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# GRB060602B = Swift J1749.4–2807: an unusual transiently accreting neutron-star X-ray binary

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## ABSTRACT

We present an analysis of the *Swift* Burst Alert Telescope (BAT) and X-ray telescope (XRT) data of GRB060602B, which is most likely an accreting neutron star in a binary system and not a gamma-ray burst. Our analysis shows that the BAT burst spectrum is consistent with a thermonuclear flash (type I X-ray burst) from the surface of an accreting neutron star in a binary system. The X-ray binary nature is further confirmed by the report of a detection of a faint point source at the position of the XRT counterpart of the burst in archival *XMM–Newton* data approximately six year before the burst and in more recent *XMM–Newton* data obtained at the end of 2006 September (nearly four months after the burst). Since the source is very likely not a gamma-ray burst, we rename the source Swift J1749.4–2807, based on the *Swift*/BAT discovery coordinates. Using the BAT data of the type I X-ray burst, we determined that the source is at most at a distance of  $6.7 \pm 1.3$  kpc. For a transiently accreting X-ray binary, its soft X-ray behaviour is atypical: its 2–10 keV X-ray luminosity (as measured using the *Swift*/XRT data) decreased by nearly three orders of magnitude in about 1 day, much faster than what is usually seen for X-ray transients. If the earlier phases of the outburst also evolved this rapidly, then many similar systems might remain undiscovered because the X-rays are difficult to detect and the type I X-ray bursts might be missed by all the sky surveying instruments. This source might be part of a class of very fast transient low-mass X-ray binary systems of which there may be a significant population in our Galaxy.

**Key words:** accretion, accretion discs – binaries: close – X-rays: binaries.

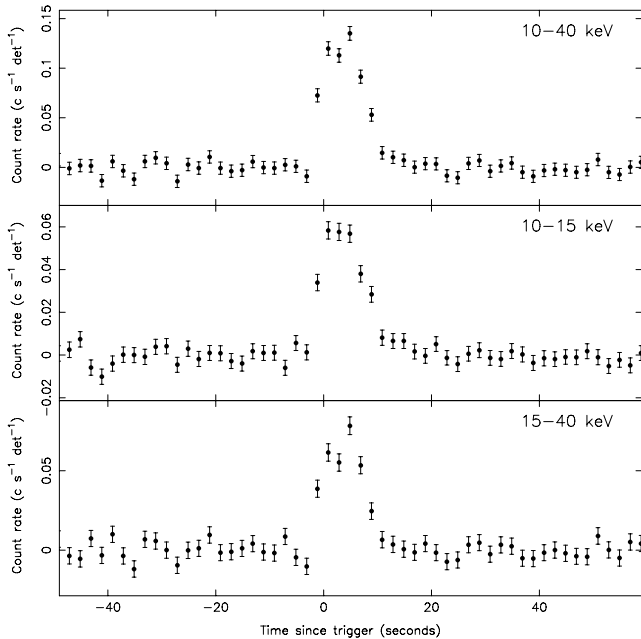
## 1 INTRODUCTION

The primary goal of the *Swift* gamma-ray burst (GRB) mission (Gehrels et al. 2004) is to discover and study GRBs. Typically, GRBs are discovered with the Burst Alert Telescope (BAT; Barthelmy et al. 2005) and then the satellite quickly slews towards the direction of the burst to facilitate observations with the X-ray telescope (XRT; Burrows et al. 2005) and the ultraviolet (UV)/optical telescope (UVOT; Roming et al. 2005). This allows detailed studies of the X-ray and UV/optical afterglows of the GRBs. In addition to detecting GRBs, the BAT also detects persistent and transient hard X-ray/soft gamma-ray sources and type I X-ray bursts from accreting neutron stars in low-mass X-ray binaries (LMXBs). Very occasionally, when the BAT discovers a burst, it is not immediately clear if it is a GRB or due to some other event such as a type I X-ray burst. The latter is the case of GRB060602B.

### 1.1 GRB060602B

On 2006 June 2, the *Swift* BAT detected a new burst named GRB060602B (Schady et al. 2006) at a position of RA =  $17^{\text{h}}49^{\text{m}}28^{\text{s}}.2$  and Dec. =  $-28^{\circ}07'15''.5$  (J2000, with a 90 per cent confidence error of 1.4 arcmin; Palmer et al. 2006). The burst lasted about 12 s and was the strongest in the 15–25 keV energy range and not seen above 50 keV (Palmer et al. 2006). The BAT spectrum could be fitted with a power-law model with a photon index of  $\sim 5$  indicating a rather soft spectrum for a GRB and suggesting that the source could be an accreting neutron-star X-ray binary which exhibited a type I X-ray burst (Palmer et al. 2006 also based on a Galactic position of  $l = 1^{\circ}15$  and  $b = -0^{\circ}30$ ). The short duration of the burst is consistent with it being a type I X-ray burst (Galloway et al. 2008). Just 83 seconds after the BAT trigger, the *Swift* XRT and UVOT began taking data of the source. No UVOT counterpart was seen but a decreasing faint X-ray source was detected (Beardmore, Godet & Sakamoto 2006; Schady et al. 2006) which first slightly increased in X-ray flux until 200 s after the trigger when it then decreased in flux following a simple power-law decay with an index of

