Disc-Jet-Wind interaction in black hole X-ray binaries

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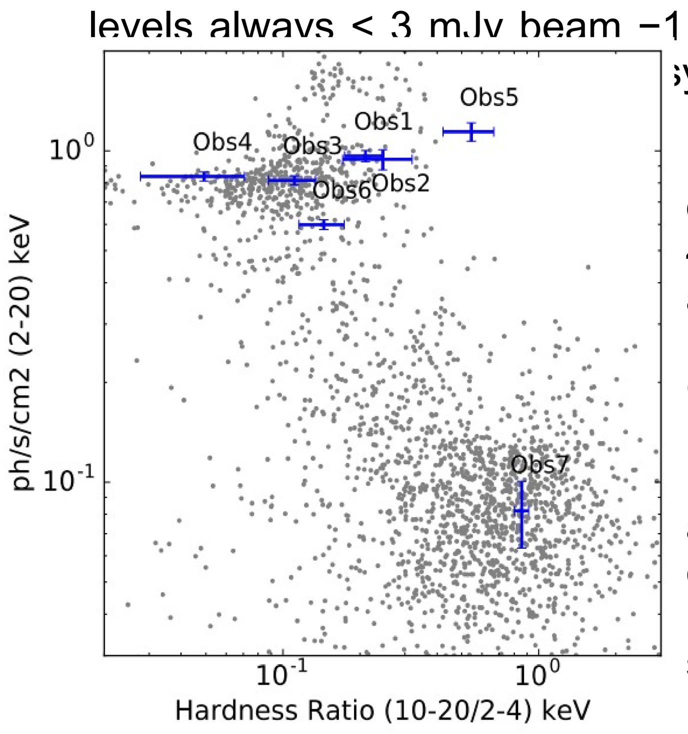
ABSTRACT

X-ray binaries, composed of a compact object (neutron star or black hole) orbiting around a companion star, constitute an excellent environment to study accretion phenomena. Outstanding open topics include the interplay between outflows (in the form of collimated winds or relativistic jets) and discs, the accretion-radiation energy balance, the radiative feedback and the relation between relativistic jets and the fundamental properties of the black holes (e.g. spin). Here, we report the analysis of two black hole low mass X-ray binaries, 4U 1630-47 and IGR J17091-3624, using X-ray high-resolution spectra.

4U 1630-47

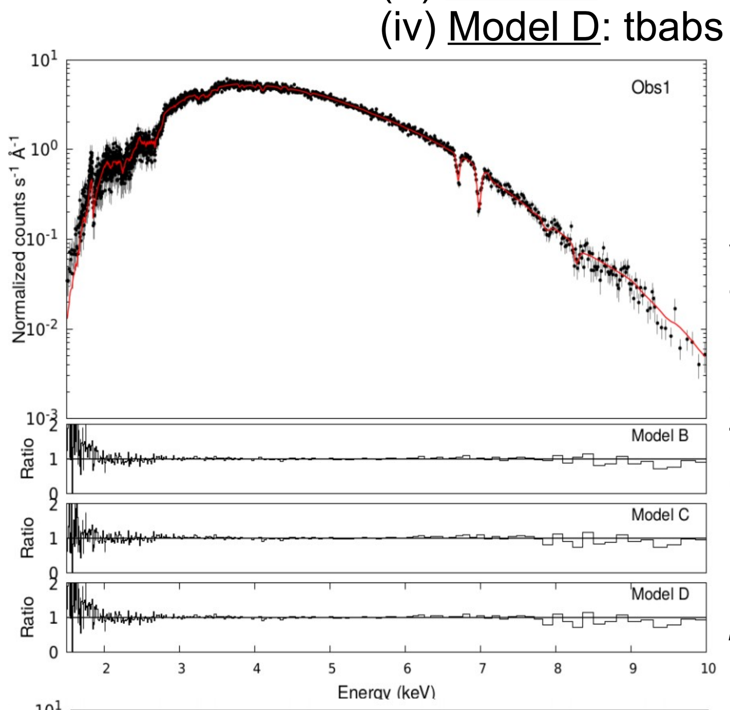
The BH LMXB 4U 1630-47 constitutes an excellent laboratory to study the disc–jet connection. It has been identified as a recurrent transient with an inclination of ~60–75°. Radio emission has been detected at flux levels always < 3 mJy beam −1 and has been identified



