Abstract. We have accumulated multiwavelength lightcurves for eight black hole X-ray binaries which have been observed to enter a supposed “soft X-ray transient” outburst, but which in fact remained in the low/hard state throughout the outburst. Comparison of the lightcurve morphologies, spectral behaviour, properties of the QPOs and the radio jet provides the first study of such objects as a subclass of X-ray transients (XRTs). However, rather than assuming that these hard state XRTs are different from “canonical” soft XRTs, we prefer to consider the possibility that a new analysis of both soft and hard state XRTs in a spectral context will provide a model capable of explaining the outburst mechanisms for the majority of black hole X-ray binaries.

1. Lightcurves

In the low/hard state (LHS) the X-ray spectrum is dominated by a power law component; this hard X-ray emission is thought to be produced in a Comptonizing corona. Corresponding X-ray power spectra for sources in the LHS show a high level of low frequency noise, a broken power law, and at least one quasi-periodic oscillation (QPO). The LHS is also characterized by a powerful, low intensity jet emitting synchrotron radiation in radio (and often higher) frequencies [1].

The X-ray lightcurves of the eight LHS XRTs we consider – V404 Cyg, A1524-62, 4U 1543-475, GRO J0422+32, GRO J1719-24, GRS 1737-31, GS 1354-64, and XTE J1118+480 – exhibit very different morphologies, and the canonical “FRED”-type lightcurve is not predominant. The optical lightcurves appear generally, although not consistently, correlated with the X-rays. Where radio coverage is available it appears that both the main outburst and secondary maxima of the X-ray lightcurves tend to be associated with radio ejections [1]. Despite the similarities in X-ray and broad-band spectral behaviour of these sources, the most notable feature of these lightcurves is their inconsistency.

2. The Low-Frequency QPO

The presence of a QPO in the power spectrum of XRTs is a common feature of the LHS, as well as the intermediate and very high states (I/VHS; [2]); however, the frequencies are lower in the LHS than in the I/VHS. In the four sources shown in Figure 1, the frequency of the LHS QPO is not constant but instead increases during the outburst. Formal cross-correlation of the QPOs with the X-ray flux does not produce a statistically significant correlation in any of these sources. In
addition, we find that the duration of the QPO frequency increase is a factor of 1.5-2 times the duration of the X-ray flux rise.

The mHz QPO of XRTs may relate to the inner edge of the accretion disc; if the softening during the outburst is due to the inner edge of the disc moving inwards we would expect the QPO frequency to increase, as observed. Alternatively, the QPO could be produced at a large radius within the disc, with its frequency inversely proportional to the disc mass. In this model, the rising QPO frequency is a signature of the accretion disc mass decreasing as it disappears into the black hole.

3. Broad-band Spectra and Jets

Nearly all black hole transients in the LHS show evidence for some form of jet behaviour. This jet is not purely a “radio jet”, as the synchrotron spectrum that is thought to be the jet signature is often seen up to IR and possibly optical frequencies. For XTE J1118+480, a synchrotron spectrum has been fit to the full range of frequencies up to the hard X-rays. For these LHS XRTs, a flat or inverted spectrum has already been well established in the radio. We compiled spectra from radio to X-rays for four sources at three different epochs (where possible) per source (Figure 2). Inspection of the resultant broad-band spectra show that despite the morphological differences between the outburst lightcurves, their spectral properties are similar; also, the spectra do not vary significantly between the various epochs. The spectra of these four XRTs are similar to that of XTE J1118+480; formal fitting of these broad-band spectra with a synchrotron spectrum is in progress. Although it is unclear whether synchrotron emission from the jet can be the dominant contributor to the broad-band spectrum, as suggested in the case of XTE J1118+480, what is clear is that the jet contribution should
not be ignored when modelling XRT outbursts, especially in the LHS.

4. Conclusions

For these LHS transient outbursts, we find the following characteristics:
- The X-ray and multi-wavelength lightcurves have very different morphologies. The relationships between the emission at various wavelengths likewise differs from source to source.
- A low frequency QPO is observed which increases in frequency during the outburst but is not directly correlated with the X-ray luminosity.
- The broad-band spectra of the LHS transients are very similar and do not vary substantially during different epochs.
- In addition to the radio signature of the jet, it may be possible to fit the broad-band spectra in the LHS with a synchrotron spectrum.

To model LHS outbursts, the Disc Instability Model (DIM) should be able to reproduce non-FRED lightcurves and also must consider the production of the power law hard X-ray emission from the corona. Models of LHS outbursts should include the jet, which is likely to be a much more significant contributor to the X-ray luminosity and broad-band emission than has been previously assumed. Finally, in recent “canonical” soft XRT outbursts (e.g. XTE J1859+226, XTE J1550-564) the sources have been observed to pass through the LHS on the rise from quiescence to the (V)HS. It is important that the power requirements of the initial LHS and its associated jet are incorporated into future attempts to model transient outbursts with the DIM, which has not been done to date.

References
1. Fender R.P., 2001, MNRAS, 322, 31.
2. Wijnands R. & van der Klis M., 1999, ApJ, 514, 939.
3. Revinitsky M.G., et al., 2000, ApJ, 530, 955.
4. Wood K.S., et al., 2001, ApJ, 563, 246.
5. Markoff S., et al., 2001, A&A, 368, 1021.