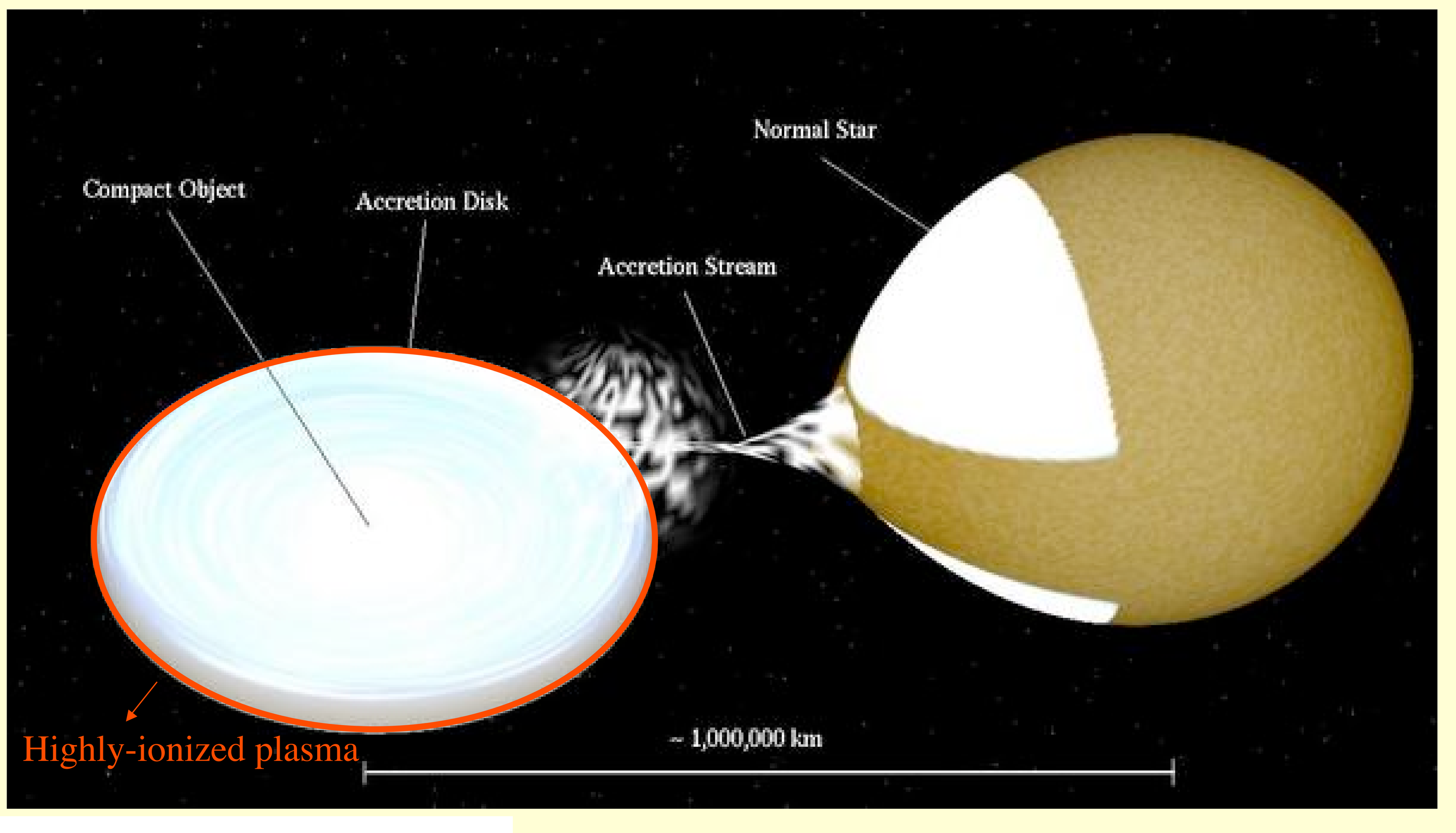
The nature of highly-ionized absorbers in LMXBs

M. Diaz Trigo[1], A. N. Parmar[1], L. Boirin[2], M. Mendez[3] and J. Kaastra[3]

[1]Astrophysics Missions Division, Research and Scientific Support Department of ESA, ESTEC, Postbus 299, NL-2200 AG Noordwijk, The Netherlands
[2]Observatoire Astronomique de Strasbourg, 11 rue de l'Universite, F-67000 Strasbourg, France
[3]SRON, National Institute for Space Research, Sorbonnelaan 2, 3584 CA Utrecht, the Netherlands