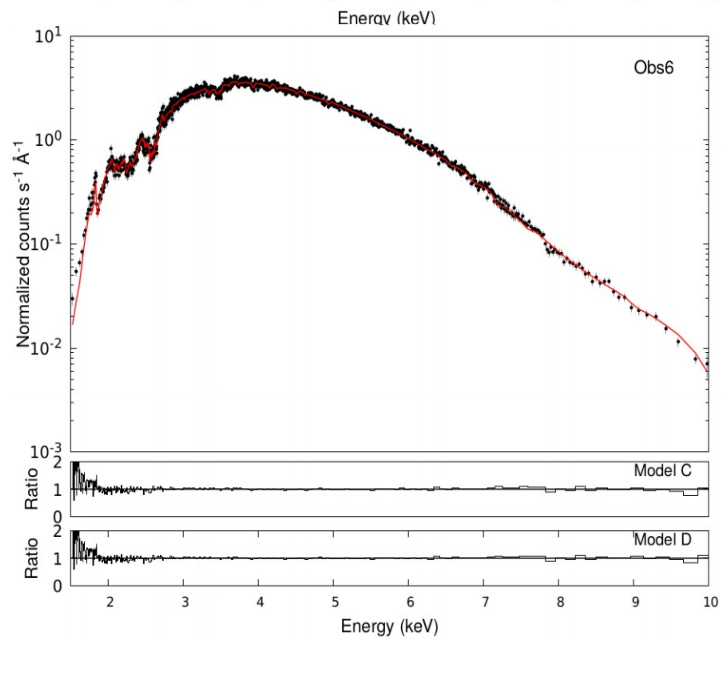
system.
Figure shows the hardness-intensity diagram of the 4U 1630-47 using MAXI/ASM daily average lightcurves. The blue points indicate the Chandra observations used in this analysis. Obs. 1-4 correspond to a soft accretion state. Obs 6 corresponds to a relatively soft-intermediate state and Obs 7 to a hard-intermediate or hard state.

In order to account for different spectral states, we fitted each HEG-ACIS observation in the 1.5–10 keV energy range using multiple phenomenological models:

(I) Model A: tbabs ⋆ (powerlaw)
(ii) Model B: tbabs ⋆ (diskbb)
(iii) Model C: tbabs ⋆ (powerlaw+diskbb)
(iv) Model D: tbabs ⋆ simpl(diskbb)



Obs 1-4 are best modeled with a *diskbb* with a relatively high temperature (1.49-1.58 keV) and show no significant hard X-ray flux (15-50 keV). In contrast, Obs 6 and 7 require two-component models (*diskbb* and a *powerlaw*) to predict the Swift/BAT flux within the errors.



We have estimated the powerlaw contribution to the total unabsorbed flux in the 2–20 keV energy range for Obs 6 and Obs 7 to be ~50% and ~65%, respectively. Also, Obs 1-4 shows multiple absorption lines which are absent in Obs 6-7

