Monitoring supergiant fast X-ray transients with Swift: results from the first year

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ABSTRACT
The advent of Swift has allowed, for the first time, the possibility to give supergiant fast X-ray transients (SFXTs), the new class of high-mass X-ray binaries discovered by the International Gamma-Ray Astrophysics Laboratory, non-serendipitous attention throughout most phases of their life. In this paper, we present our results based on the first year of intense Swift monitoring of four SFXTs, IGR J16479−4514, XTE J1739−302, IGR J17544−2619 and AX J1841.0−0536. We obtain the first assessment of how long each source spends in each state using a systematic monitoring with a sensitive instrument. The duty-cycle of inactivity is ∼17, 28, 39 and 55 per cent (∼5 per cent uncertainty), for IGR J16479−4514, AX J1841.0−0536, XTE J1739−302 and IGR J17544−2619, respectively, so that true quiescence, which is below our detection ability even with the exposures we collected in 1 yr, is a rare state, when compared with estimates from less sensitive instruments. This demonstrates that these transients accrete matter throughout their lifetime at different rates. AX J1841.0−0536 is the only source which has not undergone a bright outburst during our monitoring campaign. Although individual sources behave somewhat differently, common X-ray characteristics of this class are emerging, such as outburst lengths well in excess of hours, with a multiple peaked structure. A high dynamic range (including bright outbursts) of ∼4 orders of magnitude has been observed in IGR J17544−2619 and XTE J1739−302, of ∼3 in IGR J16479−4514 and of about 2 in AX J1841.0−0536 (this lowest range is due to the lack of bright flares). We also present a complete list of Burst Alert Telescope (BAT) on-board detections, which complements our previous work, and further confirms the continuous activity of these sources. We performed out-of-outburst intensity-based spectroscopy. In particular, spectral fits with an absorbed blackbody always result in blackbody radii of a few hundred metres, consistent with being emitted from a small portion of the neutron star surface, very likely the neutron star polar caps. We used the whole BAT data set, since the beginning of the mission, to search for periodicities due to orbital motion and found $P_{\text{orb}} = 3.32$ d for IGR J16479−4514, confirming previous findings. We also present the Ultraviolet/Optical Telescope (UVOT) data of these sources; we show the UVOT light curves of AX J1841.0−0536 and the ones of XTE J1739−302 before, during and after the outbursts.

Key words: X-rays: binaries – X-rays: individual: IGR J16479−4514 – X-rays: individual: XTE J1739−302 – X-rays: individual: IGR J17544−2619 – X-rays: individual: AX J1841.0−0536.

1 INTRODUCTION
Supergiant fast X-ray transients (SFXTs) are a subclass of high-mass X-ray binaries (HMXBs) recently discovered by the
2 OUR SAMPLE AND OBSERVATIONS

The four targets, IGR J16479−4514, XTE J1739−302, IGR J17544−2619 and AX J1841.0−0536, were selected by considering sources which, among several SFXT candidates, are confirmed SFXTs, i.e. they display both a ‘short’ transient (and recurrent) X-ray activity and they have been optically identified with supergiant companions (see Walter & Zurita Heras 2007, and references therein). XTE J1739−302 and IGR J17544−2619, in particular, are generally considered prototypical SFXTs: XTE J1739−302 was the first transient which showed an unusual X-ray behaviour (Smith et al. 1998), only recently optically associated with a blue supergiant (Negueruela et al. 2006). AX J1841.0−0536/IGR J18410−0535, was chosen because at the time it was the only SFXT, together with IGR J11215−5952, where a pulsar had been detected (Bamba et al. 2001). Finally, IGR J16479−4514 had displayed in the past a more frequent X-ray outburst occurrence than other SFXTs (see e.g. Walter & Zurita Heras 2007), and offered an a priori better chance to be caught during an outburst.

For these sources, we obtained two to three observations week−1 object−1, each 1 ks long with XRT in AUTO mode, to best exploit XRT automatic mode switching (Hill et al. 2005) in response to changes in the observed fluxes. This observing pace would naturally fit in the regular observation scheduling of gamma-ray bursts (GRBs), which are the main observing targets for Swift. We also proposed for further target of opportunity (ToO) observations whenever one of the sources showed interesting activity, (such as indications of an imminent outburst) or underwent an outburst, thus obtaining a finer sampling of the light curves and allowing us to study all phases of the evolution of an outburst.

During the first year, we collected a total of 330 Swift observations as part of our program, for a total net XRT exposure of 363 ks accumulated on all sources and distributed as shown in Table 1.

In this paper, we also include the data on the 20 d campaign (for a total on-source time of 34 ks) on IGR J16479−4514, which triggered the BAT on 2009 January 29 at 06:33 UT (image trigger = 341 452, Romano et al. 2009b). Swift slewed to the target so that the XRT started observing the field at 06:46:46.9 UT, 819.3 s after the BAT trigger. The BAT transient monitor showed enhanced emission (in excess of 20 mCrab) from 01:38:56 to 07:02:08 UT. During the image trigger interval (the 640 s starting on 2009 January 29 at 06:27:5) the rate was 0.022 ± 0.003 counts s−1 (97 mCrab). IGR J16479−4514 showed renewed activity on 2009 February 8, starting from about 20:30 UT (La Parola et al. 2009). For the 504 s pointing starting on 2009 February 08 at 20:30 UT the BAT transient monitor rate was 0.019 ± 0.003 counts s−1 (85 mCrab).

