treats the absorption by a thin slab composed of different ions, located between the ionizing source and the observer. The processes considered are the continuum and the line absorption by the ions and scattering out of the line-of-sight by the free electrons in the slab. All relevant ions are automatically taken into account. We are able to account for the complex changes in the 0.6-10 keV continuum and absorption lines during dips from the LMXBs studied here (with the exception of 4U 1746−371 where the dips are very shallow) by large increases in the column density, $N_{\rm H}^{\rm xabs}$, and decreases in the amount of ionization, ξ, of a highly-ionized absorber (see Table 1), together with much smaller increases in the $N_{\rm H}$ of a neutral absorber (for X 1624−490 the increase in the column densities of the neutral and ionized absorbers are comparable). The eclipsing binaries EXO 0748−676 and MXB 1659−298 (together with the non-eclipsing system X 1624−490) show the largest change in $N_{\rm H}$. This suggests that the size of the change in $N_{\rm H}$ may be related to the inclination angle. Thus we would be seeing X 1624−490 and XB 1254−690 very close to, and relatively far from, the planes of the accretion disks. The spectral changes during dips from LMXBs are often modeled using the "complex continuum" approach. There the X-ray emission originates from a point-like blackbody or disk-blackbody component, together with an extended power-law component. The spectral changes during dips are explained by the partial and progressive covering of the extended component by an opaque absorber. We have self-consistently demonstrated that changes in the properties of an ionized absorber provide an alternative explanation for the overall spectral changes during dips from all the dipping LMXBs studied by XMM-Newton.

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