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MONITORING SUPERGIANT FAST X-RAY TRANSIENTS WITH *SWIFT*. I. BEHAVIOR OUTSIDE OUTBURSTS

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ABSTRACT

Supergiant fast X-ray transients (SFXTs) are a new class of high-mass X-ray binaries (HMXBs) discovered thanks to the monitoring of the Galactic plane performed with the *INTEGRAL* satellite in the last 5 years. These sources display short outbursts (significantly shorter than typical Be/X-ray binaries) with a peak luminosity of a few 10^{36} erg s^{-1}. The quiescent level, measured only in a few sources, is around 10^{32} erg s^{-1}. The X-ray spectral properties are reminiscent of those of accreting pulsars; thus, it is likely that all the members of the new class are indeed HMXBs hosting a neutron star, although only two SFXTs have a measured pulse period, IGR J11215−5952 (~187 s) and IGR J18410−0535 (~4.7 s). Several competing mechanisms have been proposed to explain the shortness of these outbursts, mostly involving the structure of the wind from the supergiant companion. To characterize the properties of these sources on timescales of months (e.g., the quiescent level and the outburst recurrence), we are performing a monitoring campaign with *Swift* of four SFXTs (IGR J16479−4514, XTE J1739−302, IGR J17544−2619, and AX J1841.0−0536/IGR J18410−0535). We report on the first 4 months of *Swift* observations, which started on 2007 October 26. We detect low-level X-ray activity in all four SFXTs, which demonstrates that these transient sources accrete matter even outside their outbursts. This fainter X-ray activity is composed of many flares with a large flux variability, on timescales of thousands of seconds. The light-curve variability is also evident on larger timescales of days, weeks, and months, with a dynamic range of more than 1 order of magnitude in all four SFXTs. The X-ray spectra are typically hard, with an average 2–10 keV luminosity during this monitoring of about 10^{33}–10^{34} erg s^{-1}. We detected pulsations from the pulsar AX J1841.0−0536/IGR J18410−0535, with a period of 4.7008 ± 0.0004 s. This monitoring demonstrates that these transients spend most of the time accreting matter, although at a much lower level (~100–1000 times lower) than during the bright outbursts, and that the "true quiescence," characterized by a soft spectrum and a luminosity of a few 10^{32} erg s^{-1}, observed in the past in only a couple of members of this class, is probably a very rare state.

Subject headings: X-rays: individual (AX J1841.0−0536/IGR J18410−0535, IGR J16479−4514, IGR J17544−2619, XTE J1739−302)

Online material: color figures, machine-readable table

1. INTRODUCTION

The Galactic plane monitoring performed by the *INTEGRAL* satellite has led to the discovery of a number of new high-mass X-ray binaries (HMXBs) in the last 5 years (Bird et al. 2007). Several of these new sources are transients associated with OB supergiants and show short outbursts (a few hours, as observed with *INTEGRAL*; Negueruela et al. 2006b; Sguera et al. 2006). These sources have been called supergiant fast X-ray transients (SFXTs), and their X-ray transient behavior is quite surprising since neutron stars accreting from the winds of supergiant companions were known to be persistent. Since their bright X-ray emission, reaching 10^{36} erg s^{-1}, is concentrated in very short outbursts, they are difficult to discover, but SFXTs may be a large (and probably predominant) population of massive X-ray binaries. Their quiescent level has been observed so far in only a few sources, IGR J17544−2619 (in't Zand 2005) and IGR J08408−4503 (Leyder et al. 2007), and is at ~10^{32} erg s^{-1}, thus making SFXTs a class of transients with a large dynamic range (~10^4). Among them, particularly interesting is the case of IGR J11215−5952, which is the only SFXT to date that displays periodic outbursts (Sidoli et al. 2006) with a period of 329 days (or half of this, as recently discovered with *Swift* X-Ray Telescope [XRT]; Romano et al. 2007a; Sidoli et al. 2007). The *Swift* monitoring during the 2007 February outburst of IGR J11215−5952 represents the deepest and most complete set of X-ray observations of an outburst from an SFXT, allowed thanks to the predictable behavior of the recurrent outbursts (Romano et al. 2007b). These observations demonstrated that the accretion phase during the bright outburst lasts longer than previously thought: a few days instead of hours, with only the brightest phase lasting less than 1 day, and being characterized by a large variability with several flares lasting from a few minutes to a few hours (Romano et al. 2007b).

