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Swift follow-up observations of 17 INTEGRAL sources of uncertain or unknown nature

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ABSTRACT

Context. The positional accuracy of the IBIS telescope on-board *INTEGRAL*, albeit unprecedented in the >20 keV range, is still not good enough to identify many hard X-ray sources discovered by *INTEGRAL*. This indeed prevents counterparts from being found at other wavelengths, which is the only way to unveil the true nature of these sources.
Aims. We continue the work of trying to reveal the nature of these hard X-ray sources. This is done by analysing X-ray data collected via focusing X-ray telescopes, with the primary goal of discovering soft X-ray counterparts of the *INTEGRAL* sources to provide an accurate X-ray position. With a few arcsec accuracy, we can identify counterparts at infrared and optical wavelengths.
Methods. We analysed data from observations of 17 *INTEGRAL* sources made with the *Swift* satellite. The X-ray images obtained by the X-ray Telescope instrument allowed us to refine the position of the hard X-ray sources to an accuracy of a few arcsec. We then browsed the online catalogues (e.g., NED, SIMBAD, 2MASS, 2MASX, USNO) to search for counterparts at other wavelengths. We also made use of the X-ray spectral parameters to further distinguish between the various possibilities.
Results. For 13 sources, we find the X-ray counterpart without any ambiguity. For these, we provide the position with arcsec accuracy, identify possible infrared and optical counterparts (when found), give the magnitudes in those bands and in the optical and UV as seen with the *Swift*UVOT telescope when observations are available. We confirm the previously suggested associations and source types for IGR J03532−6829, J05346−5759, J10101−5654, J13000+2529, J13020−6359, J15479−4529, J18214−1318, and J23206+6431. We identify IGR J09025−6814 as an AGN for the first time, and we suggest that it may be a Seyfert 2. We suggest that IGR J05319−6601, J16287−5021, J17353−3539, and J17476−2253 are X-ray binaries, with J05319−6601 located in the LMC and the other three possibly being HMXBs in our Galaxy. For IGR J15161−3827 and J20286+2544, we find several possible X-ray counterparts in the IBIS error region, and we discuss which, if any, are the likely counterparts. Both are likely AGNs, although the latter could be a blend of two AGNs. For IGR J03184−0014 and J19267+1325, we find X-ray sources slightly outside the IBIS error circle. In the former, we do not favour an association of the *Swift* and *INTEGRAL* source, while it is very likely that IGR J19267+1325 and the *Swift* source are the same.

Key words. astrometry – binaries: close – galaxies: Seyfert – X-rays: binaries – X-rays: galaxies

1. Introduction

Since its launch, the INTErnational Gamma-Ray Astrophysics Laboratory (*INTEGRAL*) has detected about 500 sources as reported in a recent version of its source catalogue (Bird et al. 2007; Bodaghee et al. 2007). A large number of the sources had either not been well-studied or had not been detected prior to *INTEGRAL*. In this paper, we refer to them as "IGRs"[1]. Although ~arcmin accuracy is achieved for source positions with IBIS/ISGRI (Lebrun et al. 2003), a level that is unprecedented in the >20 keV range, this is not sufficient to unveil counterparts at other wavelengths (optical, infrared (IR), and radio), which is the best way to reveal the true nature of the IGRs.

In a recent paper, Bodaghee et al. (2007) collected known parameters (e.g., the absorption column density, $N_{\rm H}$, the pulse period for Galactic sources with X-ray pulsations, the redshift for AGN, etc.) of all sources detected by *INTEGRAL* during the first four years of activity. Their catalogue, however, contains a large number of IGRs whose high-energy position is accurate at just the arcmin level, which therefore prevents their true nature from being known. In some cases, a tentative identification is given, mainly when an AGN is found within the *INTEGRAL*/ISGRI error circle, but this is far from being secure, as other possible counterparts usually lie in the few arcmin ISGRI error regions.

In this paper, we continue our work of identifying the unknown IGRs that we started soon after the discovery of the first IGRs. A first step is to provide an ~arcsec position with soft X-ray telescopes such as *XMM-Newton*, *Chandra* (e.g., Rodriguez et al. 2003, 2006; Tomsick et al. 2006, 2008a), and also *Swift* (Rodriguez et al. 2008, hereafter paper 1). We then search for counterparts at a position consistent with the refined X-ray position of a given source. In the case of HMXBs, we also have follow-up programmes from ground-based facilities that permit us to further understand the nature of a large number of systems (Chaty et al. 2008; Rahoui et al. 2008). In paper 1, we focused on sources that were easily detected with *Swift*/XRT (Gehrels et al. 2004; Burrows et al. 2005), i.e., sources that were bright enough to be detected during single pointings lasting a few ks. In this paper, we report on the analysis of *Swift* observations (XRT imaging and spectral analysis and UVOT imaging) of seventeen IGRs that either lacked precise arcsec X-ray positions or whose Chandra

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[1] An up-to-date online catalogue of all IGRs can be found at `http://isdc.unige.ch/~rodrigue/html/igrsources.html`

Table 1. Journal of the *Swift* observations analysed in this paper.

