LINKING BURST-ONLY X-RAY BINARY SOURCES TO FAINT X-RAY TRANSIENTS

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ABSTRACT

Burst-only sources are X-ray sources discovered thanks to their bursting activity with no associated emission (at least with the monitoring instrument that led to their discovery). This bursting activity consists in one single short (tens of seconds to minutes) burst of X-ray emission, with spectral and timing properties consistent with thermonuclear (type I) bursts usually occurring on the surface of a neutron star. This likely provides a tight link between burst-only sources and neutron star X-ray binary transients. We carried out a series of snapshot observations of the entire sample of burst-only sources with the Swift satellite. We found a few sources in outburst and detected faint candidates, likely representing their quiescent counterparts. To provide a more comprehensive view, we analyzed data for three quasi-persistent faint X-ray binary transients, another sub-class closely related to burst-only sources. We discuss burst-only sources and quasi-persistent sources in the framework of neutron star transients, providing clues on their nature.

Key words: binaries: close – stars: individual (SAXJ1324.5–6313, SAXJ1818.7+1424, SAXJ1828.5–1038, SAXJ2224.9+5422, SAXJ1753.5–2349, SAXJ1806.5–2215, Swift J1749.4–2807, 1RXSJ170854.4–321857, 1RXSJ171824.2–402934, XMMJ174716.1–281048) – stars: neutron – X-rays: bursts

Online-only material: color figures

1. INTRODUCTION

Type I X-ray bursts are observationally characterized by a rapid rise of the X-ray flux (of the order of a few seconds) and an exponential decay (usually lasting a few minutes) together with a blackbody spectrum which softens as the burst decays. These bursts are interpreted as thermonuclear flashes on the surface of a neutron star, thus definitely identifying the source as a neutron star binary. In the last few years thanks to the long monitoring of the Galactic center region with the Wide-Field Cameras (WFC) onboard BeppoSAX, a number of sources showing only type I bursts without persistent emission were discovered (Cocchi et al. 2001; Cornelisse et al. 2002a, C02a hereafter). Upper limits on the quiescent emission were relatively high in the range (C02a). This level is significantly lower than the outburst peak luminosity observed in bright X-ray binary transients (e.g., Aql X-1, for a review see Campana et al. 1998), thus justifying their name: burst-only sources. A follow-up of these burst-only sources with short Chandra exposures led to the detection of possible quiescent counterparts at a level consistent with other X-ray transients in quiescence, i.e., $10^{32}$–$10^{33}$ erg s$^{-1}$ (Cornelisse et al. 2002b, C02b hereafter).

In addition to classical X-ray binary transients, the increased sensitivity level of monitoring instruments led to the discovery of faint X-ray transients with peak outburst luminosity in the $\sim 10^{36}$–$10^{37}$ erg s$^{-1}$ (Heise et al. 1999; in’t Zand 2001). The most famous example is the accreting millisecond X-ray pulsars (AXMPs) SAX J1808.4–3658 (as well as many other AMXPs; see Wijnands 2005a for a review). Furthermore, Galactic plane X-ray surveys with XMM-Newton and Chandra (e.g., Sakano et al. 2005; Muno et al. 2005; Wijnands et al. 2006) revealed the existence of a class of very faint X-ray transients (VFXTs) with peak outburst luminosities in the $10^{34}$–$10^{36}$ erg s$^{-1}$ range. A large number of them were found close to the Galactic center (Muno et al. 2005, 2008).

Close to VFXTs are quasi-persistent sources such as 1RXS J170854.4–321857, 1RXS J171824.2–402934 (in’t Zand et al. 2005) and XMMU J174716.1–281048 (Del Santo et al. 2007a). These sources are type I bursters, with the only difference with burst-only sources that they have been detected in a low-level active ($L < 10^{34}$–$10^{35}$ erg s$^{-1}$) state (at least) quite frequently.

In this paper, we exploit Swift X-ray Telescope (XRT) observations of eight burst-only sources (C02a) as well as of three quasi-persistent VFXTs (in’t Zand et al. 2005; Del Santo et al. 2007a). In Section 2, we describe the general treatment of the data. In Section 3, we analyze burst-only Swift XRT data and in Section 4 data of quasi-persistent sources. In Section 5 we discuss our results.