3 DATA REDUCTION

The XRT data were uniformly processed with standard procedures (XRTPIPELINE v0.11.6), filtering and screening criteria by using FTOOLS in the HEASOFT package (v.6.4). We considered both windowed timing (WT) and photon counting (PC) data, and selected event grades 0–2 and 0–12, respectively (Burrows et al. 2005). When appropriate, we corrected for pile-up by determining the size of the point spread function (PSF) core affected by comparing the observed and nominal PSF (Vaughan et al. 2006), and excluding from the analysis all the events that fell within that region. We used the spectral redistribution matrices v010 in the HEASARC Calibration Database (CALDB).
We retrieved the BAT orbit-by-orbit light curves (15–50 keV) covering the data range from 2005 February 12 to 2008 December 31 (MJD range 53413–54831) from the BAT transient monitor (Roming et al. 2005, 2008) page.¹

The UVOT observed the four targets simultaneously with the XRT with the ‘Filter of the Day’, i.e. the filter chosen for all observations to be carried out during a specific day in order to minimize the filter wheel usage. The only exceptions are the observations during outbursts, when all filters were used in the typical GRB sequence (Roming et al. 2005). The data analysis was performed using the UVOTIMSUM and UVOTSOURCE tasks included in the FTOOLS software. The latter task calculates the magnitude through aperture photometry within a circular region and applies specific corrections due to the detector characteristics. The reported magnitudes are on the UVOT photometric system described in Poole et al. (2008), and are not corrected for Galactic extinction. At the position of IGR J16479−4514, no detection was achieved down to a limit of $u = 21.07$ mag. For IGR J17544−2619, only engineering data were collected, as is generally the case for a field which contains a source too bright to be observed; the only exceptions were the outburst segments 0008224000, and the two following it, 00035056021 and 00035056023 (see Table 7, and Paper III), where we observe $v = 12.8$ mag and $uvw2 = 18.13 \pm 0.05$ and $18.00 \pm 0.06$ mag, respectively.

All quoted uncertainties are given at 90 per cent confidence level for one interesting parameter unless otherwise stated. The spectral indices are parametrized as $F_{\nu} \propto \nu^{-\alpha}$, where $F_{\nu}$ (erg cm$^{-2}$ s$^{-1}$ Hz$^{-1}$) is the flux density as a function of frequency $\nu$; we adopt $\Gamma = \alpha + 1$ as the photon index, $N(E) \propto E^{-\Gamma}$ (ph cm$^{-2}$ s$^{-1}$ keV$^{-1}$).

4 TIMING

4.1 XRT inactivity duty cycle

Fig. 1 shows the XRT light curves collected from 2007 October 26 to 2008 November 15, in the 0.2–10 keV band, which were corrected for pile-up, PSF losses and vignetting, and background-subtracted. Each point in the light curves refers to the average flux observed during each observation performed with XRT; the exceptions are the outbursts (listed in Table 1) where the data were binned to include at least 20 source counts per time bin to best represent the count rate dynamical range. Due to the sources being Sun-constrained between roughly 2007 December and 2008 January, depending on the target coordinates, no data were collected during those months.

Given the structure of the observing plan, we can realistically consider our monitoring as a casual sampling of the light curve at a resolution of about ~4 d. Therefore, we can calculate the percentage of time each source spent in each relative flux state. In order to do this, we divided the observations into three states, namely (i) BAT-detected outburst, (ii) intermediate state (all observations yielding a firm detection excluding outburst ones) and (iii) ‘non-detections’ (detections with a significance below 3σ). Since a few observations were interrupted by GRB events, the consequent non-detection may be due to the short exposure, not exclusively to the source being faint. Therefore, to create a uniform subsample for the latter state, we excluded all observations that had a net exposure below 900 s.

An exposure of 900 s corresponds to 2–10 keV flux limits that vary between 1 and $3 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ (3σ), depending on the source. These values were derived from a measurement of the local background and a count rate to flux conversion calculated by using the best fit absorbed power-law models of the ‘low’ (or ‘medium’ if ‘low’ was not available) state in Table 4.

We define as duty cycle of inactivity, the time each source spends undetected down to a flux limit of $1–3 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$.

\[
\text{ IDC} = \Delta T_{\Sigma} / \left[ \Sigma \Delta T_{\text{tot}}(1 - P_{\text{short}}) \right],
\]

where $\Delta T_{\Sigma}$ is sum of the exposures accumulated in all observations, each in excess of 900 s, where only a 3σ upper limit was achieved (Table 2, Column 5), $\Delta T_{\text{tot}}$ is the total exposure accumulated (Table 1, Column 5) and $P_{\text{short}}$ is the percentage of time lost to short observations (exposure <900 s, Table 2, Column 6). We obtain that IDC $\sim 17$, 28, 39, 55 per cent, for IGR J16479−4514, AX J1841.0−0536, XTE J1739−302 and IGR J17544−2619, respectively (Table 2, Column 7). We estimate an error of $\sim 5$ per cent on these values.

We accumulated all data for which no detections were obtained as single exposures (whose total exposure is $\Delta T_{\Sigma}$), and performed a

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¹ http://swift.gsfc.nasa.gov/docs/swift/results/transients/

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Table 1. Summary of the Swift/XRT monitoring campaign of the four SFXTs during the first year.

| Name          | Campaign start (yyyy-mm-dd) | Campaign end (yyyy-mm-dd) | N⁴ | Exposure⁵ (ks) | Outburst dates (yyyy-mm-dd) | BAT trigger | References               |
|---------------|-----------------------------|---------------------------|----|---------------|-----------------------------|-------------|--------------------------|
| IGR J16479−4514 | 2007-10-26                   | 2008-10-25                 | 70 | 75.2          | 2008-03-19, 2008-05-21, 2009-01-29 | 306 829     | Romano et al. (2008c)    |
| XTE J1739−302   | 2007-10-27                   | 2008-10-31                 | 95 | 116.1         | 2008-04-08, 2008-08-13, 2009-03-10 | 308 797     | Sidoli et al. (2009b)   |
| IGR J17544−2619 | 2007-10-28                   | 2008-10-31                 | 77 | 74.8          | 2007-11-08, 2008-03-31, 2009-09-04 | 308 224     | Romano et al. (2009a)    |
| AX J1841.0−0536 | 2007-10-26                   | 2008-10-15                 | 88 | 96.5          | None                        | None        | Krimm, Romano & Sidoli (2009) |
| Total          |                             |                           | 330| 362.6         |                             |             |                          |
referred to the Solar system barycentre (SSB) by using the task EARTH2SUN.