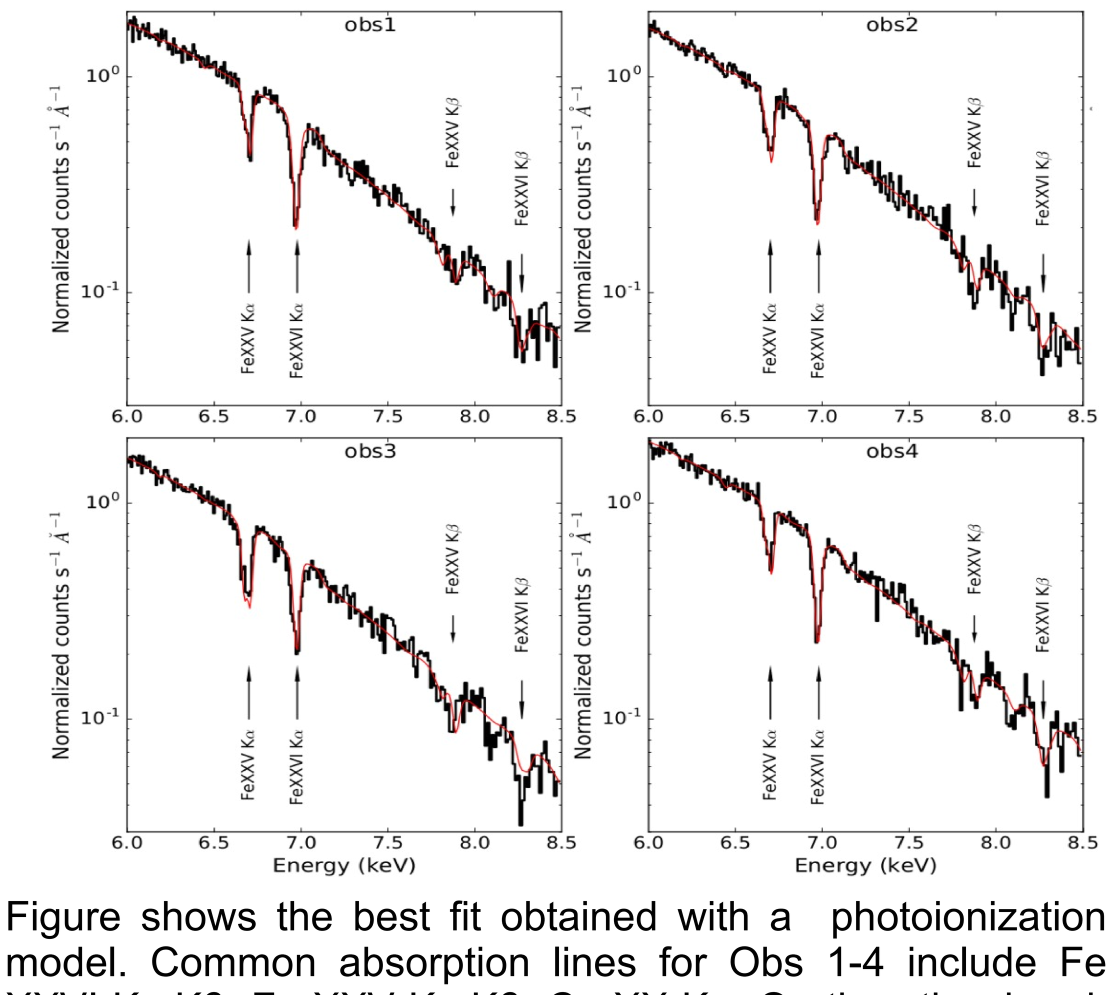
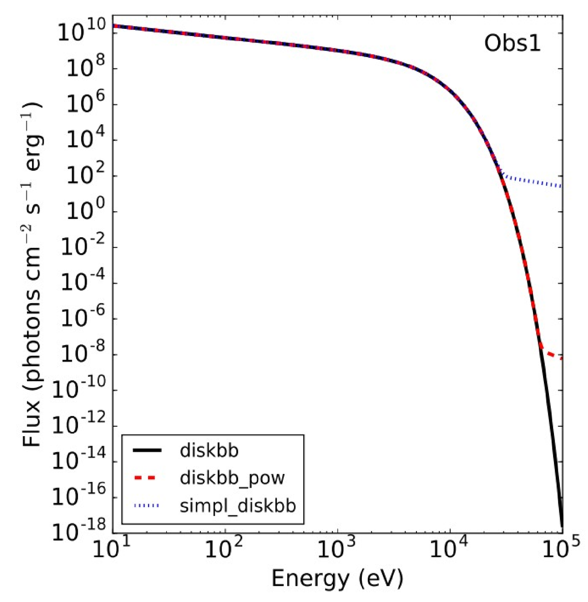