These observations allowed us to propose an alternative explanation for the SFXT outburst mechanism, which accounts for both the narrow shape of the IGR J11215−5952 X-ray light curve and the periodicity in the outburst recurrence. This model suggests the possible presence of a preferential plane in the wind mass loss from the supergiant, an equatorial wind "disk," which should also be inclined with respect to the orbital plane of the binary system to explain the shortness of the outburst (Sidoli et al. 2007); in this framework, X-ray outbursts are produced when the neutron star crosses this equatorial disk component, which is denser and slower than the "polar" wind component. Thus, depending on the

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TABLE 1

Observation Log

Name (1)	Sequence[a] (2)	Instrument/Mode (3)	Start Time (UT) (4)	End Time (UT) (5)	Net Exposure[b] (s) (6)
IGR J16479−4514.........	00152652000[c]	BAT/evt	2005-08-30 04:03:49	2005-08-30 04:13:51	602
	00030296001	XRT/WT	2005-08-30 04:11:00	2005-09-01 13:40:51	4541
	00030296001	XRT/PC	2005-08-30 04:12:41	2005-09-01 14:01:58	11408
	00030296002	XRT/PC	2005-09-10 00:15:00	2005-09-12 12:10:59	6394
	00030296003	XRT/PC	2005-09-14 00:43:34	2005-09-14 10:47:57	4182
	00030296004	XRT/PC	2005-10-18 09:17:15	2005-10-18 14:35:57	5423
	00210886000[c]	BAT/evt	2006-05-20 17:32:29	2006-05-20 17:33:12	43
	00215914000[c]	BAT/evt	2006-06-24 20:19:49	2006-06-24 20:20:32	43
	00286412000[c]	BAT/evt	2007-07-29 12:07:25	2007-07-29 12:08:08	43
	00030296005	XRT/PC	2007-10-26 08:08:36	2007-10-26 09:42:57	1176

Note.—Table 1 is published in its entirety in the electronic edition of the *Astrophysical Journal*. A portion is shown here for guidance regarding its form and content.

[a] Bold-faced observations are new; the others are archival data.

[b] The exposure time is spread over several snapshots (single continuous pointings at the target) during each observation.

[c] The source triggered *Swift* BAT.

[d] The source was detected with the *Swift* BAT hard X-ray transient monitor.

truncation of the disk, its orientation and inclination with respect to the orbital plane, together with the system eccentricity, the neutron star will cross the disk once or twice, resulting in periodic or quasi-periodic outbursts. This implies that basically *all* SFXTs should display a periodicity in the outburst recurrence, or a double periodicity, depending on the different possible geometries discussed in Sidoli et al. (2007). We note that this scenario attempts to describe in a coherent way not only SFXT outbursts but also HMXBs as a class.

Encouraged by these *Swift* results on IGR J11215−5952, we are performing the first sensitive wide-band X-ray monitoring campaign of the activity of a sample of SFXTs. A sensitive monitoring campaign carried out as frequently as possible and spanning very long timescales is crucial to fully characterize the behavior of SFXTs, to determine the properties of their quiescent state (where the accumulation of large observing time is needed to allow a meaningful spectral analysis of this faintest emission), to monitor the onset of the outbursts, and to measure the outburst recurrence period(s). Determination of the outburst pattern is fundamental in order to discover the supposed periodicities (or quasi-periodicities) implied by our proposed model. A positive (or negative) result will be possible only after several months of observations (e.g., the period for the outburst recurrence in IGR J11215−5952 is ∼165 days). This will allow us to reach a firm conclusion about periodic or nonperiodic behavior. A monitoring with these aims is now possible only with the *Swift* satellite, which offers a good sensitivity combined with a broadband coverage (from optical/UV to hard X-rays) and, most importantly, a unique flexibility. The latter becomes crucial when observing transients with short outbursts, in order to rapidly modify the original schedule when they show indications of an imminent outburst (possible “bounces” in the light curve, which would normally be missed) to catch not only the outburst but also its onset.