A folding technique was applied to the baricentred arrival times by searching in the 0.1–50 d period range and by building 16 bin pulse profiles with a step given by $P^2/(N \Delta T)$, where $N$ is the number of phase bins and $\Delta T$ is the data span length. We find significant evidence for orbital modulation for IGR J16479–4514 with a best period of $286.792 \pm 42$ s ($P_{\text{orb}} = 3.3193 \pm 0.0005$ d) referred to the epoch time MJD 54170.2050213, with a $\chi^2$ value of 155.8. As shown in the periodogram in Fig. 2(a), this periodicity stands out from the noise and is certainly not due to the satellite orbital period or its multiples, as instead is the case for the peaks appearing below 1 d. Peaks at periods higher than 5 d are multiples of the $P_{\text{orb}}$. A zoomed-in region of the periodogram around the candidate $P_{\text{orb}}$ is shown in Fig. 2(b). The statistics of the data is not Gaussian, so assessment of the significance of this periodicity needs to be performed on the noise distribution of $\chi^2$ in the periodogram. Fig. 2(c) represents the noise distribution of the powers of the periodogram after removal of the satellite orbital data period (and its multiples), and of the multiples of $P_{\text{orb}}$. In order to evaluate the significance of the signal at $P_{\text{orb}}$, we fit the distribution for $25 < \chi^2 < 80$ with an exponential function and evaluated the integral of the best-fitting function beyond the value of the $\chi^2$ obtained at $P_{\text{orb}}$. This integral yields a number of chance occurrences due to noise of $1.24 \times 10^{-5}$, corresponding to 4.5 standard deviations in Gaussian statistics. In Fig. 2(d), we show the pulsed profile folded at $P_{\text{orb}}$. There is clear evidence for an eclipse phase, whose epoch centroid, evaluated by fitting the data around the dip with a Gaussian function, is MJD 54171.11 ± 0.05. This confirms the results of Jain, Paul & Dutta (2009).

Adopting the same techniques for XTE J1739–302 (Fig. 3a), we find marginal evidence for a signal above the noise at 1 111 605.1 ± 631.3 s ($P_{\text{orb}} = 12.8658 \pm 0.0073$ d) with a $\chi^2$ value of 94.7. The second highest peak in Fig. 3(a) is the first multiple of $P_{\text{orb}}$. The chance probability to obtain this signal at $P_{\text{orb}}$ is $3.1 \times 10^{-5}$, corresponding to 2.1 standard deviations in Gaussian statistics. By repeating this kind of analysis on 1/4, 1/2, 3/4 and the whole BAT data sample, we verified that the power at this $P_{\text{orb}}$ increases with time baseline, as is expected of signal, as opposed to noise. This strengthens the possibility that this is a true periodicity.

No significant evidence for orbital periodicity was found for either IGR J17544–2619 or AX J1841.0–0536.

### 4.4 Searching for spin periodicities in XRT data

We also looked for evidence of spin periodicities in XRT data. For each source, we performed a timing analysis to search for coherent pulsations within each single observation with a slow Fourier analysis on the fundamental harmonics in the 0.0047–0.199 418 Hz frequency range (the latter being the Nyquist frequency of the data set, corresponding to a period of 5.01460 s), with the frequency resolution $d f = 1/(2\Delta T)$ Hz, where $\Delta T$ is the length of each observation. As the expected power of the pulsed emission is $P_s = K \times P_s^2 \times N_t + 2$, we only used observations with a minimum statistic content $N_t > 300$ counts, that would yield a detection with a significance greater than 3 standard deviations for a signal with a pulsed fraction of $F_p = 0.2$, and $K = 0.5$ (sinusoidal profile). No significant deviations from a statistically flat distribution was revealed in the Fourier spectra of these observations.

In order to reveal the presence of a pulsed signal that could be undetectable in single observations because of the poor statistics, we performed a stacked timing analysis on a larger set of observations.
Table 2. Duty cycle of inactivity of the four SFXTs.

| Name            | Limiting rate$^a$ (0.2–10 keV) (10$^{-3}$ counts s$^{-1}$) | Limiting $F_{0.2-10}$ (2–10 keV) (10$^{-12}$ erg cm$^{-2}$ s$^{-1}$) | Limiting $L_{0.2-10}$ (2–10 keV) (10$^{35}$ erg s$^{-1}$) | $\Delta T_{\Sigma}$ (ks) | $P_{\text{short}}$ (per cent) | IDC (per cent) | Rate$_{\Delta T_{\Sigma}}$ (0.2–10 keV) (10$^{-3}$ counts s$^{-1}$) |
|----------------|-------------------------------------------------------------|---------------------------------------------------------------|----------------------------------------------------------|--------------------------|-------------------------------|----------------|---------------------------------------------------|
| IGR J16479−4514 | 16                                                          | 2.4                                                          | 0.62                                                     | 12.2                     | 2                             | 17             | 2.9 ± 0.7                                         |
| XTE J1739−302  | 13                                                          | 1.6                                                          | 0.13                                                     | 40.3                     | 9                             | 39             | 3.9 ± 0.4                                         |
| IGR J17544−2619| 13                                                          | 1.2                                                          | 0.17                                                     | 37.0                     | 10                            | 55             | 1.9 ± 0.3                                         |
| AX J1841.0−0536| 13                                                          | 1.7                                                          | 0.45                                                     | 26.6                     | 3                             | 28             | 2.4 ± 0.4                                         |

Note. Count rates are in units of 10$^{-3}$ counts s$^{-1}$ in the 0.2–10 keV energy band. Observed fluxes and luminosities are in units of 10$^{-12}$ erg cm$^{-2}$ s$^{-1}$ and 10$^{35}$ erg s$^{-1}$ in the 2–10 keV energy band, respectively. $\Delta T_{\Sigma}$ is the sum of the exposures accumulated in all observations, each in excess of 900 s, where only a 3$\sigma$ upper limit was achieved; $P_{\text{short}}$ is the percentage of time lost to short observations; IDC is the duty cycle of inactivity, the time each source spends undetected down to a flux limit of 1–3 × 10$^{-12}$ erg cm$^{-2}$ s$^{-1}$; rate$_{\Delta T_{\Sigma}}$ is detailed in the text (Section 4.1).

$^a$Based on a single 900 s exposure.

$^b$Based on the best-fitting model for the ‘low’ (or ‘medium’ if ‘low’ unavailable) absorbed power-law model in Table 4.