Source Id (IGR)	Id	Date Obs	Tstart (UTC)	Exposure (s)
J03184−0014	00030995001	2007–11–07	00:12:58	9192
J03532−6829	00037303001	2008–07–02	13:59:56	2405
J05319−6601	00036094001	2007–01–07	07:16:32	1395
	00036094002	2008–01–01	00:05:08	17 649
J05346−5759	00037120001	2007–11–13	01:29:04	5926
	00037120002	2007–12–25	12:08:50	2762
	00037120003	2007–12–31	15:41:50	6966
J09025−6814	00037312001	2008–02–07	20:00:42	1054
	00037312002	2008–03–02	00:46:22	4119
	00037312003	2008–03–18	02:23:28	2529
	00037312004	2008–05–08	07:25:07	2269
J10101−5654	00030356001	2006–01–12	08:07:43	1201
J13000+2529	00036818001	2008–02–23	09:56:41	558
	00036818002	2008–02–22	06:43:11	744
J13020−6359	00030966001	2007–07–07	14:35:41	2705
	00030966002	2007–07–09	13:27:01	5126
	00030966003	2007–07–11	07:09:27	5512
	00030966004	2007–07–13	16:49:45	5951
J15161−3827	00036663001	2008–01–25	23:38:01	7808
	00036663002	2008–01–27	01:21:41	5309
J15479−4529	00037149001	2007–06–23	14:49:57	346
	00037149002	2007–06–24	00:28:26	3968
	00037149003	2007–06–26	00:41:28	983
	00037149004	2008–01–25	01:01:51	4758
	00037149005	2008–06–25	01:19:05	2580
	00037149006	2008-06-26	07:50:53	1685
J16287−5021	00037074001	2008–07–11	17:20:34	1944
J17353−3539	00311603004	2008–05–28	00:38:42	4540
	00311603005	2008–06–04	23:56:39	184
	00311603006	2008-06-05	06:14:18	4368
	00311603008	2008–06–14	03:48:37	3869
	00311603009	2008–07–12	04:49:18	8713
J17476−2253	00036656001	2008–07–03	20:16:28	1142
J18214−1318	00035354001	2006–02–11	15:30:34	6285
J19267+1325	00037062001	2007–07–20	11:15:50	4312
J20286+2544	00030722001	2006–06–03	14:44:55	6876
	00035276001	2005–12–16	01:19:43	4525
	00035276002	2006–03–23	00:23:43	4597
	00035276003	2006–03–28	01:20:05	921
J23206+6431	00031026001	2007–11–24	00:05:08	3978

refined X-ray position was very recently published by us (Tomsick et al. 2008a,b). We also present the identification of IR and optical counterparts obtained from online catalogues such as SIMBAD, the United States Naval Observatory (USNO), the 2 Micron All Sky Survey point source and extended source catalogues[2] (2MASS and 2MASX, Skrutskie et al. 2006), and the NASA/IPAC Extragalactic Database (NED[3]). It should be noted that although the presence of a bright *Swift* source within a given *INTEGRAL* error circle renders very likely the association between the two sources, there is a slight probability that the two sources are not associated. This is, in particular, exemplified by the few cases where several *Swift* sources are found within the *INTEGRAL* error circle. Note that this remark is also true for the association between the *Swift* sources and the proposed counterpart at other wavelengths. We cannot give a general statement about this issue, that would hold for all cases, as there is a wide range of association probabilities from possible associations to nearly certain associations. For all sources, we discuss the likelihood of association between the *INTEGRAL*, *Swift*, and counterparts at other wavelengths. Dubious cases (as, e.g., multiple possible counterparts) are discussed in more detail.

We start by introducing the *Swift* observations and briefly presenting the data reduction techniques in Sect. 2. Then, in Sect. 3, we describe the results for each source (position, counterparts, and spectral properties) and discuss their possible nature. We conclude the paper by summarising the results in Sect. 4.

2. Observations and data reduction

Among all the *Swift* pointed observations of IGRs, we mainly restricted our analysis to sources whose fine position and/or *Swift* observations were not published anywhere else[4]. We used only the pointings during which the XRT instrument was in photon counting mode since this is the only mode that provides a fine position. We also included in our study sources for which a *possible* identification had been given, e.g., based on the presence of an AGN in the IBIS error region in existing catalogues (see, e.g., Bodaghee et al. 2007). The observing log for our sample of seventeen sources is reported in Table 1.