2. SWIFT XRT OBSERVATIONS

The Swift satellite (Gehrels et al. 2004) easily offers the possibility of short snapshot observations thanks to its fast repointing capabilities and its low Earth orbit. Burst-only sources are therefore ideal targets to look for signs of activity and at the same time collect photons to identify their counterparts in quiescence. In Tables 1 (burst-only sources) and 2 (quasi-persistent VFXTs) we report the log of our observations. We concentrate on XRT data (Burrows et al. 2005), our sources being too faint for a detection with the Burst Alert Telescope and too absorbed (and faint) for a detection with the UltraViolet/Optical Telescope. Given the faintness of our sources all the data were collected in a Photon Counting mode (PC, providing two-dimensional imaging and full spectroscopic resolution).

All data were processed with the standard XRT pipeline within HEASOFT 6.5.1 (xrtpipeline v.0.12.0) in order to produce screened event files. PC data were extracted in the 0.3–10 keV energy range with standard grade filtering (0–12). Extraction regions were selected depending on source strength. Concentric background regions were used to extract background spectra. Appropriate ancillary response files were generated with the task xrtmkarf, accounting for point-spread function losses and CCD defects. We used version 010 response matrices. Data collected after 2007 August 30 were taken with a +6V CCD substrate voltage and require different filtering criteria and (slightly) different response matrices (Godet et al. 2009).
Within the BeppoSAX error circle we detect only one source (SAXJ1324−1) coincident with Chandra’s source B (error circle 3.7 arcsec) in C02b (see Figure 1). Other two sources are detected outside the BeppoSAX WFC error circle. Searching at the known positions of Chandra sources we detect one more (weak) source (see Table 3).

We concentrate on SAXJ1324−1 being the only one detected source within the BeppoSAX WFC error circle. SAXJ1324−1 was observed to vary among the three Swift XRT exposures at a...
Table 3

| Source Name | R.A. (J2000) | Decl. (J2000) | Count Rate (counts s⁻¹) |
|-------------|--------------|---------------|-------------------------|
| SAXJ1324–1 | 13 24 06.6   | –63 13 45.4   | 9.8 ± 0.8 × 10⁻³       |
| SAXJ1324–2 | 13 24 37.3   | –63 17 18.2   | 5.9 ± 2.4 × 10⁻⁴       |
| SAXJ1324–3 | 13 24 40.2   | –63 08 55.3   | 7.1 ± 2.6 × 10⁻³       |
| SAXJ1324–A | 13 24 30.2   | –63 12 41     | 7.3 ± 10⁻³ 3 σ         |
| SAXJ1324–C | 13 24 38.0   | –63 12 26     | 1.2 × 10⁻³ 3 σ         |
| SAXJ1324–D | 13 24 38.3   | –63 13 28     | 1.2 × 10⁻³ 3 σ         |
| SAXJ1324–E | 13 24 39.4   | –63 13 34     | 4.8 ± 2.3 × 10⁻⁴       |

Note. *Chandra* sources with fixed position search in XRT images.

~4.6 σ level (observed count rate are (6.0 ± 1.4) × 10⁻⁴ counts s⁻¹, (6.0 ± 1.0) × 10⁻³ counts s⁻¹ and (13.3 ± 1.2) × 10⁻³ counts s⁻¹, respectively, 1σ errors here). The third observation shows a count rate larger by a factor of 2 with respect to the previous two observations. In addition, within this last observation signs of flaring activity can be observed (see Figure 2). No similar variability was observed during the first two observations.

For spectral analysis we extracted separated spectra for observations 1+2 and 3 separately. We extracted the spectrum of SAXJ1324–1 from a 15 pixel circle centered on source (background was extracted from an annulus centered on source with 50 and 70 inner and outer radii, respectively). We first check if the two spectra are consistent. We fit the two spectra with the same model and free normalizations finding good reduced χ² values (in the range 0.8–1). This prompted us to merge the three sets of data to increase statistics. We then binned the total 266 photons to 10 photons per spectral bin and applied Churazov’s weighting within XSPEC. A power-law fit provides good results with a reduced χ² = 0.7 (with 23 degrees of freedom, dof). The column density is 9.7 ± 6.5 × 10²¹ cm⁻² (90% confidence level throughout the paper). This value is consistent with the Galactic column density value of (1.2–1.5) × 10²² cm⁻² (Kalberla et al. 2005; Dickey & Lockman 1990, respectively). The power-law photon index is Γ = 0.8 ± 0.4. A fit with other simple models provides equally good fit (see Table 4). Given this spectral model the source count rate is larger by a factor of ~ 3 with respect to the *Chandra* observation (C02b).