Table 3. BAT on-board detections in the 15–50 keV band.

| MID  | Date       | Time$^a$ | BAT trigger N.$^b$ | S/N$^c$ | MID  | Date       | Time$^a$ | BAT trigger N.$^b$ | S/N$^c$ |
|------|------------|----------|--------------------|--------|------|------------|----------|--------------------|--------|
|      |            |          |                    |        |      |            |          |                    |        |
| 53612| 2005-08-30 | 04:03:28  | 152 652 (NFI)      | 7.71   | 53581| 2005-07-30 | 00:23:12 | 12:00:28           | 5.66   |
| 53811| 2006-03-17 | 08:03:51  | 35663              |        |      |            |          |                    |        |
| 53875| 2006-05-20 | 17:32:39  | 210 886 (no slew)  | 5.78   | 53765| 2006-01-30 | 18:33:43 | 20:26:15           | 4.17   |
| 53898| 2006-06-12 | 06:58:31  | 37623              |        |      |            |          |                    |        |
| 53910| 2006-06-24 | 20:19:59  | 25194 (no slew)    | 5.34   | 53806| 2006-03-12 | 04:52:31 |                    |        |
| 54095| 2006-12-26 | 22:39:43  | 22:45:03           |        |      |            |          |                    |        |
| 54167| 2007-03-08 | 06:04:55  | 34161              |        |      |            |          |                    |        |
| 54196| 2007-04-16 | 15:22:55  | 34168              |        |      |            |          |                    |        |
| 54239| 2007-05-19 | 19:53:59  | 25269              |        |      |            |          |                    |        |
| 54310| 2007-07-29 | 12:07:35  | 286 412 (no slew)  | 9.98   | 54411| 2007-11-07 | 04:38:15 | 04:42:31           | 7.83   |
| 54320| 2007-08-08 | 21:13:51  | 35646              |        |      |            |          |                    |        |
| 54386| 2007-09-25 | 18:14:31  | 35656              |        |      |            |          |                    |        |
| 54508| 2008-02-10 | 05:35:43  | 45632              |        |      |            |          |                    |        |
| 54535| 2008-03-10 | 13:11:03  | 34973              |        |      |            |          |                    |        |
| 54544| 2008-03-19 | 22:44:47  | 306 829 (NFI)      | 12.02  | 54691| 2008-08-13 | 23:49:19 | 23:51:27           | 9.15   |
| 54572| 2008-04-16 | 17:07:11  | 34962              |        |      |            |          |                    |        |
| 54607| 2008-05-21 | 06:03:13  | 312 068 (no slew)  | 7.21   | 54724| 2008-09-15 | 12:59:59 | 13:06:23           | 6.81   |
| 54664| 2008-07-17 | 18:10:15  | 54900              |        |      |            |          |                    |        |
| 54679| 2008-08-01 | 03:38:31  | 54999              |        |      |            |          |                    |        |
| 54682| 2008-08-04 | 04:06:55  | 54424              |        |      |            |          |                    |        |
| 54687| 2008-08-09 | 01:11:51  | 54197              |        |      |            |          |                    |        |
| 54826| 2008-12-26 | 15:55:11  | 35656              |        |      |            |          |                    |        |
| 54860| 2009-01-29 | 06:32:06  | 341 452 (NFI)      | 10.68  | 54396| 2006-09-18 | 09:07:43 |                    |        |
| 53996| 2006-09-18 | 09:07:43  | 53821              |        |      |            |          |                    |        |
| 53998| 2006-09-20 | 11:11:43  | 53834              |        |      |            |          |                    |        |
| 54009| 2006-10-01 | 10:34:47  | 53845              |        |      |            |          |                    |        |
| 54035| 2006-10-27 | 00:33:11  | 54026              |        |      |            |          |                    |        |
| 54372| 2007-09-29 | 13:21:51  | 54053              |        |      |            |          |                    |        |
| 54387| 2007-10-14 | 00:39:35  | 54139              |        |      |            |          |                    |        |
| 54412| 2007-11-08 | 01:31:03  | 54197              |        |      |            |          |                    |        |

$^a$Time of the start of the BAT trigger, or the time range when on-board detections were obtained.

$^b$BAT regular trigger, as was disseminated through GCNs. NFI indicates that there are data from the narrow-field instrument; no slew, indicates that Swift did not slew to the target.

$^c$On-board image significance in units of $\sigma$.

$^d$Also reported by Blay et al. (2008).

$^e$Trigger 306830 had S/N = 21.64, see Romano et al. (2008c).

$^f$Also reported by Ducci et al. (2008).
observations. This analysis consists in summing the power spectra obtained from single observations with a common frequency range (0.005–0.2 Hz) and resolution $1/2 \Delta t_{\text{max}}$, where $\Delta t_{\text{max}}$ is the elapsed time of the longest observation. The averaged power spectrum will have a distribution with mean 2 and standard deviation $2/\sqrt{N}$, where $N$ is the number of summed power spectra. However, we cannot add arbitrarily long amounts of data without taking into account the Doppler modulation due to orbital motion which could destroy the coherence of the pulsed signal. For IGR J16479–4514, for which a firm detection of a $P_{\text{orb}}$ was obtained, we could minimize the effect of the orbital Doppler modulation, by summing the spectra which are close in orbital phase. Under the simplifying assumption of a circular orbit, we evaluated the orbital phase for each XRT observation and divided the sample in four phase intervals: 0.85–0.15, 0.15–0.35, 0.35–0.65 and 0.65–0.85. The different amplitudes were chosen to take into account the different values of the tangential velocity of the compact object along its orbit. In the four stacked spectra, we found no evidence for a significant excess above the noise distribution.