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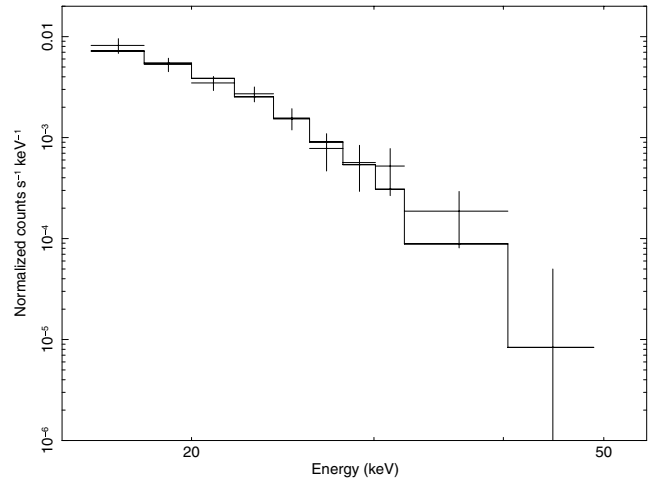
**Figure 1.** The *Swift*/BAT light curve of GRB060602B in the energy range 10–40 keV (top panel), 10–15 keV (middle panel) and 15–40 keV (bottom panel).

approximately  $-1$  (Beardmore et al. 2006). The XRT spectrum could be described by an absorbed power-law model with a photon index of 3.1. Beardmore et al. (2006) stated that the spectral and temporal properties of the source are difficult to reconcile with standard GRB afterglow models which would indicate that the source might indeed be a Galactic accreting neutron star. This conclusion was further strengthened by the detection of a faint X-ray source at the XRT position in archival *XMM-Newton* data taken nearly six years before the occurrence of the hard X-ray burst (Halpern 2006). The source was also officially retracted as a GRB (Barthelmy & Hurley 2007). To investigate the nature of this source, we analysed in detail all the available *Swift* BAT and XRT data of the source as well as several archival *XMM-Newton* observations.

## 2 SWIFT DATA ANALYSIS AND RESULTS

We analysed the BAT data of the burst using the standard threads.<sup>1</sup> The burst light curve between 15 and 40 keV is shown in Fig. 1. The burst could not be conclusively detected above 40 keV indicating a very soft burst (see also Palmer et al. 2006). Although the BAT is not calibrated below 15 keV, we also show the 10–15 and 10–40 keV light curves to demonstrate that the source had a rather high count rate at the lowest energies despite the fact that the sensitivity of the BAT drops significantly at these energies. This again points to a very soft spectral shape of the burst. The burst lasted approximately 10 s and it looks similar at different energies, although the statistics are such that we cannot rule out the same spectral variability which is normally observed for type I X-ray bursts. The burst profile does not fully resemble the fast rise, exponential decay shape typically seen in type I X-ray bursts. However, this does not rule out a type I X-ray burst nature because our statistics are rather limited, so stringent

<sup>1</sup>See the data analysis documents for the *Swift* instruments at <http://swift.gsfc.nasa.gov/docs/swift/analysis/>.



**Figure 2.** The *Swift*/BAT spectrum of GRB060602B. The points are the BAT data points and the solid line is the best-fitting blackbody model through the data.

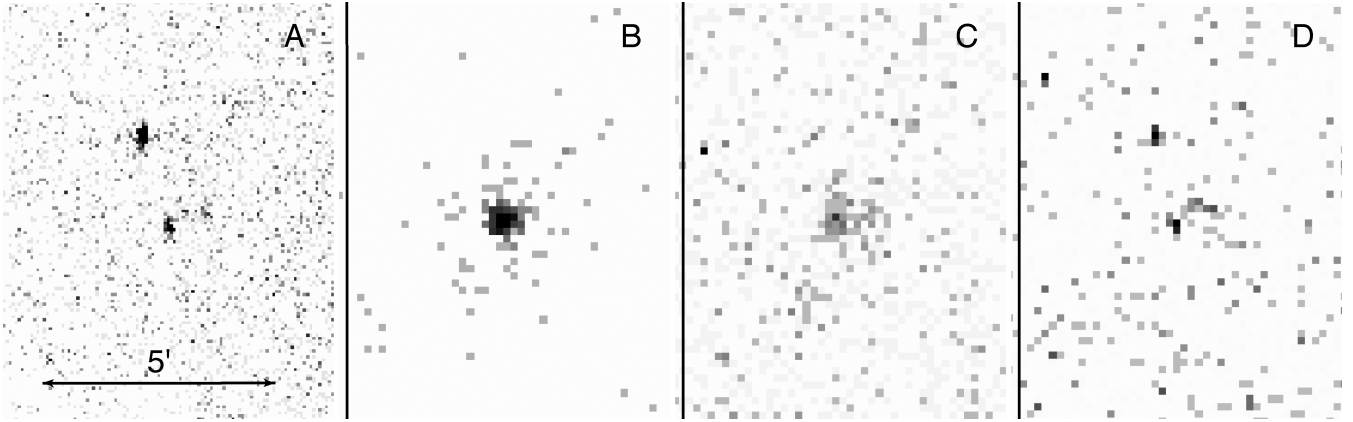
conclusion about the burst profile cannot be made. In addition, type I X-ray bursts at energies above 15 keV can have more complex burst profiles [see e.g. the type I X-ray bursts seen from 4U 0614+09 seen by Strohmayer, Markwardt & Kuulkers (2008) using BAT and the hard X-ray bursts seen with *INTEGRAL* as reported by Chelovekov, Grebenev & Sunyaev (2006)].