*Chandra’s* source B was discarded by C02b as a possible counterpart due to its spectral hardness. We confirm that the spectrum of SAXJ1324–1 is rather hard. Usually the quiescent spectrum of neutron star transients is made by a soft component and (often) a hard power-law tail. The photon index of this tail is in the 1.5–2 range. The soft component is always present apart from a few exceptions: accreting millisecond X-ray pulsars (AMXPs, Campana et al. 2004a, 2005; Wijnands et al. 2005a; Heinke et al. 2007), EXO 1745–248 in Terzan 5 (Wijnands et al. 2005b), as well as 1H1905+000 that has not been detected at all, with a very tight upper limit (Jonker et al. 2007). AMXPs quiescent luminosities are lower with respect to classical transients (e.g., SAX J1808.4–3658 has an unabsorbed 0.5–10 keV luminosity of 5 × 10³¹ erg s⁻¹).

To reach a comparable level SAXJ1324 should lie at ~ 0.5 kpc. EXO1745–248 has instead a larger quiescent luminosity (2 × 10³³ erg s⁻¹). To have this luminosity SAXJ1324 should lie at ~ 3.4 kpc. In conclusion, despite the hardness of the spectrum we cannot exclude that SAXJ1324–1 is the quiescent counterpart of SAXJ1324. In addition, fast variability (on timescale ~ 1000 s) has also been observed in X-ray transients in quiescence (Campana et al. 2004b).

Table 4

| Model              | Column Density (10³¹ cm⁻²) | Γ/kT   | χ²/ν (dof) | Flux (cgs) |
|--------------------|---------------------------|--------|-----------|------------|
| Power law          | 9.5 +0.4, 0.8 (23)        | 0.7     | 1.4 × 10⁻¹² |
| Blackbody          | 3.1 ±0.3, 1.7 ±0.4        | 0.9 (23)| 1.0 × 10⁻¹² |
| Bremstr.           | 14.9 +3.9, > 32           | 0.9 (23)| 1.4 × 10⁻¹² |
| NSA                | 4.7 +3.1, 1.2 +0.2        | 0.9 (23)| 1.0 × 10⁻¹² |

Note. *Unabsorbed flux in the 0.5–10 keV energy band.

Figure 1. *SAX* J1324.5–6313 field observed by *Swift* XRT.

(A color version of this figure is available in the online journal.)

Figure 2. *Swift* XRT light curve of *SAX* J1324.5–6313 during the third observation.

(A color version of this figure is available in the online journal.)

SAX J1752.3–3128

SAX J1752.3–3128 (hereafter SAXJ1752) was discovered by the *BeppoSAX* WFC through the detection of one type I burst over 6 Ms (Cocchi et al. 2001). Photospheric radius expansion led to a source of 9.2 kpc. *Chandra* observed this field for 4.7 ks.
two sources were detected within the error circle plus a brighter one just outside (C02b).

The Swift XRT observed SAXJ1752 for 0.5 ks (see Table 1). No sources were detected. Upper limits (3σ) of 3 × 10−2 counts s−1 at the location of the Chandra sources can be set (corresponding, using a Crab-like spectrum and the Galactic absorption, to a Chandra ACIS-S rate of ∼ 0.1 counts s−1). This indicates that the Chandra observation was much deeper than the Swift one.

3.3. SAX J1753.5−2349

SAX J1753.5−2349 (hereafter SAXJ1754) was discovered by the BeppoSAX WFC through the detection of one type I burst over 1 Ms of monitoring (in’t Zand et al. 1998). The 99% error circle is 2.5′. From the burst strength an upper limit on the distance of 8.8 kpc can be set. The upper limit on the quiescent flux from the BeppoSAX WFC is 1.6 × 10−12 erg s−1 cm−2 (0.5–7 keV, in’t Zand et al. 1998; C02b). Follow-up observations were carried out with Chandra for 5.2 ks. No sources were detected.

SAXJ1754 was observed twice by Swift (see Table 1). During the first observation (7.6 ks) no sources were detected within the BeppoSAX WFC error circle with an upper limit of × 1.5 × 10−2 counts s−1 (3σ). Following the detection of an outburst by Swift Burst Alert Telescope (BAT) and RXTE Proportional Counter Array (Markwardt et al. 2008), and INTEGRAL (Cadolle Bel et al. 2008), the Swift XRT observed the field for 1 ks. One source is well visible at the edge of the WFC error circle (see Figure 3; Degenaar & Wijnands 2008a; Starling & Evans 2008). This source (SAXJ1754−1) is bright at a level of 0.54 ± 0.03 counts s−1, i.e., ∼ 350 times brighter than in the previous observation. The source is constant within the observation.