4.5 Searching for eclipses in IGR J16479–4514 XRT data

The data of the whole XRT campaign on IGR J16479–4514 were sought for the presence of eclipses, suggested by Bozzo et al. (2008b) on the basis of the analysis of an XMM–Newton observation. We created event lists for the whole campaign and selected those inside and outside the eclipses, where by 'inside the eclipse' we consider the time interval between the start of the eclipse as defined by Bozzo et al. (2008b) and 0.6 d later [using the ephemeris from Jain et al. (2009)]. We then calculated the net (subtracted for scaled background) count rate in the two cases. We obtain $(6 \pm 1) \times 10^{-3}$ counts s$^{-1}$ (inside) and $0.169 \pm 0.002$ counts s$^{-1}$ (outside). Consistent values $(6 \pm 3) \times 10^{-3}$ and $0.203 \pm 0.003$ counts s$^{-1}$, respectively) are measured during the 2009 January outburst. This indicates that the source is in two distinct flux levels inside and outside the predicted times of the eclipses at the $\sim 50\sigma$ level. We also calculated the count rates within individual time slices inside eclipses and find that they never exceed 0.013 counts s$^{-1}$. We can thus conclude that the XRT data are consistent with the presence of an eclipse on the longest baseline so far examined. In particular, Fig. 4 shows the light curve of IGR J16479–4514 during the 2009 January 29 outburst with vertical lines marking the predicted positions of the eclipse times.
4.6 UVOT light curves

We report for the first time on optical/UV observations performed with UVOT simultaneously to our Swift/XRT monitoring of the SFXTs. In Figs 5(a) and (b), we show the UVOT u and uvw1 light curves of XTE J1739−302 of the whole campaign. The vertical dashed lines mark the two X-ray outbursts (2008 April 8, 2008 August 13; Fig. 5b). The ultraviolet filters only registered upper limits for this source during the outbursts. We consider the correspondence between the X-ray peak and the u magnitude. During the first outburst, the u band shows an increase of ~0.9 mag with respect to the campaign mean or a factor of ~2.5 in flux. Depending on the choice of background regions, this is a 2–3σ effect. During the second outburst, the u magnitude is consistent with the mean for the whole campaign; the b and v magnitudes, collected as part of the GRB-chasing filter scheme, show the same level as in the first one. The uvw1 magnitudes show a larger degree of variability when compared with the u band. We also investigated intra-day variability during the outbursts, but found no significant variation within the errors in all bands.

In Figs 6(a)–(c), we show the UVOT u and uvw1, and uvw2 light curves of AX J1841.0−0536. The u and uvw1 are remarkably stable, while the uvw2 show some degree of variability. We note that the highest point in the uvw2 light curve is not simultaneous with the X-ray peak.

5 X-RAY SPECTROSCOPY

5.1 The 2009 January 29 outburst of IGR J16479−4514

In response to the 2009 January 29 outburst of IGR J16479−4514, Swift performed a delayed slew, so that the NFI were on target >800 s after the trigger (Romano et al. 2009b). At this point, the flux registered by the BAT was rather low, and meaningful broad-band (XRT+BAT) spectroscopy is not possible, given the 107 s overlap in the observations. Therefore, here we only report the fits to the XRT data. An absorbed power-law model yielded an absorbing column of $N_H = (7.1^{+2.6}_{−1.0}) \times 10^{23}$ cm$^{-2}$, a photon index $\Gamma = 1.6 \pm 0.5$, and an unabsorbed flux in the 2–10 keV band is $2 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$. The X-ray spectrum extracted from segment 00030296087, when the source showed rebrightening (La Parola et al. 2009), was also fit with an absorbed power-law model, obtaining $\Gamma = 1.3 \pm 0.5$, $N_H = (7.1^{+2.6}_{−2.0}) \times 10^{22}$ cm$^{-2}$ and unabsorbed flux in the 2–10 keV band of $3 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$. These results are generally consistent with the ones found in Paper II, which describes the outburst of this source which occurred on 2008 March 19, 315 d earlier. We also note that, as found in Paper II, the derived $N_H$ is in excess of the one along the line of sight, $1.87 \times 10^{22}$ cm$^{-2}$. The broad-band spectroscopy of the other outbursts caught during the campaign has already been reported on elsewhere (Papers II, III and IV; see Table 1) and we will also summarize them below.

5.2 Out-of-outburst X-ray spectroscopy

In the remainder of this section, we concentrate on the out-of-outburst emission. To characterize the spectral properties of the sources in several states, we accumulated the events in each observation when the source was not in outburst and a detection was achieved. For these events, we estimated from the light curves (binned at a 100 s resolution) three count rate levels, $CR_1$, $CR_2$ and $CR_3$ (reported in Table 4) that would yield comparable statistics
(and at least 1600 counts) in the ranges \( CR_1 < CR < CR_2 \) (low), \( CR_2 < CR < CR_3 \) (medium) and \( CR > CR_3 \) (high). If the statistics did not allow this, then we only considered two intensity levels (high and medium). Exposure maps were created for each of these intensity-selected event files. We then combined the intensity-selected event files (and their exposure maps) and extracted a single spectrum for each source by integrating over all the available observing time within these intensity limits. Ancillary response files were generated with xrtmkarf, and they account for different extraction regions, vignetting and PSF corrections. The spectra were rebinned with a minimum of 20 counts per energy bin to allow \( \chi^2 \) fitting. Each spectrum was fit in the energy range 0.3–10 keV with a single absorbed power law, or an absorbed blackbody.