We reduced the *Swift* data with the `HEASoft V6.5` software package and the calibration files issued on 2008 May 1 and 2008 June 25 for the UVOT and XRT instruments, respectively. The reduction steps are identical to those presented in paper 1, and follow the standard steps described in the XRT users guide and UVOT software guides[5]. More specifically, we ran the `xrtpipeline` tool with standard screening criteria to produce level 2 (i.e., cleaned) event files from the level 1 data products. The positions of the sources were obtained with `xrtcentroid`. We co-added all individual pointings of a given source with `xselect`, before estimating the source position from the resulting mosaic. We extracted spectra and light curves with `xselect` from a circular region with a radius of 20 pixels centred on the best position, while we obtained the background products from a source-free circular region with a radius of 40 pixels (see also paper 1). Due to the presence of columns of dead pixels in the XRT, we produced "true" exposure maps to further correct the ancillary response files (see also paper 1). We rebinned the spectra to have at least 20 counts per channel which allows for χ^2-minimization in the fitting with `XSPEC 11.3.2ag`. When this criterion was not achievable, the Cash statistic (hereafter C-statistic, Cash 1976) was used instead.

When available, we analysed the UVOT level 2 data obtained from the *Swift* data archive. We first corrected the aspect for each individual UVOT exposure with the `uvotskycorr` tool, calculating the aspect correction via comparison to the USNO-B1.0

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[2] `http://www.ipac.caltech.edu/2mass/`

[3] `http://nedwww.ipac.caltech.edu/index.html`

[4] with the exceptions of IGR J10101−5654, J18214−1318, J16287-5021, and J19267+1325 whose *Chandra* positions have very recently been published by Tomsick et al. (2008a,b)

[5] both available at `http://heasarc.gsfc.nasa.gov/docs/swift/analysis/`

catalogue[6] (Monet et al. 2003). Then, we summed the aspect-corrected individual exposures with `uvotimsum`, and performed the UVOT photometry and astrometry with the `uvotdetect` tool.

3. Results

The refined X-ray positions of the sources detected by *Swift* are reported in Table 2. For each source, we searched the 2MASS, 2MASX and the USNO-B1.0 online catalogues for the presence of infrared and/or optical counterparts within the *Swift*/XRT error circle. Infrared counterparts that are newly identified from this search are reported in Table 3. The typical positional accuracy for the 2MASS sources is 0.5″ (Skrutskie et al. 2006), while that of the USNO-B1.0 sources is typically 0.2″ (Monet et al. 2003). The magnitudes and UV positions of the optical and UV counterparts are reported in Table 4. The USNO-B1.0 photometric accuracy is typically 0.3 mag (Monet et al. 2003).

We fitted the source spectra with a simple model of an absorbed power law. This provided an acceptable representation of the spectra in the large majority of the cases. The spectral parameters we obtained are reported in Table 5. The errors on the X-ray spectral parameters (including upper limits) are at the 90% confidence level. We discuss in the following subsections the results obtained for each of the sources, including the few cases where a simple absorbed power law is not sufficient, or not appropriate to represent the spectra well. To estimate the luminosity of the candidate AGN we used $H_0 = 75$ km s^{-1}Mpc^{-1} to convert the redshift (of the suggested counterpart) to distance. The lower limits on the *UVOT* magnitudes are given at the 3σ level. The UVOT positional uncertainties are dominated by a 0.5″ systematic uncertainty (90% confidence) for each source. All X-ray fluxes and luminosities are corrected for absorption. The absorption due to intervening material along the line of sight is first obtained with the `nh` tool based on the measurements of H I made by Dickey & Lockman (1990). It is also compared to the values obtained from the Leiden/Argentine/Bonn (LAB) surveys of Galactic H I in the Galaxy. The LAB Survey is the most sensitive Milky Way H I survey to date, with the most extensive coverage both spatially and kinematically and an angular resolution of 0.6 degrees (Kaberla et al. 2005). For each source, the two values are reported in Table 5 for comparison.

3.1. Confirmations of previously suggested associations

IGR J03532−6829:
Masetti et al. (2006a) suggested an association of the IGR source with PKS 0352−686, a blazar of BL Lac type at $z = 0.087$, based on its location inside the IBIS error circle (Götz et al. 2006) as well as the fact that these objects are known to be strong emitters of X- and gamma-rays. The source detected by *Swift*/XRT is 1.14″ from the position of PKS 0352−686 reported in NED, further strengthening the classification of the IGR source as a BL Lac. The extended 2MASX source that lies within the XRT error circle (Table 3) has already been associated with the BL Lac. There is also one USNO-B1.0 source and a single UVOT source within the *Swift* error circle (Table 4). The USNO-B1.0 and UVOT sources are at positions consistent with the BL Lac object given the ~30″ extension of the 2MASX source. The *Swift* source is coincident with 1RXS 035257.7−683120 which is classified as being a cluster of galaxies in SIMBAD.