Here we report on the results of the first 4 months of this ongoing campaign with *Swift*, which targeted the following sources: IGR J16479−4514, XTE J1739−302, IGR J17544−2619, and IGR J18410−0535 (see Walter & Zurita Heras [2007] and references therein, for an updated review of the parameters of these systems). The targets have been selected considering sources that, among several candidates of this newly discovered class of sources, 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 references in Walter & Zurita Heras 2007). In particular, XTE J1739−302 and IGR J17544−2619 are generally considered prototypical SFXTs; XTE J1739−302 was the first transient that showed an unusual X-ray behavior (Smith et al. 1998), only recently optically associated with a blue supergiant (Negueruela et al. 2006a). IGR J16479−4514 has displayed in the past a more frequent X-ray outburst occurrence than other SFXTs (see, e.g., Walter & Zurita Heras 2007) and offers an a priori better chance to be caught during an outburst. AX J1841.0−0536/IGR J18410−0535, on the other hand, is an interesting source that, together with IGR J11215−5952, is the only SFXT in which a pulsar has been detected (Bamba et al. 2001) and which may offer the opportunity to determine the orbital parameters from the pulsar timing on long timescales.

The results we are reporting here are concentrated on the “out-of-outburst” behavior of the four SFXTs monitored with *Swift* between 2007 October 26 and 2008 February 28. An old outburst from IGR J16479−4514 observed in 2005 in archival *Swift* data is also discussed.

2. OBSERVATIONS AND DATA ANALYSIS: NEW AND ARCHIVAL DATA

Table 1 reports the log of the *Swift* observations, which include both the new and the old ones, retrieved from the *Swift* Archive.

The XRT data were processed with standard procedures (`xrtpipeline` ver. 0.11.6), filtering, and screening criteria by using FTOOLS in the HEAsoft package (ver. 6.4). We considered both WT and PC data, depending on the count rate of the sources, and selected event grades 0–2 and 0–12, respectively. When appropriate, we corrected for pileup. To account for the background, we also extracted events within source-free regions. Ancillary response files were generated with `xrtmkarf`, and they account for different extraction regions, vignetting, and PSF corrections. We used the latest spectral redistribution matrices (v010) in the Calibration Database maintained by HEASARC. For timing analysis, the arrival times of XRT events were converted to the solar system barycenter with the task `barycorr`.

During the observations of our monitoring campaign BAT observed the sources simultaneously with XRT, and survey data