### Table 4. XRT spectroscopy of the four SFXTs (2007+2008 data set).

| Name | Spectrum | Rate (counts s\(^{-1}\)) | \( N_H \) (10\(^{22}\) cm\(^{-2}\)) | Parameter | Hardness\(^a\) ratio | Flux\(^b\) (2–10 keV) | Luminosity\(^c\) (2–10 keV) | \( \chi^2 \)/dof\(^d\) Cstat (per cent) |
|------|---------|----------------|-----------------|---------|----------------|----------------|----------------|----------------|----------------|
| IGR J16479–4514 | High | >0.52 | 7.0\(^{+0.8}_{-0.7}\) | 1.2\(^{+0.2}_{-0.2}\) | 120 | 5 | 1.1/131 |
| | Medium | [0.25–0.52] | 9.3\(^{+1.1}_{-1.0}\) | 1.5\(^{+0.2}_{-0.2}\) | 54 | 3 | 1.0/132 |
| | Low | [0.06–0.25] | 6.7\(^{+0.7}_{-0.7}\) | 1.4\(^{+0.2}_{-0.2}\) | 19 | 0.8 | 0.9/144 |
| | Very low\(^e\) | <0.06 | 3.3\(^{+1.4}_{-1.0}\) | 1.5\(^{+0.5}_{-0.4}\) | 1.8 | 0.04 | 482.3 (89.3) |
| | Very low\(^f\) | <0.06 | 0.3\(^{+0.6}_{-0.3}\) | 0.3\(^{+0.5}_{-0.4}\) | 0.9 \pm 0.3 | 1.8 | 0.05 | 471.5 (50.2) |
| XTE J1739–302 | High | >0.33 | 2.7\(^{+0.5}_{-0.4}\) | 0.9\(^{+0.2}_{-0.2}\) | 120 | 1 | 1.1/77 |
| | Medium | [0.07–0.33] | 3.6\(^{+0.6}_{-0.5}\) | 1.6\(^{+0.2}_{-0.2}\) | 15 | 0.2 | 0.9/73 |
| | Very low\(^e\) | <0.07 | 1.7\(^{+0.2}_{-1.0}\) | 1.3\(^{+0.3}_{-0.3}\) | 0.5 | 0.005 | 614.3 (96.3) |
| | Very low\(^f\) | <0.07 | 0.3\(^{+0.2}_{-0.2}\) | 0.5\(^{+0.3}_{-0.3}\) | 0.6 | 0.006 | 598.9 (64.7) |
| IGR J17544–2619 | High | >0.33 | 1.5\(^{+0.3}_{-0.3}\) | 1.4\(^{+0.2}_{-0.2}\) | 62 | 1 | 0.9/75 |
| | Medium | [0.07–0.33] | 2.1\(^{+0.3}_{-0.3}\) | 1.8\(^{+0.2}_{-0.2}\) | 14 | 0.3 | 1.0/72 |
| | Very low\(^e\) | <0.07 | 1.1\(^{+0.1}_{-0.0}\) | 2.2\(^{+0.4}_{-0.4}\) | 0.2 | 0.002 | 381.8 (83.0) |
| | Very low\(^f\) | <0.07 | 0.4\(^{+0.3}_{-0.3}\) | 1.4\(^{+0.4}_{-0.4}\) | 0.2 | 0.003 | 372.0 (53.1) |
| AX J1841.0–0536 | High | >0.4 | 2.5\(^{+0.3}_{-0.3}\) | 1.1\(^{+0.1}_{-0.1}\) | 80 | 3 | 1.2/110 |
| | Medium | [0.18–0.4] | 3.2\(^{+0.5}_{-0.5}\) | 1.3\(^{+0.2}_{-0.2}\) | 34 | 1 | 1.1/102 |
| | Low | [0.05–0.18] | 3.5\(^{+0.5}_{-0.5}\) | 1.5\(^{+0.2}_{-0.2}\) | 11 | 0.4 | 1.2/104 |
| | Very low\(^e\) | <0.05 | 0.3\(^{+0.3}_{-0.3}\) | 0.6\(^{+0.4}_{-0.4}\) | 1.3 \pm 1.0 | 0.6 | 0.02 | 449.5 (54.7) |

\(^a\)Hardness ratio 4–10 keV/0.2–4 keV.
\(^b\)Average observed 2–10 keV fluxes in units of 10\(^{-12}\) erg cm\(^{-2}\) s\(^{-1}\).
\(^c\)Average 2–10 keV X-ray luminosities in units of 10\(^{35}\) erg s\(^{-1}\) calculated adopting distances determined by Rahoui et al. (2008).
\(^d\)Reduced \( \chi^2 \) and dof, or Cash statistics Cstat and percentage of realizations (10\(^4\) trials) with statistic >Cstat.
\(^e\)Fit performed with constrained column density (see Section 5.2).
\(^f\)Fit performed with free column density (see Section 5.2).
We also extracted spectra from the event list accumulated from all observations for which no detections were obtained as single exposures (very low). These spectra consisted of \(\sim 100\) counts each, so Cash (1979) statistics and spectrally unbinned data were used, instead. When fitting with free parameters, the best fitting value for \(N_H\) turned out to be consistent with 0, i.e. well below the column derived from optical spectroscopy. In this case, we performed further fits by adopting as lower limit on the absorbing column the value derived from the Galactic extinction estimate along the line of sight to each source from Rahoui et al. (2008), with a conversion into hydrogen column, \(N_H = 1.79 \times 10^{21} A_V\) cm\(^2\) (Predehl & Schmitt 1995). As a comparison, we also report the simple hardness ratios.

The spectra and contour plots of photon index versus column density are shown in Figs 7 and 8, respectively, while the spectral parameters are reported in Table 4, where we also report the average 2–10 keV luminosities calculated by adopting distances determined by Rahoui et al. (2008) from optical spectroscopy of the supergiant companions (4.9 kpc for IGR J16479−4514, 2.7 kpc for XTE J1739−302 and 3.6 kpc for IGR J17544−2619). For AX J1841.0−0536, two estimates of the distance are available, (Nespoli, Fabregat & Mennickent 2008, 3.2\(^+2\) \(-1\) kpc) and Sguera et al. (2009, 6.9 \pm 1.7 kpc), and we assumed a distance of 5 kpc, which is consistent with both.

We note that spectral fits with an absorbed blackbody always result in blackbody radii of a few hundred metres (at the source distances, see Table 4 and Fig. 9), consistent with being emitted from a small portion of the neutron star surface, very likely the neutron star polar caps (Hickox, Narayan & Kallman 2004). Indeed, since SFXTs are wind accretors, alternative origins for the small emitting region, such as small hot regions in an accretion disc, can be discarded.
Figure 7. Spectroscopy of the 2007–2008 observing campaign. Upper panels: XRT/PC data fit with an absorbed power law. Lower panels: the residuals of the fit (in units of standard deviations). Filled blue circles, green empty circles and red filled triangles mark high, medium and low states, respectively.

Figure 8. XRT time selected spectroscopy. The $\Delta \chi^2 = 2.3, 4.61$ and 9.21 contour levels for the column density in units of $10^{22}$ cm$^{-2}$ versus the photon index, with best fits indicated by crosses. The colour scheme is the same as in Fig. 7. The labels L, M and H mark low, medium and high states, respectively.