An absorbed power-law represents the *Swift*/XRT spectrum well with $\chi^2_\nu = 0.98$ for 63 degrees of freedom (d.o.f.). The value of the absorption (Table 5) is compatible with the value of Galactic absorption along the line of sight. This indicates that the source is not significantly locally absorbed. This further argues in favour of the hard X-ray source being the blazar as these objects do not usually show significant intrinsic absorption. At $z = 0.087$, the 2–10 keV luminosity of the source is $\sim 2.5 \times 10^{44}$ erg/s. We note that the extrapolated 20–40 keV flux of the *Swift* spectrum is about twice as high as the *INTEGRAL* flux of 0.6 mCrab reported in Götz et al. (2006). If the extrapolation of the power-law is valid, then this indicates variability, as expected in a BL Lac.

IGR J05346−5759:
Based on positional coincidence and the good agreement between the *INTEGRAL* and *ROSAT* spectral shape, Götz et al. (2006) suggested that IGR J05346−5759 is the hard X-ray counterpart to TW Pic, a cataclysmic variable (CV). There is a unique and quite bright XRT source within the IBIS error circle. TW Pic is the only source given in SIMBAD that is within the XRT error circle, where it is also associated with the 2MASS source listed in Table 3. The single source that is found in the USNO-B1.0 catalogue is positionally coincident with the single detected UVOT source (see Table 4), indicating that they are the same source. We note that the UVOT magnitudes were obtained from pointing #2 for the *UVW*1 filter and pointings #1 and #3 for the other two filters. The values obtained in the latter two are compatible (within the 0.2 mag errors) and we report the mean of the two in Table 4. These spatial coincidences strengthen the association of the XRT source with the CV. The fact that CVs are known X-ray emitters, and that an increasing number have been seen at X-ray energies >20 keV, makes the suggested associations between IGR J05346−5759 and TW Pic very likely and secure.

We first checked the XRT count rates for variability between the different pointings. The source shows some variability between high flux states (up to ~0.45 cts/s) and lower flux states (down to ~0.11 cts/s). We extracted a single spectrum from one of each of the three pointings. An absorbed power-law[7] fits the data well in all cases (χ^2_ν=1.19 for 89 d.o.f., 1.29 for 14 d.o.f. and 1.26 for 98 d.o.f., for pointings #1, 2 and 3, respectively). The best spectral parameters of all three pointings are reported in Table 5, and they are in good agreement with those obtained by Götz et al. (2006) from a *ROSAT* observation of TW Pic. In addition, no cut-off is seen in the XRT spectrum (which extends to higher energy than the *ROSAT* spectrum). The extrapolation of the XRT spectral model to the 20–40 keV range leads to a flux that is compatible with the flux measured by *INTEGRAL* (0.9 mCrab). All these points (including the spatial coincidences discussed above) further confirm that IGR J05346−5759 is TW Pic, including the spectral variability of IGR J05346−5759 as TW Pic is known to be variable. This variability has been used by Norton et al. (2000) to refute the intermediate polar (IP) type for this source. We therefore conclude that IGR J05346−5759 is the hard X-ray counterpart to TW Pic, and thus, is a CV.

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[6] `http://tdc-www.harvard.edu/software/catalogs/ub1.html`

[7] Note that we chose to use a simple power-law rather than the more sophisticated models usually used to fit CV spectra in order to compare the XRT spectral parameters to those mentioned in the literature. In particular, Götz et al. (2006) showed that the extrapolation at hard X-rays of spectrum obtained with *ROSAT* was compatible with the *INTEGRAL*/IBIS one. A discussion of the emission processes at work in CVs is beyond the scope of this paper.

Table 2. X-ray position (equatorial and Galactic) of the X-ray counterparts to the 17 sources studied with *Swift*/XRT.