Abstract

X-ray observations have revealed that many superluminal jet-sources and low-mass X-ray binaries (LMXBs) exhibit narrow absorption features identified with resonant absorption from Fe XXV, Fe XXVI and other abundant ions.
We successfully model the changes in **both** the X-ray continuum and the Fe absorption features during dips from all the bright dipping LMXBs observed by XMM-Newton (EXO 0748-676, XB 1254-690, MXB 1659-298, 4U 1746-371 and XB 1916-053) as resulting primarily from an increase in column density and a decrease in the ionization state of a highly-ionized absorber in a similar way as was done for XB 1323-619 (Boirin et al, 2005).
This implies that the complex spectral changes in the X-ray continua observed from dip sources can be mostly explained by changes in the highly-ionized absorbers present in these systems. There is no need to invoke unusual abundances or partial covering of extended emission regions.



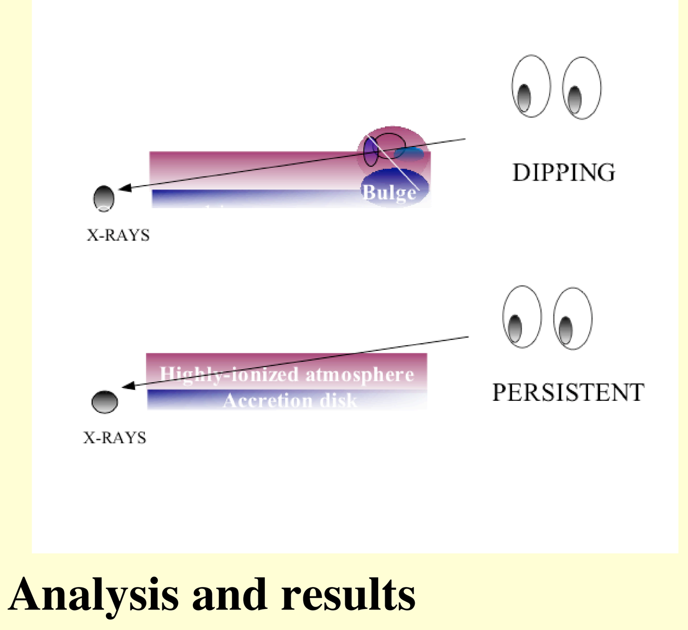


Fig. 1: Scheme of a LMXB. The highly-ionized plasma is located very likely in the outer regions of the accretion disk, resulting from the impact of the accretion flow from the companion star into the disk. The plasma is presumably less ionized and has a higher column density in the impact point of the accretion stream.

Analysis and results

XMM-Newton EPIC pn spectra were extracted and corrected for pile-up using the Science Analysis Software (SAS). After excluding bursts and eclipses, the spectra were extracted for persistent and dipping emission by visual inspection of the sources' light curves (see Fig. 2). Within the dipping intervals, between 1 and 5 spectra were extracted for each source based on intensity selection criteria.
The continuum was modeled with blackbody (bb) and power-law (pl) components modified by neutral absorption. To account for the narrow absorption features present in the residuals at around 7 keV (see Fig. 3), absorption from a photo-ionized plasma was included in the spectral model. For each source, all the EPIC pn spectra, persistent and various dipping levels, were fit simultaneously with the bb and pl components tied together.