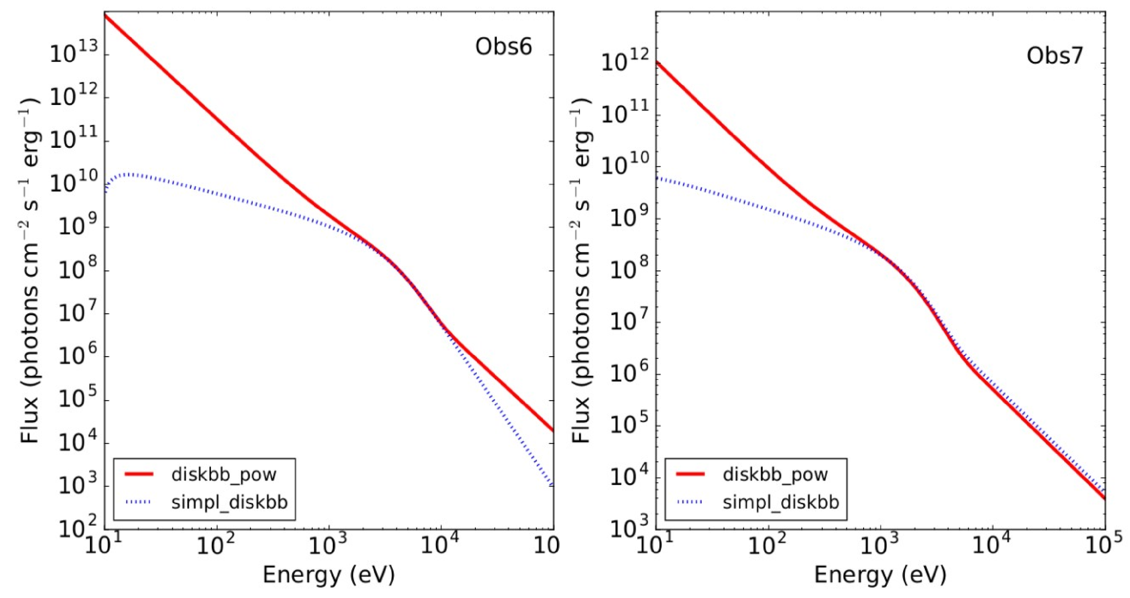
Figure shows the best fit obtained with a photoionization model. Common absorption lines for Obs 1-4 include Fe XXVI Kα,Kβ, Fe XXV Kα,Kβ, Ca XX Kα. On the other hand, S XVI Kα, Ar XVIII Kα, Si XIV Kα lines are identified only in Obs 3.

Stability curves

The equilibrium states of a photoionised plasma can be studied through the stability curve, which consists of a T versus ξ /T diagram. Parts of the curve during which the slope is positive, corresponds to thermally stable regions, and negative, corresponds to thermally unstable regions.