Name (IGR)	RA (J2000)	Dec (J2000)	Error (″)	*l* (°)	*b* (°)
J03184−0014†	$03^{h}18^{m}17.6^{s}$	−00°17′48.1″	5.7	181.8112	−45.7082
J03532−6829	$03^{h}52^{m}57.4^{s}$	−68°31′18.0″	3.5	282.8102	−40.7968
J05319−6601†	$05^{h}31^{m}52.6^{s}$	−65°59′40.2″	4.7	275.9037	−32.6650
J05346−5759	$05^{h}34^{m}50.5^{s}$	−58°01′39.3″	3.5	266.4230	−32.7788
J09025−6814†	$09^{h}02^{m}39.4$	−68°13′38.7″	4.8	284.1738	−14.1567
J10101−5654⋆	$10^{h}10^{m}11.9^{s}$	−56°55′31.6″	4.3	282.2567	−0.6719
J13000+2529†	$12^{h}59^{m}55.0^{s}$	+25°28′08.8″	6.9	352.2816	+87.4774
J13020−6359	$13^{h}01^{m}59.2^{s}$	−63°58′06.0″	3.5	304.0891	−1.1202
J15161−3827‡ #1	$15^{h}15^{m}59.3^{s}$	−38°25′48.3″	4.3	331.6935	+16.2381
#2	$15^{h}16^{m}\ 29.6^{s}$	−38°26′56.5″	4.6	331.7689	+16.1681
#3†	$15^{h}16^{m}12.7^{s}$	−38°31′02.4″	4.7	331.6819	+16.1411
#4†	$15^{h}15^{m}45.8^{s}$	−38°27′36.2″	4.7	331.6380	+16.2370
J15479−4529	$15^{h}48^{m}14.7^{s}$	−45°28′40.4″	3.5	332.4403	+7.0228
J16287−5021◦	$16^{h}28^{m}27.2^{s}$	−50°22′38.3″	4.4	334.1093	−1.1261
J17353−3539	$17^{h}35^{m}23.5^{s}$	−35°40′13.8″	3.5	353.1445	−1.7401
J17476−2253	$17^{h}47^{m}30.0^{s}$	−22°52′43.2″	4.8	5.3999	+2.7813
J18214−1318⋆	$18^{h}21^{m}19.7^{s}$	−13°18′38.2″	3.5	17.6813	+0.4856
J19267+1325◦	$19^{h}26^{m}27.0^{s}$	+13°22′03.4″	3.7	48.8032	−1.5059
J20286+2544‡ #1	$20^{h}28^{m}34.9^{s}$	+25°43′59.7″	3.9	67.0045	−7.5713
#2	$20^{h}28^{m}28.7^{s}$	+25°43′22.5″	4.4	66.9825	−7.5582
J23206+6431	$23^{h}20^{m}36.8^{s}$	+64°30′42.8″	3.8	113.3539	+3.3424

† Source is very faint, just a very slight excess (very few photons) within IBIS error; ⋆ consistent with the *Chandra* position published by Tomsick et al. (2008a); ‡ several sources within IBIS error; ◦ consistent with the *Chandra* position published by Tomsick et al. (2008b).

Table 3. List of newly identified infrared counterparts in the 2MASS and 2MASX catalogues.

Name	Counterpart	Magnitudes			Offset from the
(IGR)		*J*	*H*	K_s	XRT position (″)
J03184−0014	2MASS J03181753−0017502			15.2 ± 0.1	2.4
J03532−6829	2MASX J03525755−6831167	13.22 ± 0.04	12.50 ± 0.05	12.07±0.08	1.5
J05346−5759	2MASS J05345057−5801406	14.77 ± 0.04	14.34 ± 0.05	14.11 ± 0.06	1.4
J09025−6814	2MASX J09023946−6813365	10.24 ± 0.01	9.50 ± 0.01	9.19 ± 0.02	2.1
J13000+2529	2MASS J12595533+2528101	10.39 ± 0.02	9.80 ± 0.03	9.68 ± 0.02	4.7
J15161−3827 #1	2MASX J15155970−3825468	12.55 ± 0.03	11.83 ± 0.03	11.34 ± 0.06	4.9
#3	2MASS J15161246−3831041	10.45 ± 0.02	10.21 ± 0.02	10.13 ± 0.02	3.5
J15479−4529	2MASS J15481459−4528399	13.22 ± 0.03	12.75 ± 0.03	12.53 ± 0.03	1.2
J17353−3539	2MASS J17352361−3540128	10.23 ± 0.02	9.03 ± 0.02	8.63 ± 0.03	1.6
J17476−2253	2MASS J17472972−2252448			13.00 ± 0.07	4.2
J20286+2544 #1	2MASX J20283506+2544001	11.31 ± 0.02	10.39 ± 0.02	9.93 ± 0.03	2.3
#2	2MASX J20282884+2543241	10.05 ± 0.01	9.23 ± 0.01	8.87 ± 0.01	2.6

IGR J10101−5654:

A refined *Chandra* position for this object has recently been published by Tomsick et al. (2008a). The XRT position is 0.55″ from the 0.64″ accurate *Chandra* position (Tomsick et al. 2008a) and therefore both positions are compatible. We further confirm all the suggested associations for this object, and the fact that it is a very likely HMXB (Masetti et al. 2006c; Tomsick et al. 2008b). There are no UVOT data available for this pointing.

The spectrum is well-fitted with an absorbed power-law (C = 19.9 for 14 bins). The spectral parameters reported in Table 5 are fully consistent with those reported from the *Chandra* observation of this source (Tomsick et al. 2008a). Although the poor statistical significance of the parameters we obtain does not allow us to constrain the possible spectral variability for this source, the flux we obtain from the *Swift* observation is about five times higher than during the *Chandra* observation (Tomsick et al. 2008a). This may indicate significant variation of the mass accretion rate.

IGR J13000+2529:

Based on the spatial coincidence between the two objects, Bassani et al. (2006) suggested an association of IGR J13000+2529 with MAPS-NGP O-379-0073388, an AGN

Table 4. Magnitudes and UVOT position of the newly identified optical and UV counterparts in the USNO-B1.0 catalogue (I, R and B bands) and *Swift*/UVOT detector (V, U, $UVW1$, $UVM2$, and $UVW2$ bands). The B magnitudes are those obtained from the USNO-B1.0 catalogue, except where indicated. The long dashes indicate the absence of corresponding data.