6 DISCUSSION

We report on the results of an entire year of monitoring campaign with Swift of a subsample of SFXTs. For the first time, it is possible to investigate in depth the long-term properties of this new class of puzzling X-ray transients, assessing the characteristics of three different source states: the bright outbursts, the intermediate intensity state and the quiescence.

During this first year of monitoring, we have obtained multiwavelength observations of five outbursts of three different sources (see Table 1). As reported in Papers II, III and IV, we studied the broadband simultaneous spectra (0.3–150 keV) of three SFXTs. They can...
be fit with models traditionally adopted for accreting X-ray pulsars (absorbed cut-off power laws), even in the objects where proof of the presence of a neutron star (as derived from a spin period) is still unavailable. Considerable differences can be found in the behaviour of the absorbing column among the examined cases, and the new data from the 2009 January 29 outburst of IGR J16479–4514 fit well in this picture.

Our Swift monitoring campaign has demonstrated for the first time that X-ray emission from SFXTs is still present outside the bright outbursts, although at a much lower level ($10^{33}–10^{34}$ erg s$^{-1}$). This was already emerging from the first 4 months of this campaign (Paper I), but now we have accumulated enough statistics to allow intensity selected spectroscopy of the out-of-outburst emission. Spectral fits performed adopting simple models, such as an absorbed power law or a blackbody (more complex models were not required by the data) result in hard power law photon indices (always in the range $\Gamma \sim 0.8–2$) or in hot black bodies ($kT_{bb} \sim 1–2$ keV). It is remarkable that the statistics now accumulated allow us to constrain well the spectral parameters of the intermediate level of X-ray emission: in particular, when a blackbody model is adopted, the resulting radii of the emitter for all four SFXTs (and all the intensity states) is always only a few hundred metres (note that even with several kpc of uncertainty in the distance determination, the emitting regions are always significantly smaller than the neutron star radius). This is clearly indicative of an emitting region which is only a fraction of the neutron star surface, and can be associated in a natural way with the polar caps of the neutron star (Hickox et al. 2004). This evidence, coupled with the high level of flux variability and hard X-ray spectra, strongly supports the fact that the intermediate- and low-intensity level of SFXTs is produced by the accretion of matter onto the neutron star, demonstrating that SFXTs are sources which do not spend most of their lifetime in quiescence.

After following the X-ray light curves of the four SFXTs for 1 yr, we have obtained the first assessment of how long each source in our sample spends in each state using a systematic monitoring. The duty-cycle of inactivity is $\sim 17, 28, 39, 55$ per cent (5 per cent uncertainty), for IGR J16479–4514, AX J1841.0–0536, XTE J1739–302 and IGR J17544–2619, respectively. For IGR J16479–4514 a contribution to the time spent in inactivity is due to the X-ray eclipses, hence the above 17 per cent is in fact an upper limit to the true quiescent time. In the latter three SFXTs, this inactivity duty cycle, where the sources are undetected with Swift, can be associated with the true quiescence (i.e. no accretion) and/or with an accretion at a very low rate. Thus, the quiescence in these transients is a rare state.

The lowest luminosity level we could monitor (‘very low’ intensity level in Table 4) with Swift is reached in XTE J1739–302 ($6 \times 10^{32}$ erg s$^{-1}$, 2–10 keV) and in IGR J17544–2619 ($3 \times 10^{32}$ erg s$^{-1}$). This latter value is consistent with the quiescent state observed in IGR J17544–2619 during a Chandra observation (5.2 $\pm$ 1.3 $\times$ 10$^{32}$ erg s$^{-1}$, 0.5–10 keV; in’t Zand 2005), although the two spectra are very different. During the Chandra observation the spectrum was very soft, likely thermal (fitted with a power law resulted in a photon index $\Gamma = 5.9 \pm 1.2$), whereas our accumulated spectrum during the very-low-intensity state is much harder ($\Gamma \sim 1–2$), very likely implying low-rate accretion onto the compact object. The lowest level of X-ray emission ever detected from XTE J1739–302 has been observed with ASCA (1.1 $\times$ 10$^{-26}$ erg cm$^{-2}$ s$^{-1}$, 2–10 keV; Sakano et al. 2002), which is much lower than that observed with Swift. This comparison, together with the hard spectrum and the small emitting radius (see Table 4) observed with Swift implies that we have not reached the quiescent state in this source. Besides IGR J17544–2619, the only other SFXTs where the quiescence (characterized by a soft thermal spectrum and a very low luminosity of $\sim$10$^{32}$ erg s$^{-1}$) has been caught is IGR J08408–4503 (Leyder et al. 2007).

The low-intensity level we observe with Swift in IGR J16479–4514 is consistent with it being due to the X-ray eclipses. The possibility of an X-ray eclipse in this transient was originally suggested by Bozzo et al. (2008b), based on the variability of the iron line emission observed during an XMM–Newton observation. Then, Jain et al. (2009) found a periodicity at 3.32 d, suggesting it as a possible orbital period. We were able to confirm this periodicity from our independent analysis of the BAT data.

If we assume that this periodicity is of orbital origin, and consider a duration of the X-ray eclipse of 0.6 d (Jain et al. 2009), then the inclination $i$ of the system can be derived from the eclipse semi-angle, $\theta_e$, for an assumed supergiant radius ($R_{OB} = 23.8 R_\odot$ for a O8.5 supergiant; Vacca, Garmany & Shull 1996) as $R_{OB} = a \sqrt{\cos^2 i + \sin^2 i \sin^2 \theta_e}$. Assuming the system parameters previously adopted for IGR J16479–4514, we obtain a binary separation $a = 2 \times 10^{12}$ cm, implying an orbital inclination of $i \approx 40^\circ$.