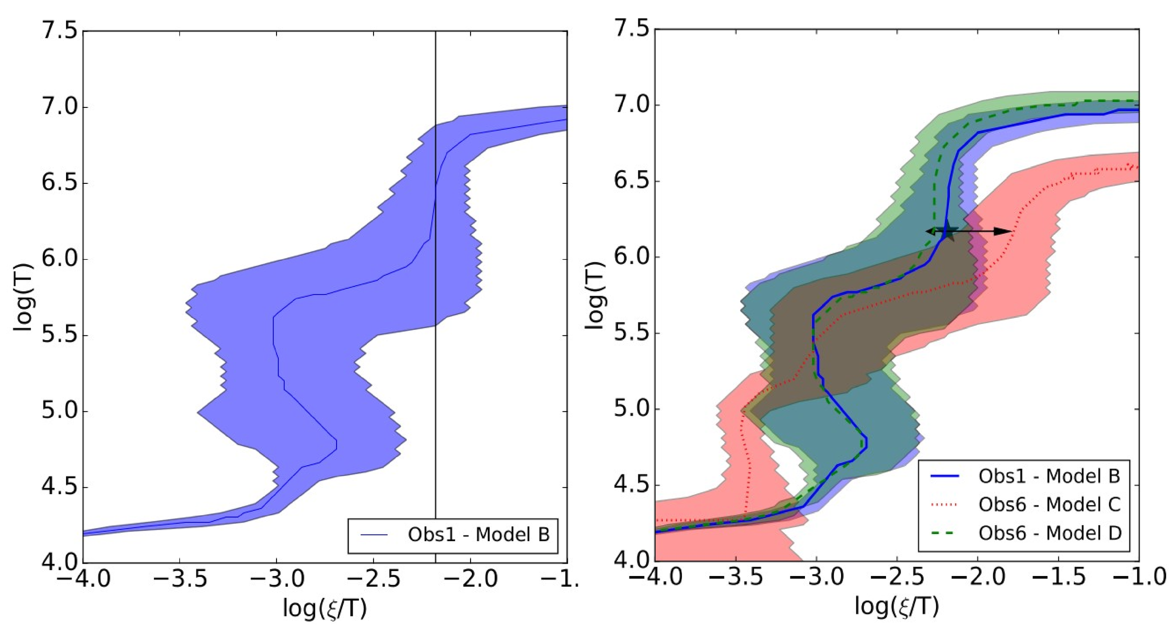
Figures show the spectral energy distributions (SEDs) obtained from the continuum modeling For Obs 1-4, different models yield differences in the SEDs only in the high-energy region. For Obs6-7, the SEDs exhibit different shapes not only in the low energy band but also in the high-energy band, depending on the



We found that the best-fit parameters obtained for Obs 1-4, using a photoionization model, lie in thermally stable parts of the curve (left panel, below). In the case of Obs 6 and 7, we found a solution thermally stable if we consider that nr^2 = constant (right panel, below). ***That is, the absence of absorption lines related to the wind is not expected due to the thermal equilibrium state of the gas predicted***. Possible options include:

1) Acceleration of the flow at the end of the soft state, producing a decrease in the plasma column density (Dyda et al. 2017)

2) The hot plasma has been exhausted during the soft state.



IGR J17091-3624

The BH LMXB IGR J17091-3624, exhibits a complex variability behavior, traced by the presence of quasi-periodic oscillations (QPOs) with low and high frequencies (Altamirano et al. 2011). A notable highly regular flaring heartbeat pattern was identified and there was a detection of an ultra fast outflow (UFO) during the outburst (King et al. 2012).

