RXTE observations of the low/hard state X-ray outburst of the new X-ray transient SWIFT J1753.5−0127

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ABSTRACT

We present the results of the analysis of Rossi X-ray Timing Explorer (RXTE) observations of the new X-ray transient, SWIFT J1753.5−0127, during its outburst in 2005 July. The source was caught at the peak of the burst with a flux of $7.19 \times 10^{-9}$ erg s$^{-1}$ cm$^{-2}$ in the 3–25 keV energy range and observed until it decreased by about a factor of 10. The photon index of the power-law component, which is dominant during the entire outburst, decreases from $\sim 1.76$ to 1.6. However, towards the end of the observations the photon index is found to increase, indicating a softening of the spectra. The presence of an ultrasoft thermal component, during the bright phases of the burst, is clear from the fits to the data. The temperature associated with this thermal component is 0.4 keV. We believe that this thermal component could be due to the presence of an accretion disc. Assuming a distance of 8.5 kpc, $L_X/L_{Edd} \simeq 0.05$ at the peak of the burst, for a black hole of mass $10 M_\odot$. The source is found to be locked in the low/hard state during the entire outburst and likely falls in the category of the X-ray transients that are observed in the low/hard state throughout the outburst. We discuss the physical scenario of the low/hard state outburst for this source.

Key words: accretion, accretion discs – instabilities – stars: variables: other – X-rays: binaries – X-rays: individual: SWIFT J1753.5−0127.

1 INTRODUCTION

Black hole candidates are known to undergo spectral state transitions between the different canonical states they enter during an outburst (Homan & Belloni 2005; Remillard & McClintock 2006). There is a subclass of X-ray transients, the Low/hard State X-ray Transients (LHXTs), that undergo outbursts which are entirely in the low/hard state throughout the burst (Brocksopp, Bandyopadhyay & Fender 2004). The accretion process during the low/hard state of the X-ray transients is still not well understood and requires an extensive study, for which this subclass of X-ray transients showing LHXT outbursts seems promising candidates.

The hard X-ray source SWIFT J1753.5−0127 was first detected by the Burst Alert Telescope (BAT) experiment on Swift satellite at RA (J2000) = 17h53m28s and Dec. (J2000) = −01°27′09″.3 on 2005 June 30 (Palmer et al. 2005). It was also observed by Swift X-ray Telescope (XRT) on 2005 July 1 and was found to be extremely bright (Burrows et al. 2005). The observations by Swift Ultra-Violet/Optical Telescope (UVOT) do not indicate any temporal variability on 10–1000 s time-scale and the spectral fits to the ultraviolet spectra give a lower limit for the temperature of the accretion disc as $116 000 K$ (Still et al. 2005). Optical observations on 2005 July 2 reveal the existence of a bright optical counterpart with $R \sim 15.8$, which was not visible on the Sloan Digital Sky Survey (SDSS) (Halpern 2005). Spectroscopic studies from the optical observations of the source on 2005 July 3 show a blue continuum with a broad, double-peaked H$\alpha$ emission line with an equivalent width of $\sim 3 \AA$ and full width at half-maximum (FWHM) $\sim 2000$ km s$^{-1}$ (Torres et al. 2005a). Simultaneous optical and infrared monitoring of the source done on 2005 July 11 show the presence of an infrared point source at the position of the optical counterpart (Torres et al. 2005b). Coordinated optical and X-ray observations to study the correlated variability in the two bands show that the high-frequency noise correlates well with the X-ray variations, whereas the low-frequency component is absent in the X-ray data (Hynes & Mullally 2005). Radio observations on 2005 July 3 measured a flux density of $2.1 \pm 0.2$ mJy at 1.7 GHz. Further radio observations on 2005 July 4 and 5 indicate the variability of the source. The radio source is found to be extended on angular scales not greater than 350 mas (Fender, Garrington & Muxlow 2005). This could imply the presence of a jet, which is associated with the low/hard state of black hole candidates. However, this source does not follow the usual radio/X-ray correlation of X-ray binaries in the low/hard state (Cadolle Bel et al. 2006). INTEGRAL observations of the source from 2005 August 10 to 12 indicate the spectrum to be typical of that of a Black Hole Candidate (BHC) in the hard state (Cadolle Bel et al. 2005, 2006). The Power Density Spectrum (PDS) of the Rossi X-ray Timing Explorer-Proportional Counter Array (RXTE)-PCA observations of the source shows a 0.6 Hz Quasi-periodic Oscillator
The observations of the source by the ASM of RXTE and XMM–Newton observations of this source on 2006 March 24, near the quiescent state of this source, by Miller, Homan & Miniutti (2006a) show the presence of an accretion disc in the low/hard state of this source.