Name	Optical counterpart	UVOT position		Magnitudes							
(IGR)	(USNO-B1.0)	RA	Dec	I	R	V	B	U	$UVW1$	$UVM2$	$UVW2$
J03532−6829	0214-0026031	$03^{\rm h}52^{\rm m}57.5^{\rm s}$	−68° 31′ 17.4″	12.7	12.3	–	13.7	–	–	–	17.28 ± 0.02
J05346−5759	0319-0039890	$05^{\rm h}34^{\rm m}50.6^{\rm s}$	−58° 01′ 40.8″	13.8	15.2	–	14.9	–	13.886 ± 0.004	13.182 ± 0.006‡	12.909 ± 0.001‡
J09025−6814	0217-0159098*	$09^{\rm h}02^{\rm m}39.5^{\rm s}$	−68° 13′ 38.2″	–	8.6	–	9.7	16.6	16.61 ± 0.02‡	17.63 ± 0.03	–
J13000+2529	1154-0199710	$12^{\rm h}59^{\rm m}55.3^{\rm s}$	25° 28′ 10.5″	10.6	11.3	–	13.0	–	15.51 ± 0.02	17.61 ± 0.06	–
J15161−3827#1	0515-0356635	–	–	10.7	10.6	–	10.6	–	–	–	–
#2	0515-0357047	–	–	18.2	18.3	–	19.0	–	–	–	–
#3	7822-02179-1	–	–	10.9	11.3	–	11.0	–	–	–	–
#4	0515-0356459	–	–	–	18.5	–	18.9	–	–	–	–
J15479−4529	–	$15^{\rm h}48^{\rm m}14.6^{\rm s}$	−45° 28′ 39.9″	–	–	–	–	–	–	–	14.501 ± 0.003‡
J17353−3539	0543-0510755	–	–	10.9	–	11.9	–	–	>20.3	>20.2	–
J17476−2253	0671-0618341	–	–	15.3	17.0	–	19.1	–	–	>19.3	–
J18214−1318	–	–	–	–	–	>19.3	>19.8°	>19.9	>20.6	>20.5	>20.9
J19267+1325	–	$19^{\rm h}26^{\rm m}27.0^{\rm s}$	13° 22′ 05.1″	–	–	–	–	–	–	–	20.54 ± 0.07
J20286+2544 #1†	1157-0462303*	$20^{\rm h}28^{\rm m}35.1^{\rm s}$	25° 43′ 59.5″	–	10.1	15.06 ± 0.01‡	11.4	18.03 ± 0.05‡	20.5 ± 0.1‡	>21.1	20.6 ± 0.1*
#2	1157-0462166	$20^{\rm h}28^{\rm m}28.9^{\rm s}$	25° 43′ 24.6″	8.9	8.7	12.897 ± 0.007‡	10.3	15.41 ± 0.01‡	16.83 ± 0.02‡	>21.1	19.15 ± 0.05‡
J23206+6431	1545-0296864	–	–	17.9	19.1	–	20.9	>21.1	–	–	–

‡ Values averaged over multiple pointing; * there are two possible USNO-B1.0 sources in the XRT error circle. This is the closest to the IR source; † the UVOT positional accuracy is dominated by a statistical uncertainty of 1.1″; $^{\circ}$ B magnitude obtained from *Swift*/UVOT; * average value obtained with `uvotsource`.

listed in the NED database. The XRT position is consistent with that of MAPS-NGP O-379-0073388, which provides further confirmation that the high energy source and the AGN are the same. We found a single 2MASS source within the XRT error circle, and although the source is not reported as extended it lies only 0.9″ from the position of the AGN reported in NED, which indicates the two objects are probably the same. A single source is also found within the XRT error circle in the USNO-B1.0 catalogue and UVOT images (Table 4).

As the source is very weak, we extracted an average spectrum from the two *Swift* pointings. The spectrum has too few counts for a spectral analysis to be possible. Although this source is the faintest from our sample that we detect with XRT, and the very low flux could indicate a lower probability that it is associated with the IGR source, the good spatial coincidence with the AGN along with the fact that this is the only XRT source in the IBIS error circle that we detect make IGR J13000+2529 a strong AGN candidate.

IGR J13020−6359:
This source was first mentioned in Bird et al. (2006) and was classified as a pulsar/HMXB in Bird et al. (2007), probably based on the positional coincidence with 2RXP J130159.6−635806, which indeed is an HMXB containing a pulsar (Chernyakova et al. 2005). Bodaghee et al. (2007) further report a distance to the source of about 5.5 kpc. We find a single XRT source within the IBIS error circle at a position compatible with that of 2RXP J130159.6−635806. This renders the association even more likely. It is unfortunate that due to its off-axis position (the pointings were aimed at PSR B1259−63), none of the UVOT exposures contains the source. There is no USNO-B1.0 source within the *Swift* error circle. We estimate a lower limit $V \gtrsim 21$ for the magnitude of an optical counterpart. Chernyakova et al. (2005) mention the presence of a $J \sim 13$, $H = 12.0$ and $K_{\rm s} = 11.3$ 2MASS source at a position compatible with that of the pulsar, that they consider as its likely counterpart.