This 3.32 d periodicity, if interpreted as the orbital period of the binary system, is puzzling, and is very difficult to reconcile with all the mechanisms proposed to explain the SFXTs phenomenon. The out-of-eclipse average X-ray luminosity of IGR J16479–4514 is $L_{X,av} \approx 10^{34}–10^{35}$ erg s$^{-1}$. It can be compared with the X-ray emission expected from Bondi–Hoyle accretion onto a neutron star. Let us assume a circular orbit (very likely, given the short period), a stellar mass of $M_{\ast} = 30 M_\odot$, a radius $R_{OB} = 23.8 R_\odot$ for the supergiant (Vacca et al. 1996), a beta-law velocity for the supergiant wind ($v(r) = v_{\infty}(1 - R_{OB}/r)^{\beta}$ with $\beta = 1$, and a conservative high terminal velocity $v_{\infty} = 2000$ km s$^{-1}$. Under these assumptions, the X-ray luminosity produced by the wind accretion for a reasonable choice of the wind mass-loss rate ($\dot{M}_w = 10^{-6} M_\odot$ yr$^{-1}$) is $\sim 10^{37}$ erg s$^{-1}$, about 2–3 orders of magnitude higher than the observed luminosity. On the other hand, the observed low
luminosity can be obtained only at a wind mass-loss rate of $M_{\text{obs}} \approx 10^{-8} - 10^{-9} \ M_\odot \ yr^{-1}$, which is not reasonable for a O8.5 supergiant.

A viable explanation to this inconsistency could be that the 3.32 d periodicity is not orbital, but is only one of the periodicities predicted in our model for the explanation of SFXTs outbursts, that is the time interval between the periodically recurrent flares when the neutron star passes throughout the preferential plane for the outflowing wind from the supergiant, twice per orbit; thus, the true orbital period can be much longer than this periodicity found (see the different geometries proposed in Sidoli et al. 2007).

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REFERENCES

Bamba A., Yokogawa J., Ueno M., Koyama K., Yamauchi S., 2001, PASJ, 53, 1179
Barthelmy S. D. et al., 2005, Space Sci. Rev., 120, 143
Blay P. et al., 2008, A&A, 489, 669
Bozzo E., Falanga M., Stella L., 2008a, ApJ, 683, 1031
Bozzo E., Stella L., Israel G., Falanga M., Campana S., 2008b, MNRAS, 391, L108
Burrows D. N. et al., 2005, Space Sci. Rev., 120, 165
Cash W., 1979, ApJ, 228, 939
Ducci L., Sidoli L., Paizis A., Mereghetti S., 2008, in Proc. 7th INTEGRAL Workshop, PoS(Integral08), 086, preprint (arXiv:0810.5463)
Gehrels N. et al., 2004, ApJ, 611, 1005
Hickox R. C., Narayan R., Kallman T. R., 2004, ApJ, 614, 881
Hill J. E. et al., 2005, Proc. SPIE, 5165, 217
in ‘t Zand J. J. M., 2005, A&A, 441, L1
Jain C., Paul B., Dutta A., 2009, MNRAS, 397, L11
Krimm H. et al., 2006, Astron. Tel., 904
Krimm H. A. et al., 2007, Astron. Tel., 1265
Krimm H. A., Barthelmy S. D., Cummings J. R., Markwardt C. B., Skinner G., Tueller J., Swift/BAT Team, 2008, in AAS/High Energy Astrophysics Division, Vol. 10, Status of the Swift/BAT Hard X-ray Transient Monitor. American Astron. Soc., Los Angeles, p. 07.01
Krimm H. A., Romano P., Sidoli L., 2009, Astron. Tel., 1971
La Parola V. et al., 2009, Astron. Tel., 1929
Leyder J.-C., Walter R., Lazos M., Masetti N., Produt N., 2007, A&A, 465, L35
Negueruela I., Smith D. M., Harrison T. E., Torrejón J. M., 2006, ApJ, 638, 982
Negueruela I., Torrejón J. M., Reig P., Ribó M., Smith D. M., 2008, in AIP Conf. Ser. Vol. 1010, A Population Explosion: The Nature & Evolution of X-ray Binaries in Diverse Environments. Am. Inst. Phys., New York, p. 252
Nespoli E., Fabregat J., Mennciek R. E., 2008, A&A, 486, 911
Poole T. S. et al., 2008, MNRAS, 383, 627
Predehl P., Schmitt J. H. M. M., 1995, A&A, 293, 889
Rahoui F., Chaty S., Lagage P.-O., Pantin E., 2008, A&A, 484, 801
Romano P., Sidoli L., Mangano V., Mereghetti S., Cusumano G., 2007, A&A, 469, L5
Romano P. et al., 2008a, Astron. Tel., 1697
Romano P. et al., 2008b, Astron. Tel., 1659
Romano P. et al., 2008c, ApJ, 680, L137 (Paper II)
Romano P. et al., 2009a, Astron. Tel., 1961
Romano P. et al., 2009b, Astron. Tel., 1920
Roming P. W. A. et al., 2005, Space Sci. Rev., 120, 95
Sakano M., Koyama K., Murakami H., Maeda Y., Yamauchi S., 2002, ApJS, 138, 19
Sguera V. et al., 2005, A&A, 444, 221
Sguera V. et al., 2007, A&A, 467, 249
Sguera V., Romero G. E., Bazzano A., Masetti N., Bird A. J., Bassani L., 2009, ApJ, 697, 1194
Sidoli L., 2008, Adv. Space Res., 43, 1464
Sidoli L., Romano P., Mereghetti S., Paizis A., Vercellone S., Mangano V., Götz D., 2007, A&A, 476, 1307
Sidoli L. et al., 2008, ApJ, 687, 1230 (Paper I)
Sidoli L. et al., 2009a, MNRAS, 397, 1528 (Paper IV)
Sidoli L. et al., 2009b, ApJ, 690, 120 (Paper III)
Smith D. M., Main D., Marshall F., Swank J., Heindl W. A., Leventhal M., in ‘t Zand J. J. M., Heise J., 1998, ApJ, 501, L181
Swank J. H., Smith D. M., Markwardt C. B., 2007, Astron. Tel., 999
Vacca W. D., Garmany C. D., Shull J. M., 1996, ApJ, 460, 914
Vaughan S. et al., 2006, ApJ, 638, 920
Walter R., Zurita Heras J., 2007, A&A, 476, 335

SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table 5. Observation log for IGR J16479−4514.
Table 6. Observation log for IGR J17391−3021.
Table 7. Observation log for IGR J17544−2619.
Table 8. Observation log for IGR J18410−0535.

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