2 OBSERVATIONS AND DATA ANALYSIS

We have analysed 58 Target of Opportunity (TOO) observations by RXTE (Bradt, Rothschild & Swank 1993), which span about 146 d of the outburst amounting to about 150 ks of data. The observations were made from 2005 July 6 to 2005 November 28. We have analysed the data from the observations of All Sky Monitor (ASM), PCA and the HEXTE instruments on RXTE. The details of the light curve and the spectral analysis of the outburst are given in the following sections.

2.1 ASM-PCA Light Curve Analysis

The observations of the source by the ASM of RXTE (Levine et al. 1996) date from 2005 July 1 to 2005 November 28. The light curve from the 1-d averaged data of ASM is shown in Fig. 1. The profile of the light curve is a typical Fast Rise Exponential Decay (FRED). The peak of the ASM light curve of the burst corresponds to 200 mCrab. The unabsorbed PCA flux in the 3–25 keV corresponding to the peak of the burst on 2005 July 6 (MJD 53557) is 7.19e−10 erg s⁻¹ cm⁻², which corresponds to \( L_x/L_{edd} \approx 0.05 \) (d/8.5 kpc)² (M/10 M⊙). The rise time of the light curve is found to be 8 d. An exponential fit to the light curve gives an e-folding time of ~30 d. The e-folding time derived from the PCA light curve (31 d) for the energy range 3–25 keV matches with that of the ASM light curve and the light curve is found to deviate from the exponential decay after ~50 d from the peak of the outburst. The bottom panel of Fig. 1 shows the hardness ratio (HR), the ratio between the count rates in the energy bands (5–12) and (3–5) keV. The HR is calculated from the 3-d averaged count rate in the two different bands so that the evolution of it can be seen clearly. This HR is \( \sim 1.0 \) at the start of the burst, increases to \( \sim 1.5 \) and remains >1.0 throughout the burst, which indicates that the source has not entered the high/soft state throughout the burst.

2.2 PCA and HEXTE data: Spectral analysis

We have extracted the PCA energy spectra from the standard-2 data which have an intrinsic resolution of 16 s. We have used the

(QPO) with a shape typically seen in BHCs (Morgan et al. 2005). Simultaneous RXTE and XMM–Newton observations of this source on 2006 March 24, near the quiescent state of this source, by Miller, Homan & Miniutti (2006a) show the presence of an accretion disc in the low/hard state of this source.

![Figure 2](https://example.com/figure2.png)

**Figure 2.** The spectrum from PCA data for one observation (Obs ID: 91423-01-01-04) fitted with a simple power-law component is shown here. The residuals are shown in the bottom panel, in units of sigma.

Proportional Counter Unit 2 (PCU2) detector data for the spectral analysis. A systematic error of 1 per cent is accounted for in the data. The spectra are extracted using FTOOLS V6.0. The background is estimated using PCABACKEST V4.0 and subtracted from the data. PCA response matrices are generated using PCARESP V10.1. We have extracted the HEXTE spectra from one of the clusters of the instrument, Cluster A. We have used the standard mode data, for which the spectral bins are in 64 channels with 16-s time bin. For the fits to the combined data in the energy range 3–180 keV, we have considered the data from PCA in the energy range 3–20 keV and that from HEXTE in the range 20–180 keV. In order to account for the uncertainties in the relative calibration of the PCA and HEXTE instruments, the normalization factor for the PCA data is frozen to 1 and that of the HEXTE data are allowed free for the fits to the combined data from both these instruments. The \( n_H \) value of the column density for interstellar absorption is fixed at \( 2.3 \times 10^{21} \) atoms cm⁻² (Miller et al. 2006a) for all the fits.