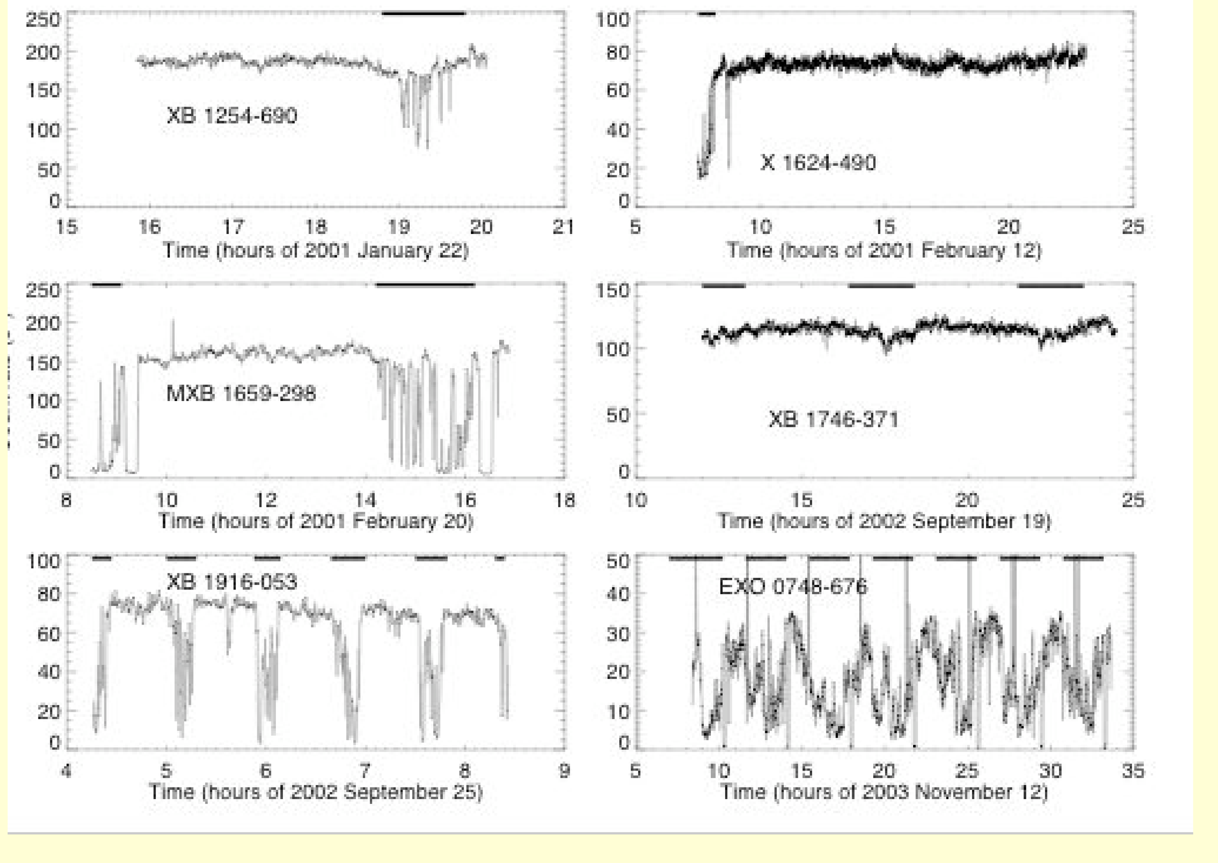


Fig. 2: EPIC PN 0.6-10 keV lightcurves for each source. The thick horizontal lines mark the intervals used to extract dip spectra.

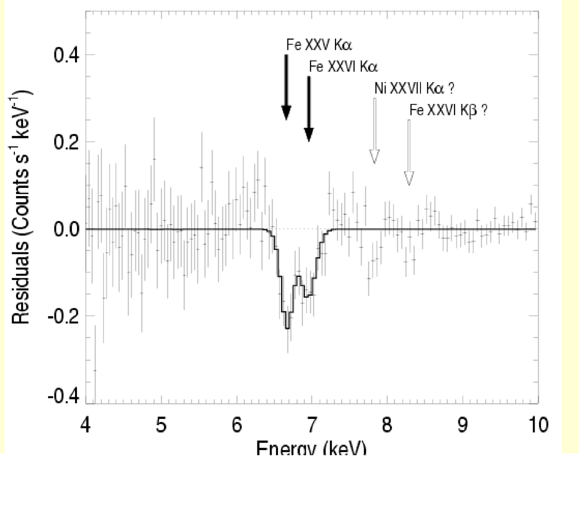


Fig. 3: XB 1916-053: 4-10 keV spectral residuals from the best-fit abs(bb+pl) model to the persistent spectrum. The theoretical energies of the Fe XXV and Fe XXVI absorption features are indicated.