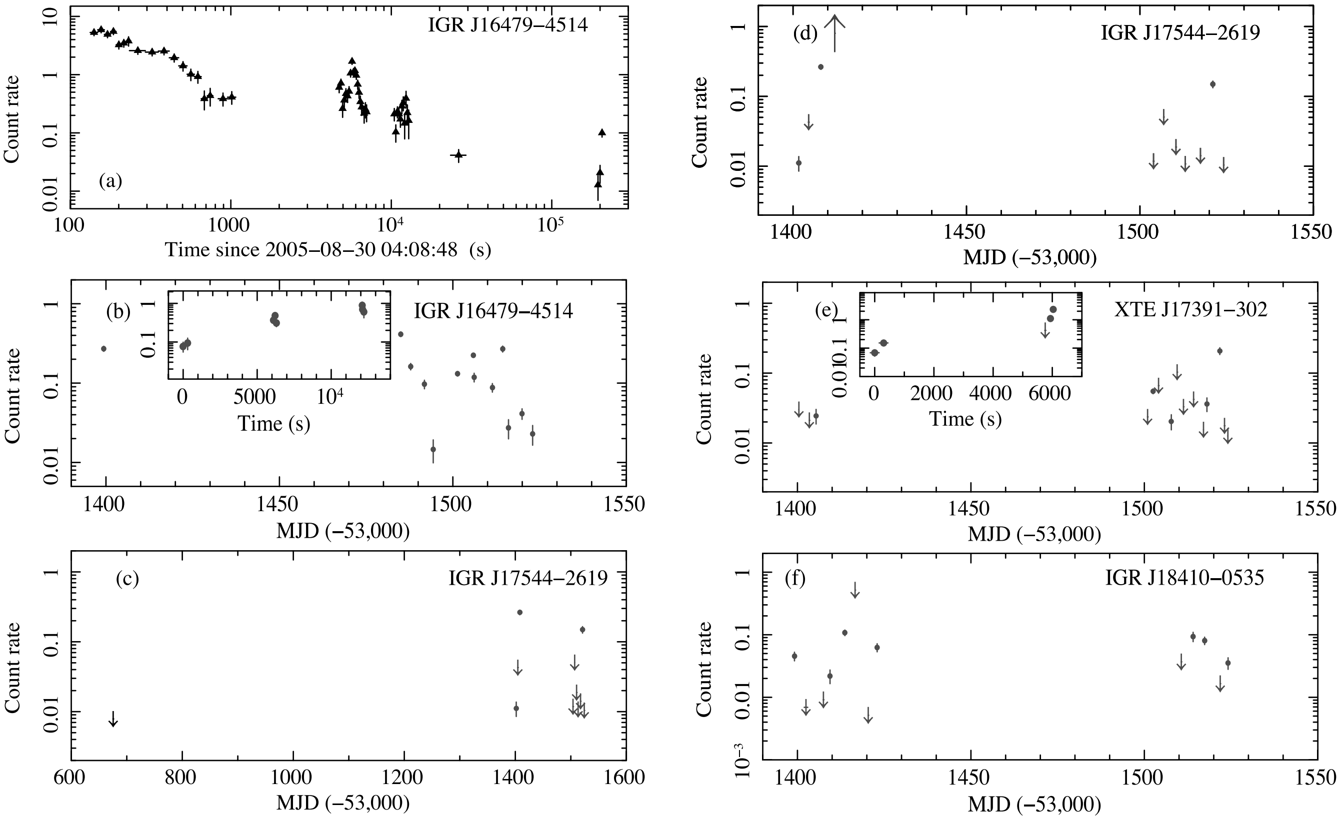

FIG. 1.—*Swift* XRT (0.2–10 keV) light curves, corrected for pileup, PSF losses, and vignetting, and background-subtracted. The triangles are archival data, i.e., observations performed before our monitoring started, and circles are the data from the ToOs we requested (from 2007 October 26, until the end of 2008 February). The downward-pointing arrows are 3 σ upper limits. (*a*) Archival data from the 2005 outburst of IGR J16479−4514, referred to as the BAT trigger (2005-08-30, 04:08:48 UT). (*b*) Data on IGR J16479−4514 collected in 2007 and 2008. The inset shows a detail of observation 014 (centered on MJD 54,514.35). (*c*) Full data set on IGR J17544−2619. (*d*) Data on IGR J17544−2619 collected in 2007 and 2008. Note that an outburst was discovered in BAT Monitor data on MJD 54,412 (*upward pointing arrow*). (*e*) Full data set on XTE J1739−302 (2007 and 2008). The inset shows a detail of observation 013 (MJD 54,521.76). (*f*) Full data set on IGR J18410−0535 (2007 and 2008). [*See the electronic edition of the Journal for a color version of this figure.*]

products, in the form of detector plane histograms (DPHs), are available.

IGR J16479−4514 (Kennea et al. 2005; Kennea 2006; Markwardt & Krimm 2006) and XTE J1739−302 also triggered the BAT in the past (see Table 1, observations labeled with footnote a), and in those cases BAT events are also available. The optical counterparts of the sources are expected to display a flux at a level of $V \sim 16$–20 mag and have been observed by UVOT. The BAT and UVOT data will be included in a forthcoming paper.