First, we have used the energy spectra from the PCA data in the energy range 3–25 keV for the fits with a simple power law. One such fit for the observation during the peak of the burst is shown in the top panel of Fig. 2, for which the photon index is found to be 1.83 as shown in Table 1. However, the fits to the data with just a simple power law show large residuals at lower energies. This can be seen in the bottom panel of Fig. 2. To account for the residuals at the lower energies, we have added a thermal component in the model. We have tried different models for it, like the multicolour disc blackbody (DISKBB in XSPEC), the blackbody component (BBODY in XSPEC) as well as the blackbody component corresponding to the boundary layer emission of a neutron star (BBODYRAD in XSPEC). The fits with these different models for the thermal component do not show a substantial difference. We decided to fit the thermal component with a DISKBB because the radius of the surface of emission at the peak of the burst as estimated using BBODYRAD is \( \sim 100 \) km for a distance of 8 kpc, which is unrealistic for a neutron star. After the inclusion of the thermal component, substantial residuals are still present around 7 keV. This is an indication of the presence of an Fe-emission line but not the absorption feature completely. However, on the addition of the smeared edge (SMEEDGE) component ["SMEEDGE" in XSPEC (Ebisawa et al. 1994), which accounts for the absorption feature], the emission feature also disappears and the fits are found to improve substantially. From the reduced chi-square value and the
ponent is found to be at ∼7 keV and this does not vary throughout the burst. The power-law component is the dominating factor in the spectra. The thermal component though necessary for the fit at low energies contributes less than 2 per cent to the total flux in the 3–25 keV range. The inclusion of the thermal component and the high-energy cut-off is required for the first 35 d of the observations, after which only the power-law component and the SMEDGE component are required. 80 days after the peak of the burst, the SMEDGE component also becomes insignificant. The data sets after this are therefore fitted with a simple power law and the absorption parameter. 

In order to explain the underlying physics, we have fitted the data with the Comptonization model (COMPTT in XSPEC) (Titarchuk et al. 1994), which describes the Comptonization of the soft seed photons from the disc by the hot plasma. Though the uncertainties on the parameters are large, the fits to the complete set of observations indicate an average temperature of the hot corona to be ∼40 keV and the optical depth of ∼1.4. In spite of the caveats of the large errors, the average value of the temperature of the seed photons from the accretion disc derived from this model, which is ∼0.4 keV, matches the temperature of the accretion disc derived from the fits mentioned above. The fit parameters for the different models are given in Table 1.

### 2.3 PCA data: Timing analysis

Timing analysis is done using the event mode PCA data which has a time resolution of 125 µs. The PDS is generated for each observation using FTOOLS. The power spectra are normalized such that their integral gives the squared rms fractional variability [(rms)**2 Hz**-1], with the expected white noise level subtracted. The PDS thus obtained are fitted with a sum of the Lorentzians. The PDS obtained from the PCA data during the peak of the burst is shown in Fig. 4. A prominent low-frequency QPO (LFQPO) at 0.891 ± 0.008 Hz with a Q-factor of 4 and an amplitude of ∼0.06 is observed. There are no kHz QPOs found in the PDS. The peaked noise and the band-limited noise are fitted with the other Lorentzians. The total rms power of the PDS is found to be 23 per cent at the peak of the outburst. In order to determine the energy dependence of the LFQPO, we generated the PDS for different energy bands. We find that the QPO is

![Figure 3](https://academic.oup.com/mnras/article-abstract/378/1/182/1155030/figure3)

**Figure 3.** The spectrum from PCA and HEXTE data, for the observation (Obs ID: 91423-01-01-04) shown in Fig. 2, fitted with a combined model of simple power law, a smeared edge (SMEDGE), high-energy cut-off and diskbb components are shown here. The residuals in the bottom panel are in units of sigma.

![Figure 4](https://academic.oup.com/mnras/article-abstract/378/1/182/1155030/figure4)

**Figure 4.** Power density spectrum showing the LFQPO, for the observation (Obs ID: 91423-01-01-04) at the peak of the burst.