As the source may be significantly variable (Chernyakova et al. 2005), we fitted each spectrum from each independent pointing separately. An absorbed power-law fits all spectra rather well (χ^2_ν in the range 0.6 to 1.40 for 30 to 13 d.o.f.). Since the absorption is poorly constrained and given that Chernyakova et al. (2005) mention a relatively stable value of 2.48×10^{22} cm^{-2}, we froze $N_{\rm H}$ to this value in all our fits. Note that for all pointings the value obtained for $N_{\rm H}$ when it is allowed to vary is in good agreement, or compatible with Chernyakova et al. (2005). The spectral results reported in Table 5 show some slight variability especially between the first pointing and the following ones, which are slightly softer. The spectral parameters are those expected for an accreting pulsar and, assuming a distance of 5.5 kpc, lead to a 2–10 keV luminosity of about 8–9 × 10^{34} erg/s, typical for these objects.

IGR J15161−3827:
Based on the positional coincidence of IGR J15161−3827 and LEDA 2816946, Masetti et al. (2006b) suggested that the latter, an AGN, is the counterpart of the high energy source. The AGN type is intermediate between a Liner and a Sey 2 at $z = 0.0365$ (Masetti et al. 2006b). The *Swift* mosaic image revealed four possible X-ray counterparts within the IBIS error circle of IGR J15161−3827. Swift J151559.3−382548, Swift J151630.0−382656, Swift J151612.2−383102, and Swift J151545.8−382738 are labeled source #1, #2, #3, and #4, respectively in Tables 2 and 3. It is a priori not possible to say which

Table 5. X-ray spectral analysis. Errors and upper limits are all given at the 90% level.

Name (IGR)	Net number ă of counts	Galactic N_H (LAB/DL)[‡] $\times 10^{22}$ cm^{-2}	N_H $\times 10^{22}$ cm^{-2}	Γ	2–10 keV flux erg cm^{-2} s^{-1}
J03184−0014	19	0.05/0.06	$0.06^{\dagger}$	$1.4^{+0.8}_{-0.7}$	$5.3^{+0.5}_{-0.3}\times 10^{-14}$
J03532−6829	1650	0.06/0.06	$0.09^{+0.04}_{-0.04}$	$1.9^{+0.1}_{-0.1}$	$1.75^{+0.14}_{-0.18}\times 10^{-11}$
J05319−6601	19	0.12/0.06	$0.12^{\dagger}$	$1.55^{+0.89}_{-0.77}$	$5^{+4}_{-3}\times 10^{-14}$
J05346−5759	2172	0.04/0.05	<0.05	$1.22^{+0.1}_{-0.09}$	$1.7^{+0.2}_{-0.1}\times 10^{-11}$
	378		<0.15	$1.75^{+0.3}_{-0.3}$	$5.7^{+1.2}_{-1.0}\times 10^{-12}$
	2516		$0.05^{+0.03}_{-0.03}$	$1.34^{+0.09}_{-0.09}$	$1.7^{+0.1}_{-0.1}\times 10^{-11}$
J09025−6814	17	0.05/0.07	9^{+123}_{-7}	<3.2	$<9.2\times 10^{-12}$
J10101−5654	86	1.35/1.77	$3.3^{+2.5}_{-1.7}$	$1.3^{+0.9}_{-0.8}$	$1.2^{+0.3}_{-0.6}\times 10^{-11}$
J13020−6359	337	1.40/1.53	$2.48^{\dagger}$	$0.9^{+0.3}_{-0.3}$	$2.3^{+0.3}_{-0.9}\times 10^{-11}$
	670		$2.48^{\dagger}$	$1.2^{+0.2}_{-0.2}$	$2.6^{+0.2}_{-0.4}\times 10^{-11}$
	471		$2.48^{\dagger}$	$1.1^{+0.2}_{-0.2}$	$2.3^{+0.3}_{-0.5}\times 10^{-11}$
	574		$2.48^{\dagger}$	$1.1^{+0.2}_{-0.2}$	$2.3^{+0.3}_{-0.5}\times 10^{-11}$
J15161−3827 #1	48	0.06/0.07	22^{+17}_{-9}	$2.0^{\dagger}$	$1.2^{+0.5}_{-0.5}\times 10^{-12}$
#2	32	0.07/0.07	<0.2	$1.2^{+0.7}_{-0.5}$	$<1.3\times 10^{-13}$
#3	18	0.07/0.07	<1.9	>2.8	$<1\times 10^{-13}$
#4	13	0.06/0.07	$0.065^{\dagger}$	$2.0^{+1.0}_{-0.9}$	$3^{+5}_{-2}\times 10^{-14}$
J16287−5021	75	1.37/1.55	$2.6^{+2.1}_{-1.6}$	$0.9^{+0.8}_{-0.8}$	$6.5^{+2.2}_{-3.0}\times 10^{-12}$
J17353−3539	416	0.69/0.63	$0.7^{+0.4}_{-0.3}$	$2.2^{+0.4}_{-0.4}$	$5.0^{+0.9}_{-0.5}\times 10^{-12}$
	803		$0.8^{+0.2}_{-0.2}$	$2.1^{+0.3}_{-0.3}$	$1.2^{+0.1}_{-0.1}\times 10^{-11}$
J17476−2253	45	0.30/0.38	$1.9^{+1.7}_{-1.1}$	$2.6^{+1.4}_{-1.0}$	$5^{+2}_{-3}\times 10^{-12}$
J18214−1318	1866	1.21/1.54	$3.5^{+0.8}_{-0.5}$	$0.4^{+0.2}_{-0.2}$	$6.7^{+0.7}_{-0.4}\times 10^{-11}$
J19267+1325	461	0.95/0.93	<0.6	$1.1^{+0.3}_{-0.3}$	$8.1^{+1.6}_{-0.7}\times 10^{-12}$
J20286+2544 #1	171	0.20/0.26	61^{+23}_{-20}	$2.5^{+1.6}_{-1.4}$	$2.1^{+1.6}_{-1.2}\times 10^{-11}$
#2	53	0.20/0.26	93^{+80}_{-61}	$2.7^{+3.1}_{-3.1}$	$<1.6\times 10^{-11}$
J23206+6431	244	0.78/0.90	$0.9^{+1.0}_{-0.7}$	$1.6^{+0.7}_{-0.5}$	$5.5^{+1.3}_{-1.0}\times 10^{-12}$