We extracted the spectrum of the whole burst and created the response matrix as outlined in the threads. We fitted the resulting spectrum (see Fig. 2) using *xSPEC* between 15 and 50 keV. As shown by Palmer et al. (2006), the BAT spectrum could be fitted well using a simple power-law model [with  $\chi^2 = 14.2$  for 14 degrees of freedom (d.o.f.)]. However, the power-law index obtained was  $\sim 5$  which suggested a thermal spectral shape. Therefore, we fitted the data with a blackbody model and we obtained a temperature of  $2.9^{+0.4}_{-0.3}$  keV and a 15–50 keV flux of  $1.7 \pm 0.1 \times 10^{-8}$  erg s $^{-1}$  cm $^{-2}$  (with  $\chi^2/\text{d.o.f.} = 11.9/14$ ). Extrapolating the flux to the energy range 0.01–100 keV results in an approximate bolometric flux of  $7^{+4}_{-2} \times 10^{-8}$  erg s $^{-1}$  cm $^{-2}$ . The inferred radius of the blackbody would be  $8^{+4}_{-3}$  km for an assumed distance of 8 kpc.

About 83 seconds after the burst was first detected with the BAT, the XRT started to observe the source (Schady et al. 2006). During the next 8 days, a total of  $\sim 55$  ks of data was obtained from this field. A log of the observations is shown in Table 1. During all observations, the photon counting mode was used. All the XRT observations were reprocessed using the standard method (see Footnote 1). Each observation was subdivided into multiple data segments (ranging from a few hundred seconds in length to about a ks). During the first observation, a relatively bright source was detected which decayed rapidly. During the remaining observations, the source was very

**Table 1.** The log of the *Swift* observations.

Obs Id	Date (2006 June)	Detectors used in analysis
00213190000	02 at 23:39	XRT, BAT
00213190001	04 at 00:18	XRT
00213190002	06 at 03:03	XRT
00213190003	07 at 03:09	XRT
00213190004	08 at 03:15	XRT
00213190005	09 at 00:22	XRT
00213190006	10 at 00:25	XRT

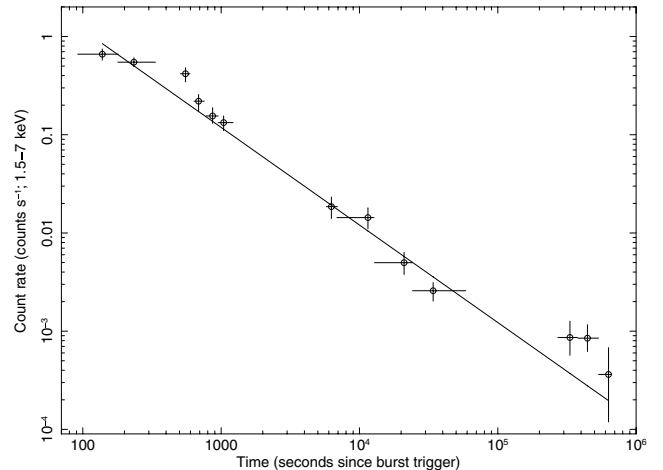


**Figure 3.** The *XMM-Newton* (left-hand panel; A) and *Swift*/XRT (right-hand three panels; B–D) images of GRB060602B. In panel B, the first  $\sim 910$  s of data taken on June 2 are shown (data set 1 and 2; Obs ID 002131900), in panel C the remaining data of June 2 (data set 3) and in D the combined data of June 4 to 10 (Obs ID 00213190001–00213190006).

faint but could still be detected when combining multiple observations (see Fig. 3). We found that below 1.5 keV hardly any source counts were present (likely due to the relatively high Galactic absorption), so we only used data between 1.5 and 7 keV to limit the effects of the background on the statistics (above 7 keV, the data were dominated by the background). The coordinates of the source as obtained from the first observation are RA =  $17^{\text{h}}49^{\text{m}}31^{\text{s}}.89$  and Dec. =  $-28^{\circ}08'02''.8$  (J2000, with a 90 per cent confidence error of 3.7 arcsec). This position is consistent with the revised position of R.A =  $17^{\text{h}}49^{\text{m}}31^{\text{s}}.94$  and Dec. =  $-28^{\circ}08'05''.8$  (J2000, with a 90 per cent confidence error of 3.3 arcsec) reported by Butler (2007). We extracted the light curve for the source using a variable extraction region (dependent on the brightness of the source to optimize the signal-to-noise ratio) and background subtracted the count rates. We adaptively binned the data so as to have 20 counts per bin (grouping was done separately for the data segments of observation 00213190000 because of the rapid decrease in count rate.).