Due to a small (uncorrected) trim (3 pixels) across the three orbits comprising the second observation, we extracted photons on an orbit-by-orbit basis. For each orbit we used a 30 pixel circular region for the source and an annular region with inner and outer radii of 60 and 80 pixels, respectively, for the background. Photons were binned to 20 counts per spectral bin. We then generated single arf files and sum them together.
an 8 pixel circular region totaling 14 counts (background is extracted from a concentric annular region of 40 and 60 inner and outer radii, respectively and accounts for 15% of the counts). Using Cash statistics (and without subtracting the background) we can estimate a power-law photon index of $\Gamma = 3.5 \pm 1.1$ or a black body temperature $T = 0.6^{+0.3}_{-0.2}$ keV (fixing the column density to the Galactic value). The 0.5–10 keV unabsorbed flux is in the $2 \times 10^{-11}$ erg s$^{-1}$ cm$^{-2}$. At a (maximum) distance of 8 kpc, this corresponds to $1 \times 10^{33}$ erg s$^{-1}$.

3.5. SAX J1818.7+1424

SAX J1819.7+1424 (hereafter SAXJ1819) was discovered by the BeppoSAX WFC through the detection of one type I burst over 1.6 Ms of monitoring (C02a). The 99% error circle is 2.9. From the burst strength an upper limit on the distance of 9.4 kpc can be set. The upper limit on the quiescent flux from the BeppoSAX WFC is $5 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$ (C02b).

Follow-up observations were carried out with Chandra for 4.8 ks. Eight sources were detected. Of these three are outside the BeppoSAX WFC error circle and two have a too bright optical counterpart (C02b).

Swift observed SAX1819 four times. We detected six sources, two within the BeppoSAX WFC error circle (SAXJ1819–1 and SAXJ1819–4, see Table 7 and Figure 4). Source SAX1819–4 (source D in Chandra) is consistent with the bright star ($V = 7.6$) HD168344 and was already discarded by C02b. The high source flux is also due to some optical flux leaking through the XRT filter.

We carry out spectral analysis for sources SAX1819–6 and SAX1819–F (see Table 8). We extracted photons from a circular region with 10 and 5 pixel radii, respectively (the small radius for source SAX1819–F was dictated by its closeness to source SAX1819–4). Background photons were extracted from an annular region of 40 (60) inner (outer) radius, centered on source. We extracted 78 and 27 counts, respectively. Given the low number of counts we grouped photons by 5 and use Churazov’s weighting scheme within XSPEC.

For both sources the spectrum is soft and it cannot be fitted with the full Galactic absorption ($1.0 \times 10^{22}$ cm$^{-2}$). The spectrum of SAX1819–6 spectrum is the softest among the two. It can be fitted equally well by any of the considered single component models (see Table 8), even if the power-law and the bremsstrahlung models describe better the high energy part of the data. This is also the case for SAX1819–F. In the case of a power-law fit and at the maximum source distance the (upper limit) on the two source luminosities are $< 1 \times 10^{32}$ erg s$^{-1}$ and $< 7 \times 10^{32}$ erg s$^{-1}$, respectively. Based on these spectral fits we cannot establish which is the true counterpart of SAXJ1819, if any.

3.6. SAX J1828.5–1037

SAX J1828.5–1037 (hereafter SAXJ1828) was discovered by the BeppoSAX WFC through the detection of one type I burst (C02a). The 99% error circle is 2.8. From the burst strength an upper limit on the distance of 6.2 kpc can be set. SAXJ1828 was previously detected during a ROSAT observation with a 0.5–2.5 keV flux of $2 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$ (C02b). SAXJ1828 was also detected by XMM-Newton during a scan of the Galactic plane (Hands et al. 2004). SAXJ1828 was found in a bright state with an unabsorbed $0.5–10$ keV flux of $5 \times 10^{-11}$ erg s$^{-1}$ cm$^{-2}$. At a distance of 6.2 kpc this implies a luminosity of $5 \times 10^{34}$ erg s$^{-1}$. The spectrum was fitted with a thermal bremsstrahlung model with equivalent temperature of 7 keV and a column density of $N_H = 5 \times 10^{22}$ cm$^{-2}$ (much larger than the Galactic value of $N_H = 1.9 \times 10^{22}$ cm$^{-2}$).
The *Swift* XRT observed SAXJ1828 for 20.7 ks. Given the detection of a transient source by *XMM-Newton* we focus on this much smaller error circle. A faint source is barely visible in the *Swift* thank to the close vicinity of the *BeppoSAX* WFC error circle. SAXJ1828 is detected with a count rate of $(7.3 \pm 2.6) \times 10^{-4}$ counts s$^{-1}$. Assuming the same spectrum and absorption in the *XMM-Newton* observation we estimate a 0.5–10 keV unabsorbed flux of $1.5 \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$ (1.9 $\times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$ in the case of a power law with photon index $\Gamma = 2$). This highlights a flux decrease by a factor of $\sim 80$ confirming the transient nature of the counterpart. This flux corresponds to a quiescent luminosity of $\sim 7 \times 10^{32}$ erg s$^{-1}$ at a distance of 6.2 kpc.