3. RESULTS

3.1. *Light Curves*

Figures 1*a*–1*f* show the results as light curves in the 0.2–10 keV band, which were corrected for pileup, PSF losses, and vignetting, and also background-subtracted. Each point in the light curves of Figures 1*b*–1*f* refers to the average flux observed during each snapshot observation performed with *Swift* XRT and reported in Table 1; each point in Figure 1*a* has at least 25 source counts per bin and minimum time bin of 15 s, while the insets in Figures 1*b* and Figure 1*e* have at least 18 source counts per bin and minimum time bin of 30 s. These insets show details of specific observations. The downward-pointing arrows are 3 σ upper limits. The lack of observations occurring roughly from 2007 December to 2008 January, depending on the target coordinates, is due to the sources being Sun-constrained. We show both archival data as triangles and the Targets of Opportunity (ToOs) we requested in the last 4 months (from 2007 October 26, until until the end of 2008 February) as circles. In particular, Figure 1*a* shows an intense outburst of IGR J16479−4514 that triggered BAT in 2005 (image trigger 152652); in that instance, this source was detected with BAT for about 60 s, with an average significance level of 8.7 σ in the 15–100 keV energy range, and an average count rate of $(7.7 \pm 0.9) \times 10^{-3}$ counts^{-1} s^{-1} det^{-1}. Unfortunately, this source was observed only once during the fall 2007 monitoring campaign because of Sun constraints (Fig. 1*b*).

Figures 1*c* and 1*d* show the full data set on IGR J17544−2619. We note that an outburst was discovered in BAT Monitor[5] data on MJD 54,412 (Krimm et al. 2007), merely 2 days after the source had become unobservable by the XRT because it was Sun-constrained. Figures 1*e* and 1*f* show the light curves of XTE J1739−302 and IGR J18410−0535, respectively.

Bamba et al. (2001) discovered coherent pulsations with a period of 4.7394 ± 0.0008 s in the brightest flare phase of the transient X-ray pulsar AX J1841.0−0536/IGR J18410−0535. In order to search for periodicities, we considered the *Swift* XRT observations with the best signal-to-noise ratio (observation IDs 00030988001, 00030988004, and 00030988005 in Table 1). We examined a frequency range centered on the above value, performing an epoch folding technique on this subset of data. The best-fit pulse period is 4.7008 ± 0.0004 s. The corresponding Pearson statistics for the pulse histogram with 10 bins (~20 mean source counts per bin) provides a reduced χ^2 of 6.3 (9 degrees of

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[5] See http://swift.gsfc.nasa.gov/docs/swift/results/transients/index.html.

TABLE 2

XRT Spectroscopy of the Four SFXTs out of Outburst (2007+2008 Data Set)

Source	$N_{\rm H}$	Parameter	Average Observed Flux	Average Luminosity	$\chi^2_{\rm red}$ (dof)
Absorbed power law:		Γ	2–10 keV	2–10 keV	
IGR J16479−4514......	$7.7^{+1.0}_{-0.9}$	$1.6^{+0.2}_{-0.2}$	2.03	87	0.969 (112)
XTE J1739−302.........	$3.3^{+0.04}_{-0.04}$	$1.4^{+0.4}_{-0.4}$	0.37	3.9	1.16 (21)
IGR J17544−2619......	$3.2^{+1.2}_{-0.9}$	$2.1^{+0.6}_{-0.5}$	0.32	6.3	0.916 (16)
IGR J18410−0535......	$4.2^{+1.7}_{-1.1}$	$1.6^{+0.6}_{-0.4}$	0.35	13	0.59 (20)
Absorbed blackbody:		$kT_{\rm bb}$			
IGR J16479−4514......	$4.5^{+0.6}_{-0.5}$	1.6 ± 0.1	1.85	62	0.954 (112)
XTE J1739−302.........	$1.6^{+0.6}_{-0.5}$	1.5 ± 0.2	0.32	3.0	1.08 (21)
IGR J17544−2619......	$1.5^{+0.6}_{-0.4}$	1.1 ± 0.1	0.26	4.4	1.109 (16)
IGR J18410−0535......	$2.0^{+0.9}_{-0.6}$	1.5 ± 0.2	0.30	9.6	0.72 (20)

Notes.—The data are fit with two models: an absorbed power law and an absorbed blackbody. Γ is the power-law photon index, and $kT_{\rm bb}$ is the blackbody temperature. The column $N_{\rm H}$ is in units of 10^{22} cm^{-2}. Average observed fluxes are in units of 10^{-11} erg cm^{-2} s^{-1}. X-ray luminosities are in units of 10^{33} erg s^{-1} in the 2–10 keV energy band and have been calculated 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). IGR J18410−0535 is located in the direction of the Scutum Arm, at a distance probably comprising between 1 and 10 kpc (Bamba et al. 2001); for this source we will arbitrarily assume 5 kpc.

freedom) that, even taking into account the $\sim 10^3$ searched periods, has a virtually null probability of chance occurrence.

