A test of truncation in the accretion discs of transient black hole X-ray binaries

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Abstract:

The truncated disc model is generally used to explain the differences between the observation properties of the soft and hard state in X-ray binaries. However there is still some disagreement on the extent of this truncation. In this study we will use the best observational data and current spectral models to test whether of not truncation is required for a number of transient low-mass X-ray binaries.

Introduction:

The outbursts of low-mass X-ray binaries show two main spectral states: soft and hard. The soft state, generally found at the peak of an outburst, shows a X-ray spectrum dominated by thermal emission originating from the accretion disc with a weak high energy tail. The hard state is dominated by non-thermal emission, possibly from scattering within a corona of hot electrons above the disc, along with a weaker thermal emission.

The existence of these two states is usually thought to be from a change in the geometry of the accreting region. In the soft state, there will be a disc down to the inner most stable orbit, whereas in the hard state, the disc will truncate and be replaced with a radiatively inefficient accretion flow.

We will test this by fitting a model of four components (absorption, power-law, thermal, and reflection), with the assumption that at all times the disc extends down to r_{ISCO} around a spin 0 black hole. We then attempt to fit this model to soft and hard state data, along with an independent fit of the absorption parameters, to evaluate the physicality of this model and whether or not relaxation of the assumptions is required for a reasonable fit.

Observations:

We have looked at a total of 57 XMM-Newton observations from a sample of low mass X-ray binaries. EPIC-pn and RGS data were reduced using the standard methods. Observations with very low count rates were excluded from the sample.

The two example sources shown here are GROJ1655-40 and SwiftJ1753.5-0127. GROJ1655 has a soft state observation (rev964), while SwiftJ1753.5 is in the hard state (rev1152).

RGS Analysis:

Using XSPEC we fit the RGS data in the 11-24Å range with the model ISMabs*(simpl*kerrbb). If the source had multiple observations then they were fit simultaneously. The free parameters were: H, O, OII, OIII, N, NII, NIII and Fe.

Below, in Fig1, the spectra for the two example sources are shown. Comparison of our H column densities with the values from Willingale et al. (2013) give an almost exact agreement for SwiftJ1753.5 (0.285×10^{22} cm^{-2}), while GROJ1655's is a little larger (0.928×10^{22} cm^{-2} vs. 0.722×10^{22} cm^{-2}).

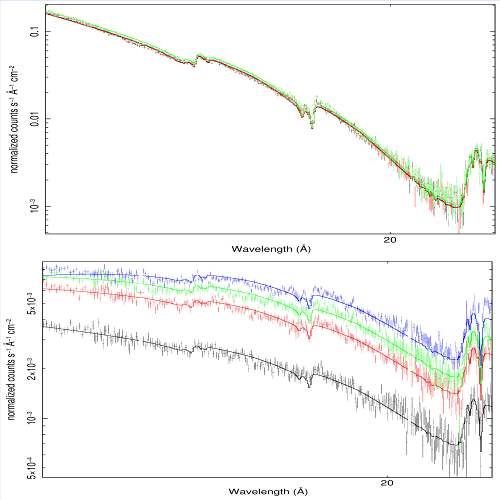

Fig1: RGS spectra for GROJ1655-40 (top) and SwiftJ1753.5-0127 (bottom), fitted with the model ISMabs*(simpl*kerrbb).

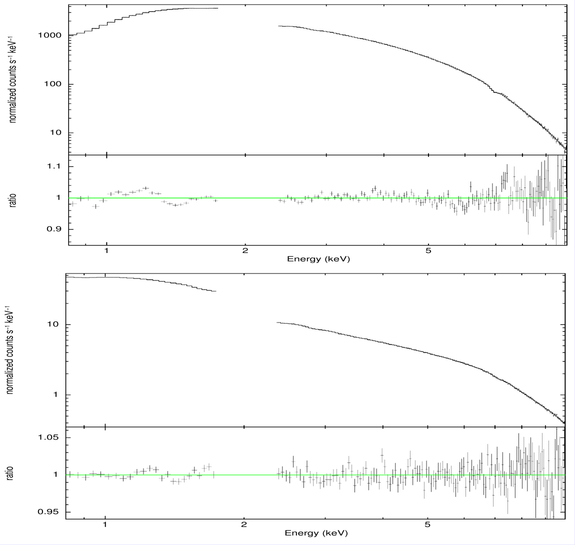

Fig2: EPIC-pn spectra for GROJ1655-40 (top) and SwiftJ1753.5-0127 (bottom), fitted with the model ISMabs*(simpl*kerrbb+relxill+ga).

EPIC-pn Analysis:

Using the RGS analysis to provide the absorption parameters we moved on to fitting the EPIC-pn spectra.

Data was fit between 0.8-10.0keV, with the 1.75-2.35keV region removed to avoid instrumental residuals.

We used the model ISMabs*(simpl*kerrbb+relxill+ga).

The free parameters were: the spectral index (Γ_{simpl}) and scattering fraction (f_{scat}) from simpl, mass accretion rate (mdot) and colour correction fraction (f_{col}) from kerrbb, and the spectral index (Γ_{rel}), log of the ionization parameter (logξ)and normalization (N_{rel}) from relxill.

The Gaussian is fit at around 7keV to account for the presence of a wind. The two spectral indexes are not tied together. For the brightest spectra simpl was very poorly constrained and removed from any further analysis.

The spin is fixed at 0, and the inner and outer disc radii are set to r_{ISCO} and $100r_g$ respectively. The iron abundance and reflection fraction of the disc are both fixed at 1.

The spectra and residuals are shown in Fig2.

We ran MCMC analysis for the fits with 100 walkers and 100000 steps, the results of which can be seen in Fig3.

It can be seen that an untruncated disc can produce a fit with physical parameters and few significant residuals.

The results for the remainder of the sources and a more comprehensive analysis can be found in Eckersall et al. (in prep).

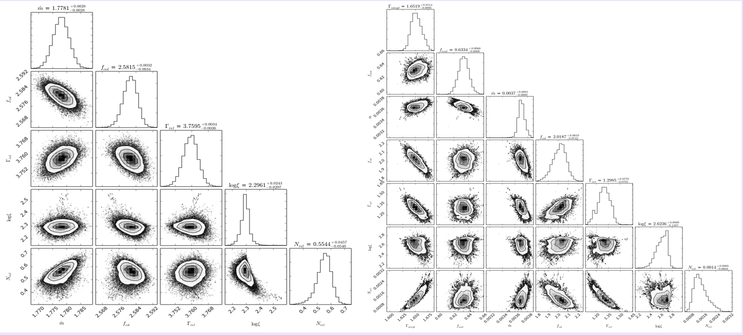

Fig3: Results of the MCMC analysis for GROJ1655-40 (left) and Swiftj1753.5-0127 (right). The parameter values and errors can be seen above the histograms.