A new outburst from this source was detected at the end of 2008 October (Degenaar & Wijnands 2008b). Three observations were carried out by the *Swift* XRT (see Table 1). We extracted spectra from the same 15 pixel region and the background from an annular region 40 (60) pixel inner (outer) radius. We bin the spectra of the three observations containing 141, 40, and 261 photons, respectively, to 10 counts per spectral bin and applied Churazov’s weighting scheme. We then fitted the three spectra keeping the same column density. We find a heavily absorbed source with $N_H = 4.1^{+1.5}_{-0.6} \times 10^{22}$ cm$^{-2}$, consistent with the *XMM-Newton* value. The power-law photon indices are $1.7^{+0.9}_{-0.7}$, $1.4^{+1.0}_{-0.8}$, and $1.7^{+0.6}_{-0.5}$, respectively. The overall $\chi^2_{red} = 0.7$ with 36 dof. A fit with the same power-law photon index provides similar results ($\chi^2_{red} = 0.7$ with 38 dof) and a photon index $\Gamma = 1.6^{+0.8}_{-0.4}$. The 0.5–10 keV unabsorbed fluxes for the three observations are 9.2, 9.7, and 22.9 $\times 10^{-11}$ erg s$^{-1}$ cm$^{-2}$, resulting in luminosities of 4.5, 4.7, and $1.1 \times 10^{36}$ erg s$^{-1}$, respectively.

### 3.7. SAX J2224.9+5421

SAX J2224.9+5421 (hereafter SAXJ2224) was discovered by the *BeppoSAX* WFC through the detection of one short (2.6 s) type I burst (C02b). The fact that the type I burst is short casts some doubts on the X-ray binary nature of the object. At the same time the goodness of the blackbody fit to the burst spectrum and the absence of such short X-ray flashes hints for a Galactic object. The 99% error circle is 3.2. From the burst strength an upper limit on the distance of 7.1 kpc can be set. A strong upper limit on the flux was obtained a few hours after the burst with a repointing of the *BeppoSAX* satellite. The source was not detected with the MECS instrument with an upper limit on the 2–10 keV flux of $1.3 \times 10^{-13}$ erg s$^{-1}$ cm$^{-2}$ (C02b), which translates to an upper limit in luminosity of $\lesssim 8 \times 10^{32}$ erg s$^{-1}$ (at 7.1 kpc). This source was not covered by *Chandra* observations.

The *Swift* XRT observed SAXJ2224 four times for a total exposure time of 22.7 ks. There is just one source within the *BeppoSAX* WFC error box and one close to it (see Figure 5 and Table 9). For SAXJ2224–1, we collected just 24 photons in the 0.3–10 keV energy range. Data were rebinned to 6 photons per channel and Churazov’s weighting scheme was used. The column density was fixed to the Galactic value of $5 \times 10^{21}$ cm$^{-2}$ (leaving free the column density it will converge to a value higher than the Galactic value). The source spectrum is hard (see Table 10). At the maximum distance of 7.1 kpc the X-ray luminosity is $8 \times 10^{32}$ erg s$^{-1}$. In the 2–10 keV the upper limit in luminosity is $7 \times 10^{32}$ erg s$^{-1}$, i.e., comparable to the *BeppoSAX* MECS upper limit.