3.2. *Spectra*

The long-term light curves of all sources show a large variability over timescales of hours, days, and weeks, with a frequent low-level flaring activity. In order to characterize the spectral properties of the sources in this fainter state, we extracted a single spectrum for each source, integrating over all the available observing time when the source is not in outburst. The average spectral parameters are reported in Table 2. They display hard and highly absorbed spectra (see Fig. 2), with absorption in excess of the total interstellar Galactic value toward the sources.

The spectrum of the source IGR J16479−4514 during the bright outburst reported in Figure 1*a* is fit well by a highly absorbed [column density of $(4–10) \times 10^{22}$ cm^{22}] hard power law (photon index, Γ, in the range 0.6–1.4). During the fainter state monitored in 2008 (see Fig. 2*a*), the spectrum appears softer ($\Gamma = 1.4–1.8$) and equally highly absorbed. There is no evidence for a variable absorbing column density in IGR J16479−4514 between the long-term low-level emission and the bright outburst observed in 2005.

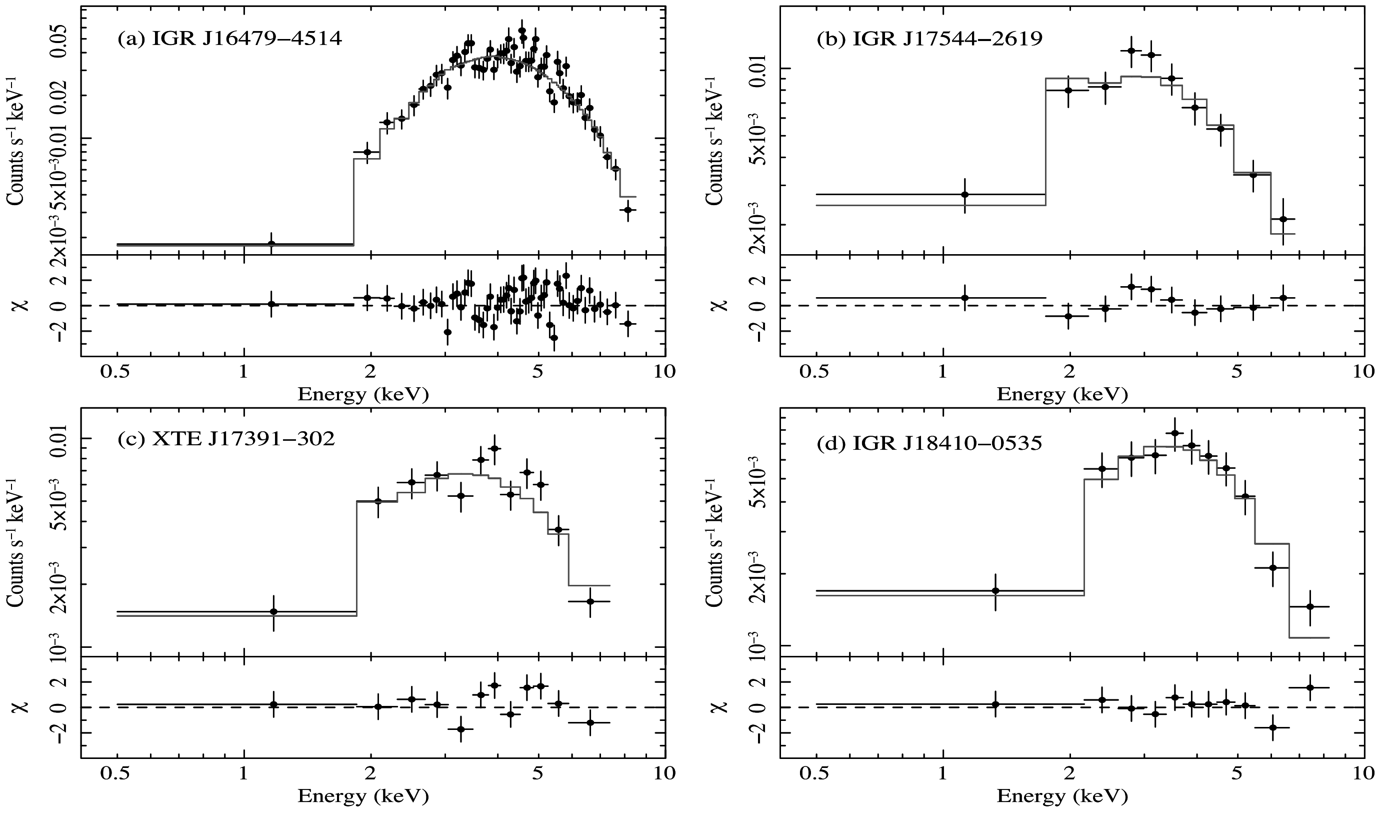

Fig. 2.—*Swift* XRT spectra. *Top*: Out-of-outburst data from the four SFXTs in our sample, fit with an absorbed power-law model. *Bottom*: Residuals of the fit (in units of standard deviations). [*See the electronic edition of the Journal for a color version of this figure.*]

4. DISCUSSION

We report here on the results of the first sensitive long-term X-ray monitoring of SFXT light curves, performed with *Swift*, focusing on the out-of-outburst X-ray behavior.

The first months of these observations of a sample of four transients reveal that they spend most of the time in a low-level X-ray activity that is far from being a true quiescent state. All four of these sources display, outside the bright outbursts, a highly variable low-level X-ray activity, characterized by a flaring behavior with a large dynamic range: more than 1 order of magnitude for all the sources. The average