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### Table 1. Table showing the fit parameters and the reduced chi-square for the fits to the PCA and HEXTE data for the observation (Obs ID: 91423-01-01-04) during the peak of the burst.

| Model                  | PL    | PL*T desteği | PL*SMEDGE | PL*SMEDGE*HEcut | COMPTT*SMEDGE+DISKBB |
|------------------------|-------|--------------|-----------|-----------------|----------------------|
| **Fits for PCA (3–25 keV) data** |       |              |           |                 |                      |
| $T_{in}$ (keV)         | 1.831 | 1.744        | 1.78 ± 0.006 | 1.76 ± 0.12     |                      |
| $E_{cut}$ (keV)        |       |              | 1.096     | 0.42 ± 0.086    | 38.2 ± 9.8          |
| $T_{0}$ (keV)          |       |              |           | 0.43 ± 0.04     | 6.6 ± 0.13           |
| $KT_{e}$ (keV)         |       |              |           |                 | 44.6 ± 8.7           |
| $\tau$                |       |              |           |                 | 1.08 ± 0.23          |
| Reduced chi-square     |       |              |           |                 | 1.3                  |

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Explanations for the abbreviations in the table are as follows:

- **PL** – power law
- **HEcut** – high-energy cut-off
- **PI** – photon index of the power law
- **$T_{in}$** – temperature of the disc
- **$T_{0}$** – temperature of the disc which is the source of the seed photons
- **$KT_{e}$** – temperature of the plasma
- **$\tau$** – optical depth of the plasma

**Figure 3.** The spectrum from PCA and HEXTE data, for the observation (Obs ID: 91423-01-01-04) shown in Fig. 2, fitted with a combined model of simple power law, a smeared edge (SMEDGE), high-energy cut-off and diskbb components are shown here. The residuals in the bottom panel are in units of sigma.
prominent in all the data sets in the energy range of 3–15 keV. Its presence at higher energies is evident only in few data sets.

### 2.4 Evolution of parameters

We have plotted different parameters and the observed flux as a function of MJD in Fig. 5. This figure shows the time evolution of various parameters like the PCA count rate (in the energy range 3–25 keV), the photon index, the HR [the ratio of the PCA count rate in the energy bands from (8.6–18.0) to (5.0–8.6) keV, as defined by Muno, Remillard & Chakrabarty 2002; Remillard & McClintock 2006], the LFQPO and the rms amplitude of the power density spectrum in the frequency range from 0.1 to 10 Hz. It may be noted that the entire set of data available is from the peak to the decay of the burst.

The power-law component is dominant throughout the decay of the burst. The photon index is found to be 1.76 at the peak of the burst and decreases up to 1.70 within a day although the flux decrease observed is within the level of 1σ. After this abrupt decrease, the photon index of the power law further decreases almost linearly from 1.7 to 1.6 within a span of 30–35 d. Later, the photon index hovers around 1.61 till about 90 d, after which there is a slow trend of increase seen towards the end of the observations. The HR is also found to indicate a similar behaviour, with HR showing an abrupt increase from 0.81 to 0.85 within a day followed by an almost linear increase from 0.85 to 0.92 within 30–35 d and then levelling off at 0.92 till 90 d. The tendency for HR to decrease gradually after 90 d up to the end of the burst is also similar to the photon index. The spectral softening observed after 90 d is very gradual with time and continues till the end of the observations. This behaviour of spectral softening is observed in a few other sources like XTE J1550−564 (Belloni et al. 2002; Sturmer et al. 2005).

The centroid frequency of the QPO is found to be 0.891 Hz at the peak of the outburst and is found to decrease abruptly to 0.66 Hz within a day and then it decreases almost linearly from 0.66 to 0.2 Hz within a span of about 35 d. Later, the QPO is visible only intermittently at lower values of about 0.2 Hz and is observed only till 70 d, after which it is not detectable. The rms power of the PDS (0.1 to 10.0 Hz), however, exhibits a more uniform trend with a slow decrease from 23 to 15 per cent till the end of the burst. This trend is also seen if the frequency range of the PDS is extended down to 0.01 Hz.