### 3.8. Swift J1749.4–2807

One additional burst-only source was detected by *Swift* in 2006. *Swift J1749.4–2807* (Swift J1749 in the following) showed a soft burst detected only up to $\sim 40$ keV with the BAT (Schady et al. 2006). A blackbody fit provided a temperature of 3 keV. An upper limit on distance of $6.7 \pm 1.3$ kpc can be set. The source was then followed up from 83 s to $\sim 8$ d by the XRT (Wijnands et al. 2009). The source showed a monotonic decrease following a power law with index $-0.99 \pm 0.05$. *Swift* J1749 decreased in flux by three orders of magnitude. The unabsorbed 0.5–10 keV luminosity in outburst resulted in $\sim 10^{36}$ erg s$^{-1}$ making this source a likely faint X-ray transient.
The data are therefore consistent with a progressive decrease of the column density. The first spectrum is consistent with the Chandra one with $\Gamma = 1.98 \pm 0.05$ and the column density is consistent too $N_H = (4.3 \pm 0.2) \times 10^{21}$ cm$^{-2}$. The source 0.5–10 keV luminosity during the first observation is $3.3 \times 10^{36}$ erg s$^{-1}$, at the high end of the observed range. The second observation found the source in a much fainter state ($3.6 \times 10^{35}$ erg s$^{-1}$). The spectral index is also softer $\Gamma = 2.4 \pm 0.1$. This is the faintest level ever attained by RXSJ1708.

4.2. IRXS J171824.2–402934

IRXS J171824.2–402934 (RXSJ1718 in the following) was detected and identified during the ROSAT all sky survey (1990 September), and it was later reobserved twice with the ROSAT HRI (1994 March and September; Kaptein et al. 2000). The BeppoSAX WFC never detected the persistent emission but a bright burst. An upper limit on distance is in the 6–8 kpc range (Kaptein et al. 2000). In the following we assume $d = 6$ kpc. RXSJ1718 was observed by Chandra for 15 ks. The source is well detected with a power-law spectrum $\Gamma = 2.1 \pm 0.2$ ($N_H = 1.3^{+0.1}_{-0.2} \times 10^{22}$ cm$^{-2}$). The observed 0.5–10 keV luminosity is $5 \times 10^{32}$ erg s$^{-1}$ (in’t Zand et al. 2005).

Swift observed RXSJ1718 for 78 ks. Two short observations were carried out in 2006 September 2007 and January, whereas the bulk of the data comes from prolonged observation following a source flare (see Table 2 and Figure 7). The source underwent a rebrightening by a factor of $\sim 10$, showing strong variability among different observations (Figure 7). Given the large wealth of data we divided the entire set. Data before 2008 were grouped together. The flare data were then divided according to the source count rate into four intervals: $> 0.2$ counts s$^{-1}$, $0.1$–$0.2$ counts s$^{-1}$, $0.05$–$0.1$ counts s$^{-1}$, and $< 0.05$ counts s$^{-1}$. Data were extracted from a circular region centered on source with radius 20, 25, 20, 15 and 15 pixels, respectively. The background was extracted from an annular region with 60 (80) inner (outer) radius.

An absorbed power-law model can fit all the data. The spectral parameters and fluxes are reported in Table 11. The overall fit with variable $\Gamma$ but the same column density ($N_H = (1.2 \pm 0.1) \times 10^{22}$ cm$^{-2}$) is good with $\chi^2_{\text{red}} = 0.99$ for 248 dof. As can be seen from Table 11 there is a clear softening of the spectrum at decreasing luminosities. This has been observed in other neutron star transients during the decay to quiescence (e.g., Jonker et al. 2004). An equivalent fit can be obtained with a power-law model (with the same $\Gamma$ for all the spectra) plus the same blackbody component for all the spectra leaving only the normalization of the power-law component free across different observations. The fit is even better than the previous one with $\chi^2_{\text{red}} = 0.91$ (for 250 dof). The best-fit values are $N_H = (1.3 \pm 0.1) \times 10^{22}$ cm$^{-2}$, $k \Gamma = 0.27 \pm 0.04$ keV, $R = 2.2^{+1.5}_{-0.8}$ km, and $\Gamma = 2.0 \pm 0.1$. The data are therefore consistent with a progressive decrease of the power-law component only with luminosity.