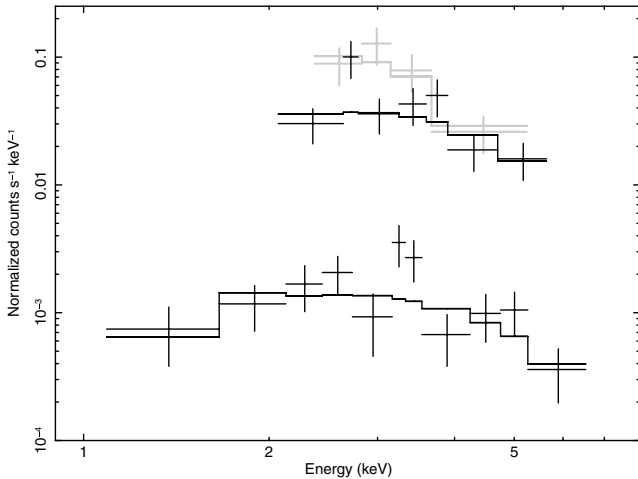
Initially, we found that the count rate slightly increased during the first  $\sim 200$  s, decreasing steadily after that (see also Schady et al. 2006). However, when we checked the source profile obtained and compared it with the expected profile using the point spread function of the XRT, we found that the source likely suffered from pileup during the initial part of the light curve. We estimated the amount of pileup by comparing the two profiles and corrected the count rates for it. The resulting light curves are shown in Fig. 4. Clearly, the initial rise has disappeared and the source decreases in flux from the start of the XRT observations until it reached a more constant level in the later observations. We fitted the resulting decay curve using different models and found that a simple power-law decay model with an index of  $-0.99 \pm 0.05$  fitted the decay curve best (Fig. 4; see also Beardmore et al. 2006), although formally still not acceptable ( $\chi^2 = 28.4$ , d.o.f. = 11). This is due to the third point and the last few points in the decay light curve which are significantly above the general decay trend. This indicates that the decay was not perfectly smooth and possible small flares occurred on top of the power-law decay.

Adding a constant level at the end of the decay did not improve the fit significantly (the resulting  $\chi^2 = 26.1$  for 10 d.o.f.); the index obtained was again  $\sim -1$ . We also tried fitting an exponential decay function (with and without a levelling off at the end;  $\chi^2/\text{d.o.f} = 83.6/10$  and  $\chi^2/\text{d.o.f} = 52.2/9$ , respectively), but no such model could reproduce the data.



**Figure 4.** The *Swift*/XRT light curve of GRB060602B (1.5–7 keV). The solid line is the best power-law decay model.

The investigation of the X-ray spectrum of the source was complicated by three factors: the fact that the source was rapidly decaying (which might possibly be accompanied by spectral changes), the pileup during the first  $\sim 1000$  s of the data and the very faint fluxes in the late stages of the decay. We focused on the data of observation 00213190000 and divided it into three data sets: the first set contained the first  $\sim 250$  s of the data of this observation, the second set contained the next  $\sim 660$  s of the data (starting about 550 s after the beginning of the observation) and the third set contained the remaining data ( $\sim 16$  ks of exposure time spread out over 53 ks). The first data set was most affected by pileup, so we extracted the spectrum using only GRADES 0 and using an annulus extraction region with an inner radius of 8 pixels and an outer radius of 30 pixels. The second data set suffered from less-severe pileup, so the annulus extraction region had an inner radius of 3 pixels (and the same outer radius; also only GRADES 0 were extracted). For the third set, the pileup was negligible and we used a circular extraction region with a radius of 20 pixel and GRADES 0 to 12. We used the pre-made response matrices but we created our own ancillary response matrices which take into account the size and shape of the extraction region. For the background spectrum, we used



**Figure 5.** The *Swift*/XRT spectrum of GRB060602B during observation 00213190000: the top two data points are for data set 1 (grey) and 2 (black); the bottom data set is set 3. The solid lines through the data points represent the best-fitting model.

four source-free circular extraction regions, all with radii of 20 pixels, and combined the data from all the four regions. After re-binning the spectra to have 10 counts per bin, we fitted them using XSPEC. The observations 00213190001 to 00213190006 could not be used to investigate the spectrum because, even though the source was detected when combining these observations (Fig. 3), the number of counts detected was not enough to obtain a useful spectrum.