In order to study the variation of these parameters as a function of flux, we plot the same in Fig. 6. It may be noted that since the observations cover the decay portion of the burst, the time line in this figure goes from right- to the left-hand side. The softening of the spectra at low flux levels (towards the end of the burst) can be clearly seen in the top two panels of Fig. 6, which shows the photon index and the HR as a function of PCA flux. The QPO frequency follows a linear trend as a function of flux, which is seen in the third panel. The rms power of the PDS shows an abrupt decrease at low flux levels as shown in the bottom panel of the figure. The time evolution of the disc parameters, like the temperature of the disc, the inner radius of the disc, etc., is difficult to comment upon as the uncertainties on these parameters are large. The high-energy cut-off is found to be about 40 keV on an average and a straight line fit to the values during the entire outburst does not show any systematic change during the decay.
3 DISCUSSIONS

3.1 On the nature of the source

The fits to the XMM–Newton data by Miller et al. (2006a) give an \( q_{\text{in}} \) of \( \sim 2.3 \times 10^4 \) atoms cm\(^{-2} \), which is a nominal value for Galactic interstellar absorption. The optical observations (Halpern 2005) of the source reveal the presence of a bright optical counterpart with \( R \sim 15.8 \) mag indicating the system to be a low-mass X-ray binary (LMXB), with a reddened companion star. The spectral analysis of the source indicating the hard spectrum with a power-law dominance and the timing analysis of the data indicating the presence of LFQPOs at \(< 1 \) Hz are typical features observed in BHCs. There are no kHz QPOs found in the power spectrum. Fig. 4 shows the LFQPO at \( \sim 0.891 \) Hz. All the above points indicate that this source could be a galactic LMXB with a stellar mass black hole as the compact object more likely than a neutron star.

In addition, the fits to the thermal component in the spectra with a blackbody component (‘BBODYRAD’ in XSPEC) for a normalized surface area, corresponding to the boundary layer of a neutron star, gives an estimate of the radius of the compact object \( \sim 100 \) km, for a typical distance of 8 kpc, at the peak of the burst and is found to be \( > 20 \) km till the end of the outburst. From this, it can be surmised that the probability for the compact object being a neutron star is almost negligible.

3.2 On the spectra and the underlying physics of the burst

The low/hard spectral state of BHCs is typified with a dominant power-law component, contributing \( > 80 \) per cent of the total flux in 2–20 keV range, having a spectral index between 1.4 and 2.1. The total rms power (\( r \)), in the power density spectrum, integrated over the frequency range 0.1–10 Hz is strong with \( r > 0.1 \) (Remillard & McClintock 2006).

We find that for SWIFT J1753.5–0127, the power-law component dominates the spectra throughout the burst with the spectral index decreasing from 1.76 to 1.6. Further, the thermal component, though present during the bright phases of the outburst, contributes only \( < 2 \) per cent of the total flux in the 3–25 keV energy range. This, along with the presence of LFQPOs \(< 1 \) Hz and the rms power in the frequency range 0.1–10 Hz being \( > 10 \) per cent (shown in Fig. 5), clearly indicates that the source is locked in the low/hard state throughout the outburst and never made it to the high/soft state.

In all the LHXT outbursts observed till date, the presence of a hot accretion disc component in spectra of the 3–25 keV energy range is not reported. We find a DISKBB component at 0.4 keV in addition to the presence of a SMEDGE component, which is usually attributed to be the disc reflection component. The inner radius of the disc (estimated from the normalization factor of DISKBB component) turns out to be \( < 4 R_g \) for a black hole of mass 10 M\(_{\odot} \). We find that the contribution of the disc component is seen only till 35 d and the SMEDGE component is seen till 80 d after the peak of the outburst.

We suppose that the reason for the lack of a thermal component in the later part of the burst in the 3–25 keV range is due to the reduced sensitivity of the RXTE-PCA instrument at energies below 3 keV and that the accretion disc continues to exist even towards the end of the burst. The presence of the accretion disc during the low/hard state approaching quiescence for this source, SWIFT J1753.5–0127, was strongly suggested by Miller et al. (2006a), with simultaneous RXTE and XMM–Newton observations, after about 118 d from the last observation of the outburst discussed in this paper. The fits to the XMM–Newton data by Miller et al. (2006a) imply the presence of an accretion disc extending near to the inner stable circular orbit with an \( R_{\text{in}} \leq 6 R_g \) for a black hole of mass 10 M\(_{\odot} \). All these provide the evidence for the presence of the inner accretion disc in a low/hard state X-ray outburst.