### Table 10

| Model       | Column Density (10$^{21}$ cm$^{-2}$) | $\Gamma/kT$ (···/keV) | $\chi^2_{\text{red}}$ (dof) | Flux* (ergs) |
|-------------|------------------------------------|------------------------|-----------------------------|-------------|
| Power law   | 0.5 (fix)                           | $1.1^{+0.8}_{-0.7}$    | 0.6 (2)                     | $1.3 \times 10^{-15}$ |
| Blackbody   | 0.5 (fix)                           | $0.9^{+0.8}_{-0.6}$    | 0.7 (2)                     | $7.4 \times 10^{-14}$ |
| Bremstr.    | 0.5 (fix)                           | $> 3.9$                | 0.7 (2)                     | $1.1 \times 10^{-13}$ |

Note. * Unabsorbed flux in the 0.5–10 keV energy band.
flux is 8 down to a limiting 2–10 keV flux of...gion with (Sidoli & Mereghetti 2003). Exposure of the same...XMM-Newton was discovered as a faint X-ray transient in 2003 with (Del Santo et al. 2007a). The 2–10 keV flux at the discovery...10.9 ks (see also Degenaar & Wijnands 2007; Sidoli et al. 2008a, 2008b). The (mean) spectrum can be well fitted ($\chi^2_{\text{red}} = 0.8$ for 18 dof) with an absorbed $N_H = (7.9 \pm 2.9) \times 10^{22}$ cm$^{-2}$ power law with photon index $\Gamma = 1.8 \pm 0.8$. Fixing the column density to the XMM-Newton value we have $\Gamma = 1.9 \pm 0.3$. The mean flux is $8.8 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$ (the conversion from observed rate to unabsorbed 2–10 keV flux is $2.8 \times 10^{-10}$ erg s$^{-1}$ cm$^{-2}$).

### 4.3. XMMU J174716.1–281048

XMMU J174716.1–281048 (XMMJ1747 in the following) was discovered as a faint X-ray transient in 2003 with XMM-Newton (Sidoli & Mereghetti 2003). Exposure of the same region with XMM-Newton and Chandra did not reveal any source down to a limiting 2–10 keV flux of $\sim 3 \times 10^{-14}$ erg s$^{-1}$ cm$^{-2}$ (Del Santo et al. 2007a). The 2–10 keV flux at the discovery was $7 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$. The spectrum was fitted well by an absorbed power law with $\Gamma = 2.1 \pm 0.1$ and a high column density of $N_H = (8.9 \pm 0.5) \times 10^{22}$ cm$^{-2}$. A further XMM-Newton observation in 2005 detected the source with a similar spectrum and a 2–10 keV flux of $3 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$ (Del Santo et al. 2007a).

INTEGRAL detected several type I bursts from this source, leading to a distance estimate of $\sim 8$ kpc, consistent with lying close to the Galactic center (Del Santo et al. 2007a, 2007b). The source was always found in an active state, testifying for the long duration of the outburst. Swift observed XMMJ1747 several times for a total time of 10.9 ks (see also Degenaar & Wijnands 2007; Sidoli et al. 2008a, 2008b). The source is highly variable by more than a factor of 10 (Figure 8). We first divided the data into intensity bins (above and below a rate of 0.04 c s$^{-1}$) but found no spectral differences (including errors) so we merge the entire dataset into a single spectrum. Data were rebinned to 20 photons per energy channel. The (mean) spectrum can be well fitted ($\chi^2_{\text{red}} = 0.8$ for 18 dof) with an absorbed $N_H = (7.9 \pm 2.9) \times 10^{22}$ cm$^{-2}$ power law with photon index $\Gamma = 1.8 \pm 0.8$. Fixing the column density to the XMM-Newton value we have $\Gamma = 1.9 \pm 0.3$. The mean flux is $8.8 \times 10^{-12}$ erg s$^{-1}$ cm$^{-2}$ (the conversion from observed rate to unabsorbed 2–10 keV flux is $2.8 \times 10^{-10}$ erg s$^{-1}$ cm$^{-2}$).

According to this spectrum XMMJ1747 spanned a 2–10 keV luminosity of $2 \times 10^{34} - 2 \times 10^{35}$ erg s$^{-1}$ at 8 kpc.

### 5. DISCUSSION

In the framework of low mass transients, burst-only sources stand as peculiar, firmly established, neutron star binary systems. The sources were discovered by long monitoring of the Galactic center region by the WFC onboard BeppoSAX, through type I burst activity but without the detection of persistent emission (C02a). This behavior has been recently interpreted in terms of sedimentation of CNO nuclei, leading to strong H/He flashes (Peng et al. 2007). The initial sample consisted of nine sources. Two of them are low persistent sources ending with seven burst-only sources (actually one was also detected during outburst by RXTE-ASM). C02b carried out a follow-up of five of these sources, having the remaining two a ROSAT and a BeppoSAX detected counterpart (C02b). One new source was recently detected by the BAT onboard Swift and it was followed up down to the likely level of quiescence (Wijnands et al. 2009).