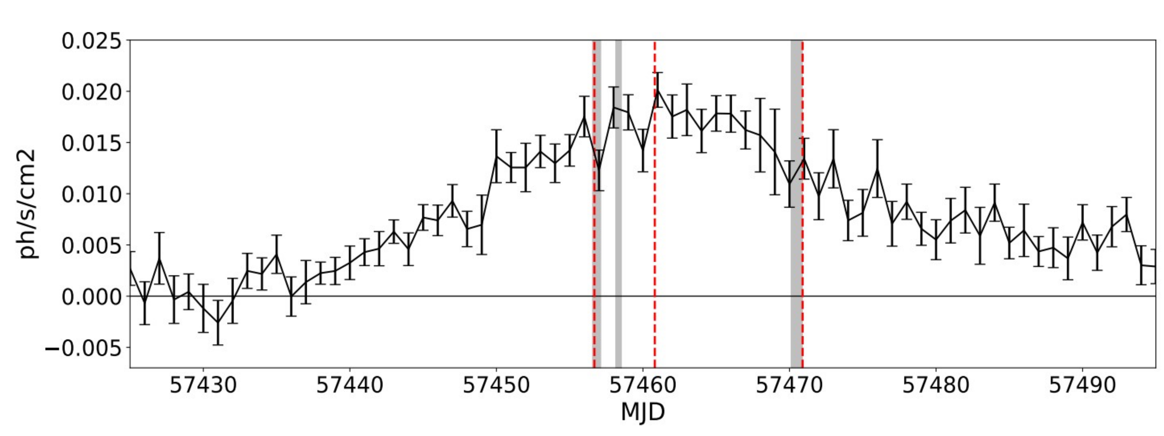
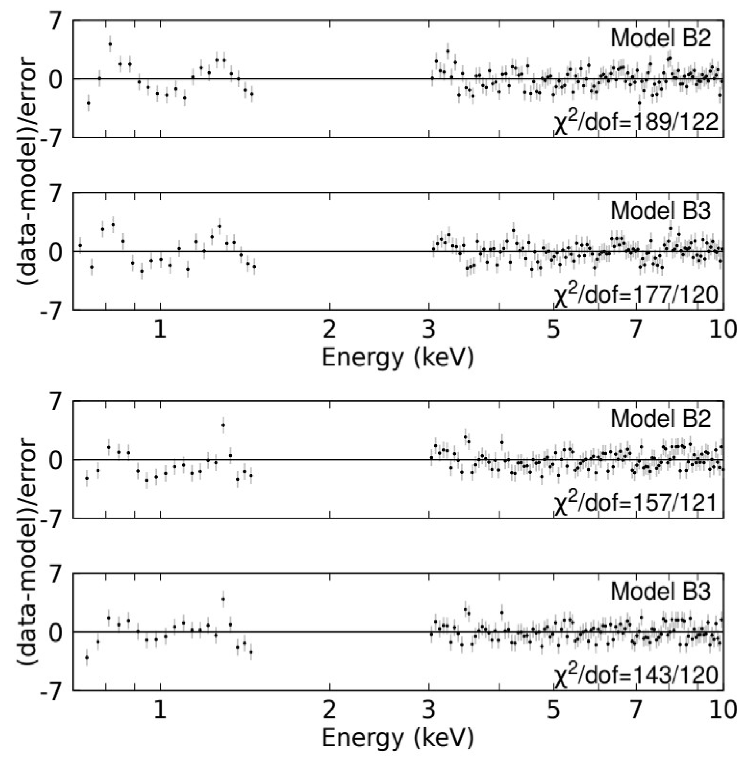


Figure shows the Swift/BAT daily average lightcurve of the LMXB IGR J17091-3624 in the 15–50 keV energy range. Shaded regions indicate the dates for the three XMM-newton observations analyzed in this work while vertical red lines indicate the dates for the ATCA observations.

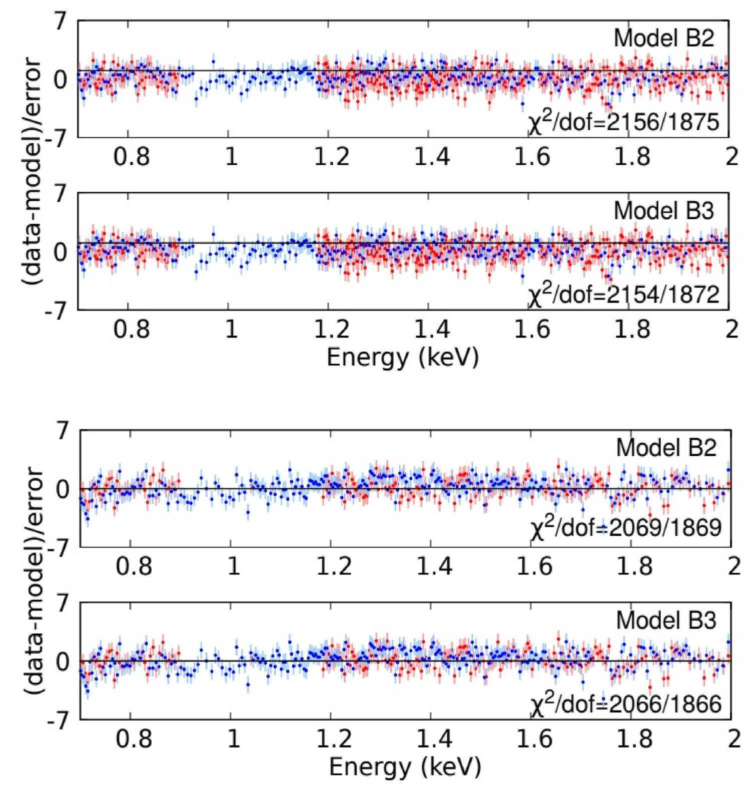
We fitted each observation with the following models, created hierarchically.