Fits to all the RXTE data sets of the outburst of the source, SWIFT J1753.5–0127, show that the spectrum is, however, dominated by the power-law component, which can be described by the inverse Comptonization of seed photons from the accretion disc by a hot plasma near the central compact object. This picture is supported by modelling the data using the Comptonization model (COMPTT in XSPEC), the results of which show an accretion disc of temperature \( \sim 0.4 \) keV and a hot corona of temperature \( \sim 40 \) keV with an optical depth \( \sim 1.4 \). This Comptonization region could be a corona, a Compton cloud or a post-shock region as referred in the literature.

The LFQPOs less than 1 Hz are observed up to about 35 d. The QPOs seen in the PDS of all the observations are found to be from the photons predominantly in the energy range 3–15 keV. Since there is a contribution from the photons at high energies, it appears that the QPOs have both a thermal and a non-thermal component. Simple Keplerian inflow of matter predicts higher frequencies for a 10 M\(_{\odot} \) black hole. The centroid frequency decreases with time and appears to be linearly correlated with the flux (Fig. 6). This correlation does not favour the global normal disc oscillation model (Titarchuk & Fiorito 2004) for the origin of QPOs in this source, as also indicated by Zhang et al. (2007). The trend of photon index and QPO correlation as seen in Fig. 7 is similar to that predicted by the transition layer (TL) model of Titarchuk & Fiorito (2004). The optical depth (\( \tau \)) of the transition layer is estimated to be \( \sim 1.8 \) from fig. 6 in Titarchuk & Fiorito (2004) for a photon index of 1.7. This is comparable to the value of 1.4 for the optical depth of the corona derived from the COMPTT model as applied to these observations.

Using fig. 4 in Titarchuk & Fiorito (2004), which relates LFQPO frequency to the outer radius of the transition layer, the 0.9 to 0.7 QPO frequency decrease observed in our data corresponds to 20 to 30 \( R_g \), which translates to 600–750 km for a 10 M\(_{\odot} \) black hole. This size of TL is, however, much larger than the estimated \( R_{\text{in}} \) from the DISKBB model which is of the order of 100 km. Therefore, the current observations can match the size of the transition layer only if the QPO-versus-TL size relationship can be proportionally reduced for a lower mass black hole of the order of 3 M\(_{\odot} \) black hole. However, we hasten to add that although the range of spectral index predicted by the transition layer theory for low/hard state (\( \Gamma = 1.6 \pm 0.2 \)) applies to our observations, the observed dependence of spectral index on flux is not predicted by the model. In addition, this model predicts that the low- and high-frequency QPOs are correlated. We do not observe any high-frequency QPO for this source.

![Figure 7. Photon index as a function of LFQPO.](https://academic.oup.com/mnras/article-abstract/378/1/182/1155030/3781821155030)
3.3 On the light curve of the burst

The profile of the light curve of this source, SWIFT J1753.5−0127, is of a FRED type. The e-folding time of the light curve is \( \sim 31 \) d which is a nominal value found in X-ray novae outbursts. The FRED-type light curves of the X-ray outbursts are supposed to be originating due to the instabilities in accretion disc (Chen, Shrader & Livio 1997). This can be explained either by the Disc Instability Model (DIM) (Lasota 2001) or by the disc diffusion propagation model (Wood et al. 2001). The correlation of QPO frequency with source flux as seen in Fig. 6 does not favour the disc diffusion propagation model (Wood et al. 2001).

Since the profile of the light curve is a FRED, which is associated with the disc, it can be considered that the outburst could have been triggered due to some instability in the disc. It may be noted that the e-folding decay time of this outburst (31 d) is also associated with similar time-scales on which several spectral parameters show a change in behaviour indicating a strong correlation between the spectral and light-curve characteristics. The disc probably starts receding with the abrupt decrease in the spectral index within a day, and by the end of 35 d, it cools to the extent that it is not detectable in the 3–25 keV region. This change is indicated by the increase in hardness and decrease in the QPO frequency within a day of the outburst.