We observed the original set of seven sources with Swift XRT (see Table 12). We confirm and improve the detections in quiescence of SAX J1754 and SAX J2225, and discover the counterpart to SAX J1754. For SAX J1752 we do not have enough data. For the other three sources we detect possible counterparts with different degrees of certainty. From this limited sample we can hint that a common characteristic seems to be a hardness of the X-ray spectrum in quiescence. This is at variance with classical neutron star transients in quiescence (Campana et al. 1998) but is more common in lower luminosity transient in quiescence as accreting millisecond X-ray pulsars. We also infer the presence of some variability in many of the proposed counterparts in quiescence, which likely is a common characteristic of neutron star transients in quiescence (Campana et al. 2004b).

In addition to burst-only sources we also observed three faint persistent (or quasi-persistent) sources with Swift XRT (see Table 12). These sources are characterized by strong variability (and RXS J1718 showed an outburst). These sources have softer spectra and higher "quiescent" fluxes with respect to burst-only sources.

The comparison between the two classes calls for an explanation. Faint persistent bursting sources are difficult to explain within disk instability models. In our sample RXS J1708 has the highest mean persistent luminosity (around $10^{36}$ erg s$^{-1}$) and can be accounted for by a ~60 minute binary system with...
a $\sim 0.1 ~M_\odot$ companion. Such a system can provide the required mean accretion rate (e.g., Bildsten & Chakrabarty 2001; King 2000) and retain a stable accretion disk (e.g., Lasota et al. 2008). On the contrary RXS J1718 and XMMU J1747 have lower mean luminosities ($\sim 5 \times 10^{34} ~\text{erg s}^{-1}$) and to maintain a stable system very short orbital periods ($\lesssim 10$ min) and very low mass companions ($\lesssim 0.01 ~M_\odot$) are needed. These constraints seem to be too demanding and we suggest that these systems are instead quasi-persistent systems (as already suggested for XMMU J1747), i.e., with long outbursts like classical transients as KS1731−260 or EXO 0748−676 but they will likely turn down to quiescence in the next years.

For burst-only sources we have detected three out of seven sources in outburst, likely indicating that these sources are really transient in nature. Swift J1749, if typical, indicates that outbursts are faint and very short (from outburst to quiescence in less than a week). This can explain why peak luminosities and mean accretion rates (for typical $\sim 10^4$ duty cycles) of burst-only sources are very low, hinting to VFXTs. King & Wijnands (2006) discussed several possibilities to explain the nature of VFXTs. The only one working with neutron star primaries concerns systems that formed with brown dwarfs (or even planetary systems) from the beginning or high-inclination systems. We note here that the column densities we found for burst-only sources are consistent (or less) than the Galactic value, thus, constraining the presence of additional material.

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Table 12
Observational Summary

| Source             | Counterpart | Quiescent $L^*$ \((\text{erg s}^{-1})\) | Outburst | Maximum Observed $L^*$ \((\text{erg s}^{-1})\) |
|--------------------|-------------|--------------------------------|----------|--------------------------------|
| SAX J1324.5−6361   | ?           | $< 7 \times 10^{33}$          | N        | ...                             |
| SAX J1752.3−3138   | N           | $\lesssim 1 \times 10^{33}$   | Y        | $\lesssim 5 \times 10^{35}$     |
| SAX J1806.5−2215   | ?           | $\lesssim 4 \times 10^{33}$   | Y        | $\lesssim 2 \times 10^{36}$     |
| SAX J1818.7+1424   | ?           | $< 7 \times 10^{32}$          | N        | ...                             |
| SAX J1828.5−1037   | Y           | $6 \times 10^{32}$            | Y        | $\lesssim 1 \times 10^{36}$     |
| SAX J2224.9+5421   | Y           | $8 \times 10^{32}$            | N        | ...                             |
| Swift J1749.4−2807 | Y           | $\lesssim 3 \times 10^{32}$   | Y        | $\lesssim 1 \times 10^{36}$     |

Notes.

a Unabsorbed luminosity in the 0.5−10 keV energy band. Here we indicate upper limits since we have just an upper limit to the distance from Type I bursts.

b Given the very high absorption we quote the unabsorbed luminosity in the 2−10 keV energy band.