- Model A1: *tbabs*(powerlaw+diskbb+gauss)*
- Model B1: *tbabs*(nthcomp+diskbb+gauss)*
- Model A2: *IONeq*(powerlaw+diskbb+gauss)*
- Model B2: *IONeq*(nthcomp+diskbb+gauss)*
- Model A3: *IONeq*warmabs*(powerlaw+diskbb+gauss)*
- Model B3: *IONeq*warmabs*(nthcomp+diskbb+gauss)*

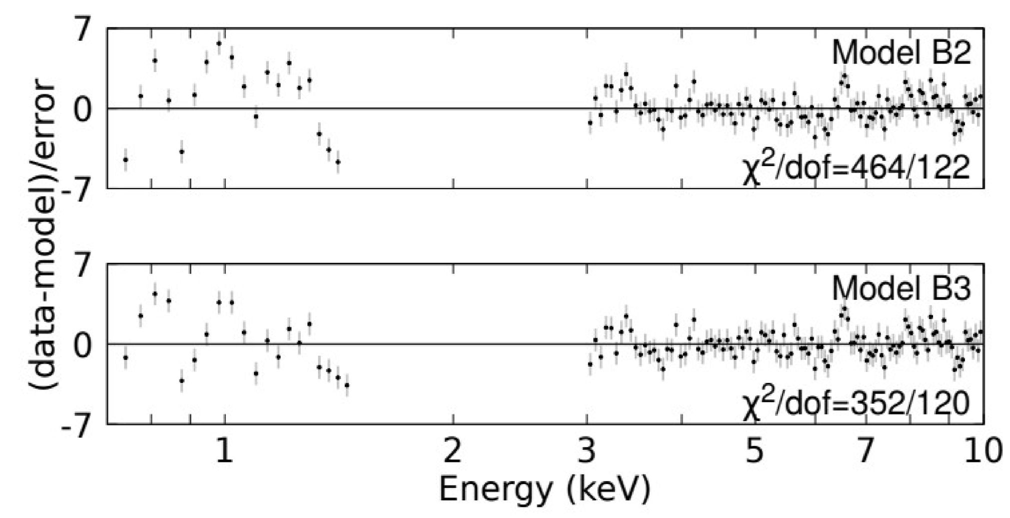
IONeq (Gatuzz & Churazov 2018) is an X-ray absorption model which assumes collisional ionization equilibrium and allows the modeling of absorption features due to the presence of multiple ISM phases