A similar FRED profile has been seen in the 40–150 keV light curve of GRO J0422+32 during its 1992 low/hard state X-ray outburst detected by Burst And Transient Source Experiment on Compton Gamma Ray Observatory (BATSE on CGRO) (Van der Hooft et al. 1999). Since there was no soft X-ray coverage during the early stages of the burst, it could not be proved that an ultrasoft disc component existed or not (Petitsch et al. 1993).

The light curves of most of the X-ray outbursts in the low/hard state of the sources observed in the 2–10 keV energy range are found to be of triangular shape with or without a plateau. None of these outbursts is found to be reported with an ultrasoft component associated with an accretion disc in their spectra. However, the presence of a cool outer disc can be found implicitly from the reflection components in the spectra. Whether a common instability model with difference in parameters can explain both the FRED profile and the triangular profile for low/hard X-ray outbursts is still an open question.

3.4 On the possible explanations for a low/hard state X-ray outburst

While Brocksopp et al. (2004) try to look for a possibility of explaining the behaviour of these LHXTs as part of the outburst mechanisms associated with other canonical soft X-ray transients (SXTs), Meyer-Hofmeister (2004) gives an explanation in terms of short orbital periods, which result in less mass accumulation in a smaller accretion disc giving rise to relatively low peak luminosities during the outbursts.

It is stated (Meyer-Hofmeister 2004) that for low peak luminosities, i.e. low-mass flow rate in the disc, coronal evaporation truncates the thin disc even in the outburst and an advection-dominated accretion flow (ADAF) occurs resulting in a spectrum that remains hard. Also the evaporation efficiency is stated to be proportional to the mass of the compact object and larger the mass, larger is the truncation radius of the inner disc (Meyer-Hofmeister 2004). The behaviour of SWIFT J1753.5−0127 can also be explained by the ADAF model, if the compact object is a less massive black hole, resulting in lesser evaporation efficiency allowing the disc to extend near the inner stable circular orbit accounting for the thermal component, while having a contribution of evaporation of the disc to give rise to the overwhelming hard state of the outburst. We also see a softening towards the end of the burst which is seen in Fig. 5 and more clearly in Fig. 6. Spectral softening at low luminosities is predicted by the ADAF model (Esin, McClintock & Narayan 1997). This could imply that it is possibly an ADAF which is being observed at the low flux levels of the burst approaching quiescence.

There are some sources which have been observed only in low/hard state outbursts. They are GRO J0422+32 (Van der Hooft et al. 1999), GRS 1716−249 (Hjellming & Rupen 1996), GS 2023+338, 1E1747.0−2942 and GR 1578−258, amongst which the last two have been reported to be persistent sources (Cui et al. 1997; Grebenev, Pavlinsky & Sunyaev 1997). The reason for a source to show low/hard state X-ray outbursts only and not having any canonical outbursts could have something to do with the orbital parameters of the system as such. Such systems can be classified as LHXTs, as mentioned by Brocksopp et al. (2004). There are also sources, which have had state transitions in canonical outbursts, at times showing low/hard state outbursts. A few of them are XTE J1118+480, XTE J1550−564, GX 339−4, Cyg X-1, etc. The low/hard state X-ray outbursts shown by these sources can be classified as ‘failed outbursts’ in the canonical SXTs, which could be due to low mass accretion rate or due to discrete accretion events.

While there are many models to explain the varied outbursts from different sources, whether a common model will be able to explain all these different natures of the outbursts or not is still an open question.

3.5 Conclusions

Spectral and timing analysis of RXTE observations of the source, SWIFT J1753.5−0127, show that the source was in the low/hard state throughout the outburst. The physical picture of the burst is explained by the Comptonization of the seed photons by the hot corona near the compact object. The FRED profile of the light curve, usually uncommon in low/hard X-ray outbursts, and the presence of a multicolour blackbody component in the fits to the spectra imply a likely association of the burst with the instabilities in the accretion disc. The LFQPOs <1 Hz and the rms power between 10 and 30 per cent, along with the spectral behaviour of the source with an optical counterpart of magnitude \( R \sim 15.8 \), indicate this source to be a LMXB with a stellar mass black hole, most likely, as the compact object. Thereby, this source falls in the category of SXTs that show low/hard state X-ray outbursts.