The three individual data sets from observation 00213190000 could be well fitted with a single component model (e.g. a disc blackbody or power-law model; reduced  $\chi^2$  around 0.8–1.0), but when fitting the first data set with an absorbed power-law model the resulting index was  $>6$  and a column density  $N_{\text{H}} > 10^{23} \text{ cm}^{-2}$  (albeit with large errors). These values indicate that the spectrum most likely has a thermal shape instead of a non-thermal one (although we note that a thermal model and a power-law model fit the data equally well). The other two data sets were consistent with a power-law model with indices between 2 and 3. To obtain the best constraints on the fit parameters, we fitted the three data sets simultaneously and tied the column density  $N_{\text{H}}$  between the observations. For the first data set, we used a disc blackbody model but for the other two a power-law model. This combination of models fitted the data reasonably well ( $\chi^2/\text{d.o.f.} = 19.2/15$ ) and the resulting fit parameters are listed in Table 2 (see also Fig. 5). We used a disc blackbody model in the first, brightest part of the observation and a power-law model for the fainter parts because such models are commonly used for X-ray transients at similar brightness levels. We note, however, that the obtained parameters using these models are

**Table 2.** The results of the *Swift*/XRT spectral analysis.

Set	$N_{\text{H}}^1$ ( $\times 10^{22} \text{ cm}^{-2}$ )	$kT$ (keV)	$\Gamma$	Flux <sup>2</sup> ( $\text{erg s}^{-1} \text{ cm}^{-2}$ )
1	$3_{-2}^{+4}$	$0.8_{-0.2}^{+0.5}$		$8.0 \times 10^{-11}$
2			$1.9_{-1.0}^{+1.5}$	$3.1 \times 10^{-11}$
3			$2.2_{-0.7}^{+1.9}$	$4.6 \times 10^{-13}$

<sup>1</sup>The column density was tied between the three data sets.

<sup>2</sup>For 2–10 keV, and not corrected for absorption.

**Table 3.** The log of the *XMM-Newton* observations.

Obs Id	Date	Detectors used	Filter
0112980101	2000 September 23	MOS1, MOS2, pn	Medium
0410580401	2006 September 22	MOS1, MOS2	Thick
0410580501	2006 September 26	MOS1, MOS2	Thick

just an indication of the spectral shape of the source since many different types of models or combination of models fit the data equally well. The only tentative conclusion we can draw from these data is that the source seemed to switch from a thermal-like spectrum to a non-thermal spectrum during the first hundreds of seconds of the decay. Because of the large uncertainties in the fit parameter and in determining which model should be used to fit the data, the errors on the absorbed fluxes are very large (several tens of per cent) and even larger on the unabsorbed fluxes. The fluxes quoted in Table 2 are not corrected for absorption; typically correction factors range between 1.3 and 1.6. Due to uncertainties of extrapolating the model outside the fitting range, we restrict ourselves to quoting only the 2–10 keV fluxes.

### 3 XMM-NEWTON DATA ANALYSIS AND RESULTS

The position of GRB060602B was in the field of view of three *XMM-Newton* (Jansen et al. 2001; Strüder et al. 2001; Turner et al. 2001) observations (see Table 3). One observation was before the burst detected from the source (nearly six years before, Fig. 3; see also Halpern 2006) and the source is listed in the second *XMM-Newton* Serendipitous Source Catalogue<sup>2</sup> (Watson et al. 2008; provided by the *XMM-Newton* Survey Science Centre) as 2XMM J174931.6–280805. The other two were performed almost four months after the *Swift* observations. We analysed these observations using SAS.<sup>3</sup> All instruments were active but here we only discuss the data as obtained with the European Photon Imaging Camera (EPIC) instruments (due to the very low flux of the source, it was not detected in the RGS instruments). For all the data sets, the MOS cameras were operating in full window mode. In contrast, the pn camera was used in full window mode only for 2000 September 23; for the other two dates, it was in timing mode which is not well suited to study faint sources. Therefore, we only used the pn data obtained during the first observation.

We searched for background flares using light curves for photon energies above 10 keV. During the first observation, one bright flare was present and we removed it from the data (this removed several hundreds of seconds of the data). During the other two observations, no background flares were present and all the data could be used. For each observation, we combined the data of the EPIC cameras to obtain the highest signal-to-noise ratio for the determination of the source position. Due to the high offset angle and the faintness of the source, the *XMM-Newton* positions have a relatively large error (up to 4 arcsec) and the positions are not better than the one we obtained using *Swift* when the source was in outburst. However, during all three observations, the position of the faint *XMM-Newton* source was consistent with the *Swift*/XRT position of GRB060602B. The count rates of the source were extracted using the FUNCNTS program