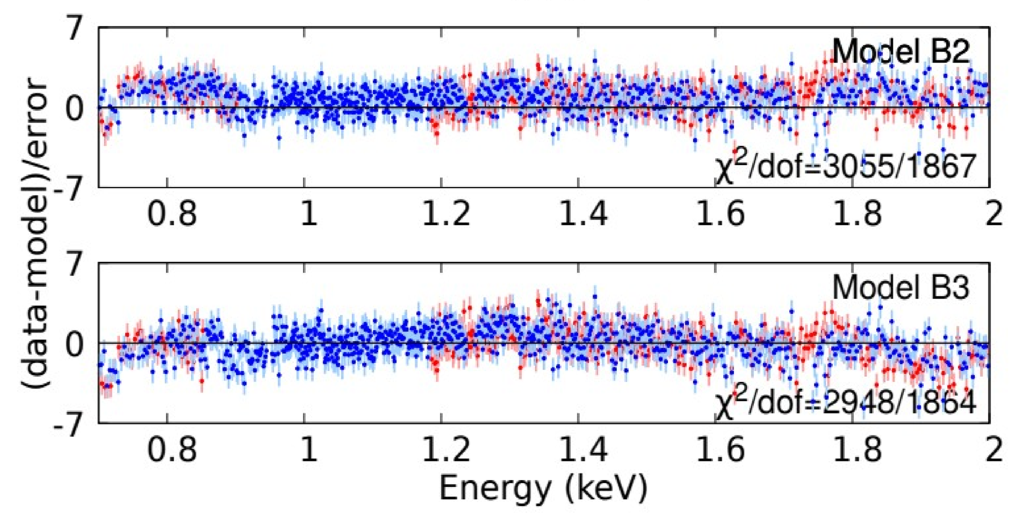


EPIC-pn spectra for observations 1 (top panel) and 2 (bottom panel). When including a photoionised absorber we have found a small improvement in the statistic of the fits, compared to a model that only includes absorption due to the ISM (i.e. model B3 vs. B2).

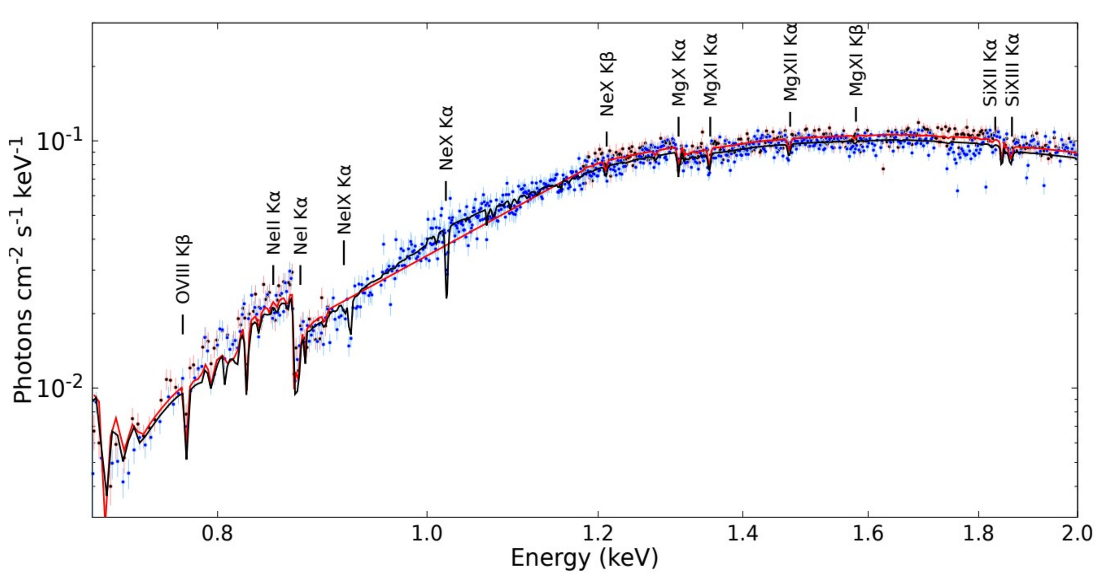


RGS spectra for observations 1 (top panel) and 2 (bottom panel). We found that the fits do not improve (i.e. the change in the statistic is negligible) when including a photionised absorber.





For Obs. 3 we have identified a local photoionised absorber with no significant blueshift in both EPIC-pn and RGS spectra (i.e. model B3 compared to model B2). It is important to note that we are able to distinguish between the photoionised component intrinsic to the source and the absorption associated to the local ISM.



This absorber, traced mainly by Ne X, Mg XII, Si XIII and Fe XVIII, is identified simultaneously with a compact jet and it could be a permanent structure or a precursor of an outflowing wind. Future X-ray observations of bright LMXBs, with high inclination and during hard accretion states, will help to better understand the origin of such plasma.

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