The QPO frequency observed during the first 35 d after the peak of outburst is almost linearly correlated with the flux and the photon index. During the same period, a spectral hardening and diminishing contribution of disc are also found. These factors rule out some of the current models for outbursts. There is also a softening of spectrum seen towards the end of the burst, accompanied with very small change in source flux. While the transition layer model and the ADAF model can explain some of the observed features, both the models indicate that the compact object in this system is most probably a low-mass black hole.

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REFERENCES

Belloni T., Colombo A. P., Homan J., Campana S., Van der Klis M., 2002, A&A, 390, 199
Bradt H. V., Rothschild R. E., Swank J. H., 1993, A&AS, 97, 355
Brocksopp C., Bandyopadhyay R. M., Fender R. P., 2004, New Astron., 9, 249
Burrows D. N., Racusin J., Morris D. C., Roming P., Chester M., La Verghetta R., Markwardt C. B., Barthelmy S. D., 2005, The Astronomer’s Telegram, 547
Cadolle Bel M., Rodriguez J., Goldwurm A., Goldoni P., Laurent P., Ubertini P., Mereghetti S., 2005, The Astronomer’s Telegram, 574
Cadolle Bel M. et al., 2007, ApJ, in press (astro-ph/0612575)
Chen W., Shrader C. R., Livio M., 1997, ApJ, 491, 312
Cui W., Heindi W. A., Swank J. H., Smith D. M., Morgan E. H., Remillard R., Marshall F. E., 1997, ApJ, 487, L73
Ebisawa K. et al., 1994, PASJ, 46, 375
Esin A. A., McClintock J. E., Narayan R., 1997, ApJ, 489, 865
Fender R., Garrington S., Muxlow T., 2005, The Astronomer’s Telegram, 558
Grebenev S. A., Pavlinsky M. N., Sunyaev R. A., 1997, Proceedings of 2nd INTEGRAL Workshop, ‘The Transparent Universe’, St. Malo, France, 1996, ESA SP-382 (March 1997)
Halpern J. P., 2005, The Astronomer’s Telegram, 549
Hjellming R. M., Rupen M. P., Shrader C. R., Campbell-Wilson D., Hunstead R. W., McKay D. J., 1996, ApJ, 470, L105
Homan J., Belloni T., 2005, Ap&SS, 300, 107
Hynes R. I., Mullally F., 2005, The Astronomer’s Telegram, 562
Lasota J.-P., 2001, New Astron. Rev., 45, 449
Levine A. M., Bradt H., Cui W., Jernigan J. G., Morgan E. H., 1996, ApJ, 469, L33
Meyer-Hofmeister E., 2004, A&A, 423, 321
Miller J. M., Homan J., Miniutti G., 2006, ApJ, 652, L113
Morgan E., Swank J., Markwardt C., Gehrels N., 2005, The Astronomer’s Telegram, 550
Muno M. P., Remillard R. A., Chakrabarty D., 2002, ApJ, 568, L35
Palmer D. M., Barthelmy S. D., Cummings J. R., Gehrels N., Krimm H. A., Markwardt C. B., Sakamoto T., Tueller J., 2005, The Astronomer’s Telegram, 546
Pietsch W., Haberl F., Gehrels N., Petre R., 1993, A&A, 273, L11
Remillard R., McClintock J. E., 2006, ARA&A, 44, 49
Still M., Roming P., Brocksopp C., Markwardt C. B., 2005, The Astronomer’s Telegram, 553
Sturmer S. J., Shrader C. R., 2005, ApJ, 625, 923
Titarchuk L., 1994, ApJ, 434, 570
Titarchuk L., Osherovich V., 2000, ApJ, 542, 111
Titarchuk L., Fiorito, 2004, ApJ, 612, 988
Torres M. A. P. et al., 2005a, The Astronomer’s Telegram, 551
Torres M. A. P. et al., 2005b, The Astronomer’s Telegram, 566
Van der Hooft F. et al., 1999, ApJ, 513, 477
Wood K. S., Titarchuk L., Ray P. S., Wolff M. T., Lovellette M. N., Bandyopadhyay R. M., 2001, ApJ, 563, 246
Zhang G. B., Qu J. L., Zhang S., Zhang C. M., Zhang F., Chen W., Song L. M., Yang S. P., 2007, ApJ, in press (astro-ph/0701489)

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