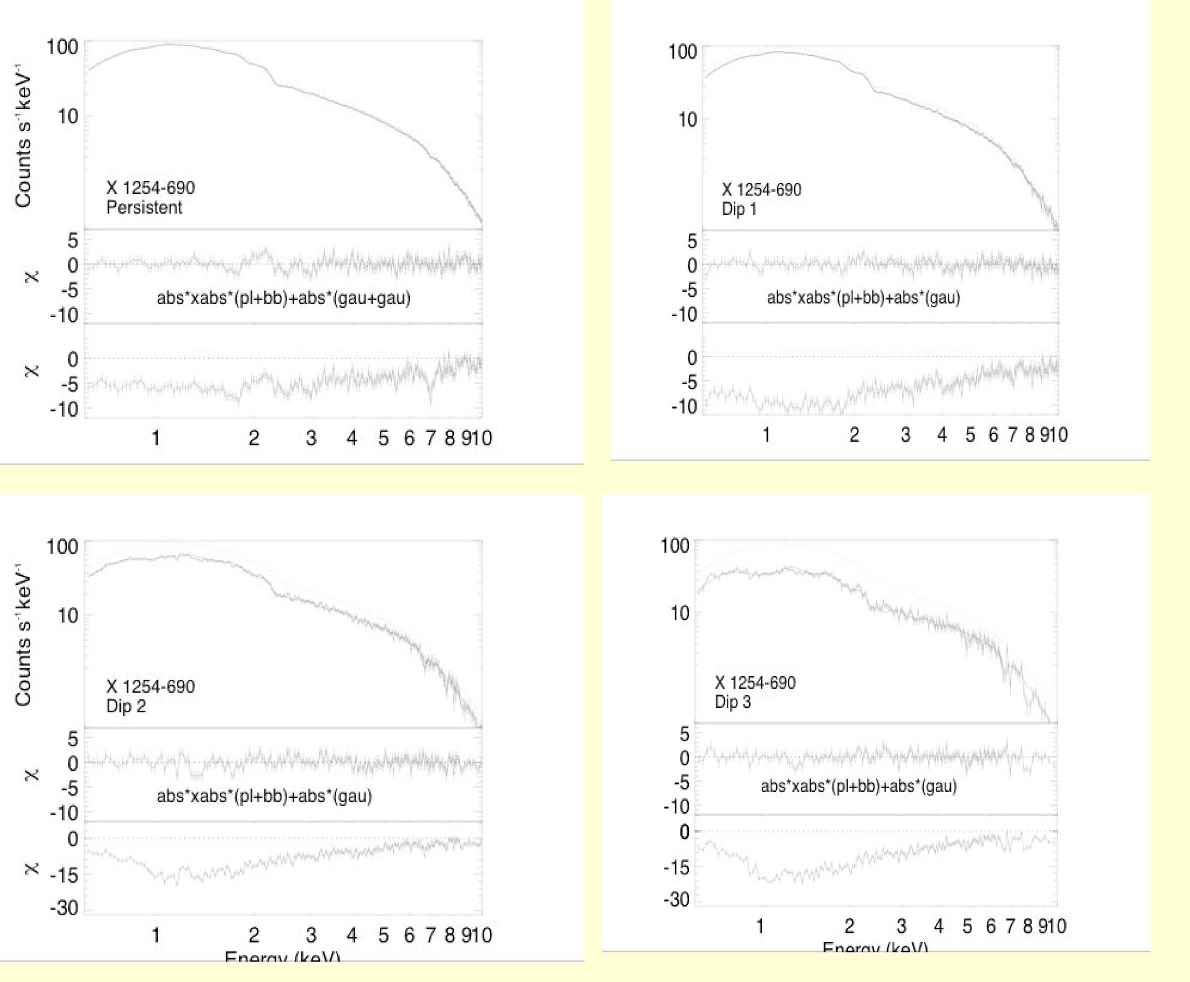


Fig. 4: XB 1254-690: EPIC pn persistent spectrum and 3 dipping spectra fit with a model consisting of a power-law and a blackbody, modified by absorption from neutral (abs) and ionized (xabs) material together with two narrow emission lines (gau) modified by absorption from neutral material (abs). The middle panels show the residuals in units of standard deviations from the above model. The lower panels show residuals when N_H^{xabs} is set to 0.