spectra of this X-ray emission are characterized by hard power-law photon indexes (in the range 1–2), high absorbing column densities, and average fluxes that translate into X-ray luminosities of a few 10^{33} erg s^{-1} (see Table 2), assuming the distances optically determined by Rahoui et al. (2008), up to an average level of $(6–8) \times 10^{34}$ erg s^{-1} observed in IGR J16479−4514.

Previous X-ray observations of SFXTs outside outbursts consist of a few short exposures with *ASCA*, *Swift* XRT, *Chandra*, and *XMM-Newton*, which were not part of a systematic monitoring campaign. During these observations, the true quiescent state was caught in IGR J17544−2619 (in't Zand 2005), in IGR J08408−4503 (Leyder et al. 2007), and probably in XTE J1739−302 (Sakano et al. 2002). This quiescence is characterized by a luminosity of $\sim 10^{32}$ erg s^{-1} and by a very soft spectrum; for example, in IGR J17544−2619, the fit with a power law resulted in a photon index of almost 6 (in't Zand 2005). The kind of low-level activity we observe now with *Swift* on long timescales of months has only been observed before in single short exposures targeted on IGR J17544−2619 (González-Riestra et al. 2004) and on XTE J1739−302 (Smith et al. 2006), during observations that covered only a few tens of ks. Our *Swift* monitoring campaign, after 4 months of observations (on average 1–2 ks of net exposure per source twice or three times a week depending on the source), has already demonstrated that accretion at a low-level rate is a very frequent and more typical state in SFXTs, and that instead the quiescence seems to be a much rarer behavior for these sources than previously thought. These findings firmly establish that SFXTs cannot be considered as sources that undergo long periods of quiescence only occasionally interrupted by the sudden accretion of matter from the wind of the supergiant companion. Instead, they continue accreting matter even when they are not in outburst, over long timescales of months, with a large variability in the X-ray flux.