<sup>2</sup><http://xmmssc-www.star.le.ac.uk/Catalogue/2XMM/>

<sup>3</sup><http://xmm.vilspa.esa.es/sas/>; version 7.0.0

**Table 4.** The results of the *XMM-Newton* analysis.

Detector	0112980101	0410580401	0410580501
MOS1			
– Count rate ( $\times 10^{-3}$ counts $s^{-1}$ )	$4.4 \pm 1.1$	$2.5 \pm 0.7$	$3.4 \pm 0.8$
– Absorbed flux	$1.3 \pm 0.3$	$0.8 \pm 0.2$	$1.1 \pm 0.2$
– Unabsorbed flux	$1.7 \pm 0.4$	$1.0 \pm 0.3$	$1.4 \pm 0.2$
MOS2			
– Count rate ( $\times 10^{-3}$ counts $s^{-1}$ )	$4.9 \pm 1.1$	$5.0 \pm 1.0$	$3.5 \pm 0.9$
– Absorbed flux	$1.5 \pm 0.3$	$1.5 \pm 0.4$	$1.1 \pm 0.3$
– Unabsorbed flux	$1.9 \pm 0.4$	$2.0 \pm 0.4$	$1.4 \pm 0.4$
pn			
– Count rate ( $\times 10^{-3}$ counts $s^{-1}$ )	$14 \pm 2$		
– Absorbed flux	$1.4 \pm 0.2$		
– Unabsorbed flux	$1.8 \pm 0.3$		

Note. The count rates are for 0.2–12 keV for the MOS instruments and 0.3–12 keV for the pn detectors and the fluxes are for 2–10 keV and in units of  $10^{-13}$  erg  $s^{-1}$   $cm^{-2}$  and where calculated using `WEBPIMMS` and an absorbed power-law model using  $N_H = 3 \times 10^{22}$   $cm^{-2}$  and a power-law index of 2.

from the `FUNTOOLS` package. The count rates were background subtracted and exposure corrected. As source extraction region we used a circle with a radius of 15 arcsec and as background region a circle with a radius of 2 arcmin in a region free of sources close to the position of GRB060602B. The observed count rates are listed in Table 4. The low count rates observed for the source did not allow for a spectral analysis. We estimated the source flux using `WEBPIMMS`<sup>4</sup> and assuming an absorbed power-law spectral shape with a column density of  $3 \times 10^{22}$   $cm^{-2}$  (as measured for the *Swift*/XRT outburst data; see Table 2) and a power-law index of 2. The resulting fluxes are also listed in Table 4. We also calculated the expected *Swift*/XRT count rate for the last two observations; the obtained 1.5–7 keV *Swift*/XRT count rates are  $1–2 \times 10^{-3}$  count  $s^{-1}$  which is a bit higher than that observed at the end of the outburst with the XRT but is likely consistent when taking into account the many uncertainties and assumptions made. Therefore, *Swift* very likely observed the full decay outburst of this source, all the way down to quiescence.

#### 4 NON-DETECTION OF THE SOURCE BY THE ALL-SKY MONITOR ABOARD *RXTE*

The all-sky-monitor [ASM; Levine et al. 1996; which is aboard the *Rossi X-ray Timing Explorer (RXTE)*; Bradt, Rothschild & Swank 1993] light curve for GRB060602B was determined over the duration of the *RXTE* mission (1996 January to 2007 August). The systematic uncertainties are important in this case, since the source is only  $1^{\circ}2$  from the Galactic Centre and  $0^{\circ}22$  from the X-ray transient IGR J17497–2821 (Walter et al. 2007).<sup>5</sup> In this region of the sky, an average of 24 X-ray sources must be included in the coded mask deconvolution for each 90-s exposure by one of the ASM cameras. For GRB060602B, the ASM light curve shows no significant detections in either 90-s exposures or weekly intervals. In particular, on 2006 June 2, there are only five ASM camera exposures with an

<sup>4</sup>Available at <http://heasarc.gsfc.nasa.gov/Tools/w3pimms.html>.

<sup>5</sup>IGR J17497–2821 was in outburst in 2006 September/October and we detected this outburst with the ASM and observed a maximum flux of 25 mCrab (1.5–12 keV; 1 week bins), which is near the threshold for the ASM sensitivity at the Galactic Centre.

average flux of  $34 \pm 18$  mCrab. The weekly exposures during 2006 May and June are near average levels, with upper limits in the range 20–35 mCrab (1.5–12 keV) per week over this interval.

## 5 DISCUSSION

We reported on the *Swift* BAT and XRT data of the X-ray burst source GRB060602B. The BAT spectrum could be well fitted with a blackbody model with a temperature of  $\sim 2.9$  keV and inferred radius of  $\sim 8$  km, which is in the range of temperatures and radii seen from type I X-ray bursts from the neutron stars in LMXBs (see e.g. Lewin, van Paradijs & Taam 1993; Kuulkers et al. 2003 and references therein). This result, together with the detections of the source (with a roughly constant luminosity) in archival (six years before the burst) and more recently obtained (four months after) *XMM-Newton* data, strongly indicates that the source is indeed not a gamma-ray burst but an accreting neutron star (as first suggested by Palmer et al. 2006 and Halpern 2006). We rename the source *Swift* J1749.4–2807 based on the revised BAT discovery coordinates (Palmer et al. 2006) and we will use this name from now on.