Fig. 4 shows the best-fit model and residuals from the fit for XB 1254-690 for persistent and dipping spectra. The changes in the continuum can be modeled primarily by changes in the ionized absorber, strong increase of the density column N_H^{xabs} and decrease of the ionization parameter ξ, and a small increase in the amount of neutral absorption N_H. The deepest line in the persistent spectrum is identified with Fe XXVI 1s-2p Lyα. During dipping, the equivalent width of the Fe XXVI line decreases and lines of less-ionized species of Fe, such as Fe XXV, appear.
Similar fits have been obtained for all the studied sources. Table 1 shows the persistent values of the neutral and ionized absorber during persistent emission and the changes from persistent to deepest dip intervals for those sources and Fig. 5 shows the evolution of N_H^{xabs} and ξ from persistent to the deepest dip intervals for each source.
The size of the change in N_H may be related to the inclination angle. XB 1254-690 and XB 1323-619, which show the smallest relative changes of N_H, have also the less deep dips, consistent with viewing the source relatively far from the disk plane, while the eclipsing binaries EXO 0748-676 and MXB 1659-298 show the largest changes in N_H.

LMXB	N_H	$\Delta N_H/(N_H-N_{Hgal})$	N_H^{xabs}	ΔN_H^{xabs}	Log(ξ)	ΔLog(ξ)
	(10^{22} cm^{-2})		(10^{22} cm^{-2})		erg cm s^{-1}	
XB 1916-053	0.432	2.8	4.2	50	3.05	-0.5
XB 1323-619	3.50	0.4	3.8	33	3.9	-0.8
EXO 0748-676	0.11	Inf.	3.5	12	2.45	-0.2
XB 1254-690	0.346	1.0	8.4	39	4.3	-1.4
MXB 1659-298	0.304	3.5	7.6	41	3.80	-1.4
XB 1624–490	10.7	5.7	13	55	3.6	-0.2

Table 1: The persistent values of N_H, N_H^{xabs} and log(ξ) and the changes in these parameters from persistent to the deepest dip intervals observed for each source.

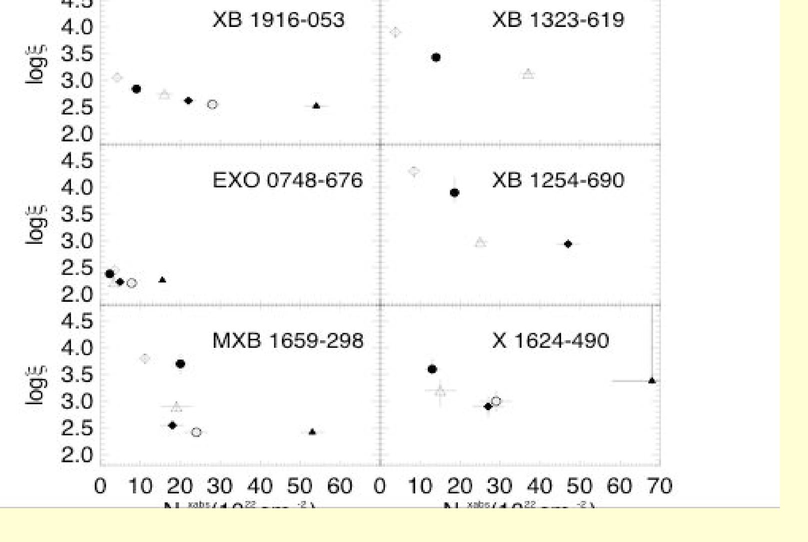


Fig. 5: Evolution of log (ξ) N_h^{xabs} for the LMXBs studied. Empty diamonds, filled circles, empty triangles, filled diamonds, empty circles and filled triangles indicate the persistent and Dip 1 to Dip 5 intervals, respectively.

Conclusions

The highly-ionized absorber model has been presented as an alternative to neutral absorber models to explain the dipping phenomenon *and* the presence of narrow absorption features in the spectra of dipping LMXBs.
This model explains the complex changes in the 0.6-10 keV continuum during dips from 4U 1323-62, X 1916-053, EXO 0748-676, XB 1254-690, MXB 1659-298 and X 1624-490.
During persistent emission, almost all the abundant elements, except Fe, are fully ionized.
During dips, the N_H of the ionized absorber increases and the ionization parameter decreases, consistent with less-ionized material in the line of sight. There is also a small increase in the N_H of neutral material.

References
Boirin, L., Mendez, M., Diaz Trigo, M., Parmar, A.N. and Kaastra, J. 2005, A&A, 436,195

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