We measured the pulsar period in XRT data of the SFXT IGR J18410−0535. Compared with the period determined in *ASCA* data by Bamba et al. (2001), there is evidence for a spin-up trend, with a pulse period difference of $\Delta P = -0.0386 \pm 0.0009$ s, and an average period derivative, $\dot{P}$, of -1.5×10^{-10} s s^{-1}, between the two determinations separated by ∼2965 days. Since the orbital parameters are unknown, it is not possible to correct for the Doppler delay due to the orbital motion in the binary system. Moreover, a spin-up trend is often observed in HMXBs (see, e.g., Bildsten et al. 1997) induced by the accretion torque (Ghosh & Lamb 1979); thus, at this stage it is not possible to discriminate between the two effects. To estimate the maximum possible shift on the pulse period due to the orbit, we can assume that the pulsar is orbiting near to the surface of the OB supergiant companion; in this case the shift is about 0.2% difference between the two period measurements, which is less than what we observe, and thus a good fraction of the pulse period change is real. More determinations of the spin period are needed to characterize the orbit and will hopefully be available in the next months of this observing campaign. On the other hand, in addition to the large-intensity variability and hard spectral properties, this is a further confirmation of the fact that this source is still accreting matter even at much lower rates than in outburst.

The main hypotheses proposed to explain the SFXTs' behavior (especially their outburst durations) are based on the structure of the wind of the OB supergiant companions. In't Zand (2005) originally proposed that the sudden accretion of material from the clumpy wind of the supergiant could give rise to the bright short outbursts. Negueruela et al. (2005) suggested that the SFXT orbits should be highly eccentric to explain the low luminosity in quiescence. More recently, the idea of a clumpy and spherically symmetric wind has been associated with an eccentric and/or wide orbit (Walter & Zurita Heras 2007; Negueruela et al. 2007). For these authors the main difference between the SFXTs and the persistent HMXB depends on the number of clumps encountered and accreted by the compact object along its orbit; in persistent systems the rate is very high because the orbit lies within ∼2 stellar radii from the supergiant, while in the SFXTs the orbit probably lies at higher distances, in a region where the wind clumps' density is much lower. Negueruela et al. (2008) suggest that outside this radius the space is effectively void, and the probability for the neutron star to accrete a wind clump is very low. In this model the SFXT outbursts are produced by the accretion of a single clump, and the X-ray luminosity can be used to determine the mass of the clump, when the flare duration is known (Walter & Zurita Heras 2007). In this case, the mass of the single clumps accreted to explain the low-level flaring activity we observe with *Swift* should be about 2 orders of magnitude lower than that during the bright outburst (where the luminosity exceeds 10^{36} erg s^{-1}), assuming the same flare duration.

A second hypothesis has been proposed by Sidoli et al. (2007) and is based on the shape of the light curve observed during the 2007 outburst from the unique SFXT displaying periodic outbursts, IGR J11215−5952. This set of observations clearly demonstrated that the SFXT outbursts cannot be produced by the accretion of a single clump, nor by a spherical distribution of clumps. The X-ray light curve of the 2007 February outburst was too narrow and steep to be explained by an enhanced accretion rate when the neutron star approaches the periastron passage orbiting a supergiant with a spherically symmetric wind, even in a binary system with an extremely high eccentricity. This strongly suggested some degree of anisotropy in the supergiant wind, which could be explained by the presence of a second denser wind component (besides the polar spherically symmetric wind) in the form of an equatorial wind "disk" from the supergiant donor. The shortness of the outburst is also indicative of an equatorial wind that is inclined with respect to the orbital plane. A flaring activity was detected and could be explained with a wind that is inhomogeneous in addition to being anisotropic (Sidoli et al. 2007).

Basically, the main difference between the two hypotheses indeed resides in the spherical (e.g., Negueruela et al. 2008) vs. anisotropic wind (Sidoli et al. 2007). In both models the low-level X-ray activity could be explained as follows: in the first scenario, it could probably be produced by clumps with a distribution of sizes and masses (breakup of clumps to smaller sizes at larger distances in the eccentric case, or a distribution of clump sizes in the noneccentric case), while in the anisotropic wind scenario the low level X-ray emission is very easily explained by the fact that the neutron star, when not undergoing a bright outburst, is not crossing the "disk" wind component from the supergiant donor but in any case accretes matter from the polar supergiant wind, which is faster and 2 orders of magnitude less dense than the equatorial wind component.

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Facility: Swift

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