The nature of the donor star in this system is unclear. If the donor is a relatively high-mass star ( $> 10 M_{\odot}$ ), *Swift* J1749.4–2807 might be a member of the group of recently identified supergiant fast X-ray transients (see e.g. Sguera et al. 2006 and references therein). These are systems harbouring likely a OB supergiant and they exhibit fast X-ray outbursts. However, despite that the typical outburst luminosities of these systems are around  $10^{36}$  erg  $s^{-1}$ , which is similar to what we see for *Swift* J1749.4–2807, the duration of the outbursts of the supergiant fast X-ray transients is generally much shorter (only a few minutes to at the most a few hours; e.g. Sguera et al. 2006, although some outbursts lasted significantly longer but the majority have a very short duration) and the outbursts are more erratic than what we have observed for *Swift* J1749.4–2807. Moreover, no high-mass X-ray binary has so far ever exhibited a type I X-ray burst. Although burst-like events have been observed from, for example, SMC X-1, such events have typical X-ray spectra which are not consistent with a blackbody model (Angelini, White & Stella 1991). Therefore, we consider most likely that this system has a low-mass companion star (with mass  $< 1 M_{\odot}$ ) and that *Swift* J1749.4–2807 is not a supergiant fast X-ray transient.

If the BAT burst was indeed a type I X-ray burst, we can obtain a distance estimate towards the source. Assuming that the Eddington limit was reached during the burst and that the burst ignited in a hydrogen-poor environment, we can use the empirically determined Eddington luminosity by Kuulkers et al. (2003;  $3.8 \times 10^{38}$  erg  $s^{-1}$ ) to obtain a distance of  $6.7 \pm 1.3$  kpc. If we instead use equation (6) of Galloway et al. (2008), we obtain a distance of  $5.6 \pm 1.1$  kpc for hydrogen-poor bursts and  $4.3 \pm 0.9$  kpc for hydrogen-rich bursts (assuming a neutron star with a mass of  $1.4 M_{\odot}$  and a radius of 10 km). We note that the fluxes we obtain are those averaged over the whole burst and therefore it is possible that the peak flux was even higher and thus the distance smaller. Furthermore, if the burst we observed was not Eddington limited, then the distance would also be smaller.

Although the BAT burst spectrum strongly suggests that the source is a Galactic accreting neutron star, the XRT data are atypical for what is observed for ordinary neutron-star X-ray transients. Such systems are typically active (when in outburst) for weeks to months (some even years to decades) with a decay time-scale (i.e. the e-folding time) of at least a few days to weeks (see e.g. Chen, Shrader & Livio 1997; Campana et al. 1998; Jonker et al. 2003). In contrast, within  $\sim 1$  d, *Swift* J1749.4–2807 decreased in flux by

three orders of magnitude: from close to  $10^{-10}$  erg s $^{-1}$  cm $^{-2}$  (the 2–10 keV flux during the first XRT data set) to about  $10^{-13}$  erg s $^{-1}$  cm $^{-2}$  (as measured during the last XRT data and the archival *XMM–Newton* observations). Assuming a distance of 6.7 kpc, the measured peak luminosity was close to  $5 \times 10^{35}$  erg s $^{-1}$  (for the energy range 2–10 keV). However, if the X-ray flux began already to decay at a similar rate at the end of the type I X-ray burst, then the source must have been accreting at about 10 times higher luminosity ( $\sim 5 \times 10^{36}$  erg s $^{-1}$ ) when the burst occurred. The latter is a typical X-ray luminosity for the known active bursting sources in our Galaxy. Note that if the decay started at the end of the burst, then the source decreased by nearly four orders of magnitude in flux in one day! However, with the current data it cannot be assessed whether or not the source had a similar decay rate in the time between the type I X-ray burst and the start of the XRT observations. Furthermore, it is also unclear if the occurrence of the burst in some way triggered the decay of the source or if the two are unrelated. The observed tentative change in spectral shape has been seen for many neutron-star X-ray transients. Those systems typically change their spectral shape from thermally dominated to non-thermally dominated around a few times  $10^{36}$  erg s $^{-1}$  (see e.g. Maccarone & Coppi 2003; Gladstone, Done & Gierliński 2007), which is close to the X-ray luminosity at which we observe the spectral shape of Swift J1749.4–2807 to change.

The exact duration of the outburst is also unclear. It is possible that the source was active for a considerable amount of time (days to even weeks) before the BAT burst occurred. If true, the 2–10 keV flux of the source before the burst should not have been much above approximately  $5 \times 10^{-10}$  erg s $^{-1}$  (corresponding to a few times  $10^{36}$  erg s $^{-1}$ ) otherwise we would have detected the source with the *RXTE/ASM*. It is also possible that the rise and the peak were as fast as the decay observed in this source. For a type I X-ray burst to occur, a certain amount of matter must be accreted. However, for ordinary neutron star LMXBs the bursts can recur within hours to a day when they have luminosities similar to those observed for our source when the burst occurred (Galloway et al. 2008). Therefore, it is possible that the source was active for only a day or so and still accumulated enough matter to exhibit the burst and then disappeared again. Sources which exhibit such short outbursts are easily missed by monitoring instruments. This could then indicate that a significant number of similar systems may be present in our Galaxy but which are usually missed when they are in outburst. Their faint accretion luminosity and their short outbursts might make them very difficult to detect with monitoring instruments; their bright type I X-ray bursts might also easily be missed.<sup>6</sup>

Interestingly, there is one class of neutron-star X-ray binaries which might be such a class of sources and might be related to Swift J1749.4–2807: the so-called burst-only sources (see Cornelisse et al. 2004, for an overview of these sources). These systems are accreting neutron star sources which were discovered (mostly with *BeppoSAX* but also with *INTEGRAL*) because a type I X-ray burst was detected from them but which could not be detected outside the bursts with any of the monitoring instruments in orbit. The accretion luminosities of these sources at the time of the type I X-ray bursts should be below  $\sim 10^{36}$  erg s $^{-1}$  for them to remain undetectable.

More sensitive follow-up observations with, for example, *Chandra* or *XMM–Newton* found that although some are persistent sources with very low luminosities, most of them were likely neutron-star transients which most of the time were in a very dim quiescent state (with X-ray luminosities of the order of  $10^{32}$  erg s $^{-1}$  or less; see Cornelisse et al. 2002b, 2004). In such systems, the type I bursts were seen during one of their very-faint X-ray outbursts.

One of these burst-only sources (called SAX J2224.9+5421; Cornelisse et al. 2002a) was of particular interest because within 8 h after the Wide Field Camera of *BeppoSAX* discovered it through its burst,<sup>7</sup> *BeppoSAX* pointed at the source using the narrow field instrument (NFI) and could detect the source only at a 2–10 keV flux of  $\sim 1.3 \times 10^{-13}$  erg s $^{-1}$  cm $^{-2}$  (Antonelli et al. 1999) resulting in a luminosity of  $\sim 8 \times 10^{32}$  erg s $^{-1}$  (assuming a distance of 7.1 kpc; Cornelisse et al. 2002a). This detection of the source at a very faint level only 8 h after the occurrence of the burst is very reminiscent of what we have observed for Swift J1749.4–2807. Only  $\sim 8$  h after the burst, the XRT 2–10 keV flux of Swift J1749.4–2807 had decreased already to around  $5 \times 10^{-13}$  erg s $^{-1}$  cm $^{-2}$ , which is of the same order of magnitude as the flux observed for SAX J2224.9+5421 outside its burst. Cornelisse et al. (2002b) suggested that SAX J2224.9+5421 could be bursting at very low (near quiescent) X-ray luminosities, but our results on Swift J1749.4–2807 also suggest that both the sources could be very similar sources which exhibit a relatively faint (but not very faint) outburst, but they decay very rapidly after the occurrence of their type I X-ray bursts.

Determining the exact accretion luminosity at which the bursts occur is important in understanding the burst physics since the burst properties depend strongly on the accretion rate at the time the burst occurs. Although the accretion situation is evident for Swift J1749.4–2807, it remains unclear for SAX J2224.9+5421. Clearly, for these systems and others similar to them, the very short slew time available with *Swift* is necessary to distinguish between the different scenarios.

Swift J1749.4–2807 decayed rapidly to a constant level which was very similar to what *XMM–Newton* saw from the source six years before the occurrence of the burst and four months after it. Therefore, this constant flux level very likely represents the quiescent flux of the source which, for a distance of 6.7 kpc, results in a 2–10 keV luminosity of  $0.5\text{--}1.0 \times 10^{33}$  erg s $^{-1}$  (see also Halpern 2006). This is very similar to the quiescent luminosity seen for other neutron-star X-ray transients in their quiescent state. Sadly, due to the faintness of the source, no spectral information could be obtained but the high  $N_{\text{H}}$  (as measured in outburst with the XRT) in front of the source makes it difficult to detect any soft, thermal component and it is very likely that the emission we observe is (mostly) due to a non-thermal component. With the current data, no sensible upper limits can be obtained on any thermal component with which we could test cooling models for accretion-heated neutron stars. A longer exposure observation with *XMM–Newton* (with the source on axis) or a deep *Chandra* observation (with its much lower background) is needed to study the quiescent emission of this source with the detail necessary to allow comparative studies with other quiescent neutron-star X-ray transients.

<sup>6</sup> We can also speculate that a class of similarly very fast transients is present in the Galaxy which harbour a black hole instead of a neutron star. Such systems would be even more difficult to find because the discovery characteristic, the type I X-ray bursts, which allowed the known systems to be found, do not occur for black hole systems.

<sup>7</sup> We note that the type I X-ray burst nature of this *BeppoSAX* burst could not conclusively be established (Cornelisse et al. 2002a) and it is possible that the source is of a different, as yet unknown, origin. However, for the current paper, we assume it was indeed a type I X-ray burst.

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