[‡] Values of weighted average Galactic N_H respectively obtained from Leiden/Argentine/Bonn (LAB) and Dickey & Lockman (DL) surveys of Galactic H I in the Galaxy; [†] unconstrained parameter that was fixed during the spectral fit.

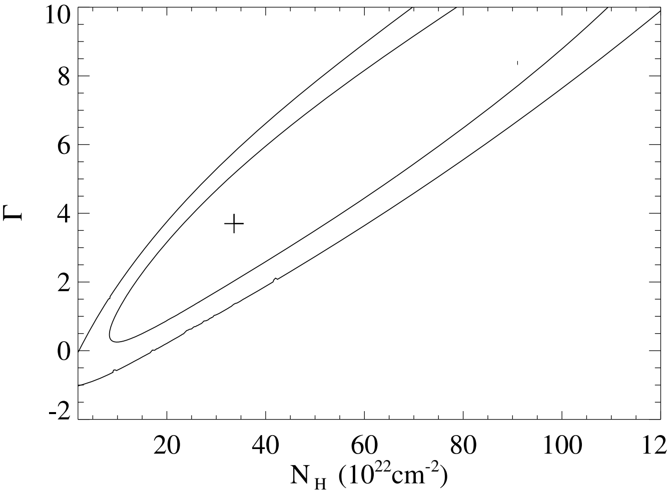

Fig. 1. Contour plot of the power-law photon index Γ vs. N_H in IGR J15161−3827 source #1. The contours represent ΔC = 2.30 and 4.61.

(if any) is the true counterpart. Two of these are compatible with IR counterparts found in the 2MASS and 2MASX catalogues, although 2MASX J15155970−3825468 is 4.9″ from the *Swift* position and therefore is slightly outside the XRT error circle of source #1. It is, however, an extended source, and the XRT error circle still contains a significant part of the source. This source is the one suggested by Masetti et al. (2006b) as the counterpart to the IGR source. A USNO-B1.0 source lies at 5.4″ from the XRT position, at a position compatible with the 2MASX source (offset by 0.7″), given the extension of the latter. Source #3 has a position compatible with an IR point source, which is consistent with being TYC 7822-2179-1 catalogued as a star in SIMBAD and also reported in the USNO-B1.0 catalogue (Table 4). There are USNO-B1.0 counterparts for the other two sources as well, although the source #4 counterpart does not have measurement in the *I*-band (Table 4). There are no UVOT data available for either of the two XRT pointings.

We extracted an average spectrum from the two pointings for each of the four sources. The spectrum of source #1 has a low statistical quality. The spectrum was fitted with an absorbed power-law (C = 38.5 for 15 bins). When all parameters are left free to vary, they are very poorly constrained (Table 5). Although only an upper limit can be obtained from the absorption, visual inspection of the spectrum shows that the source may show significant absorption. Fig. 1 represents the contour plot of Γ vs. N_H. It is clear from this figure that the value of N_H is tightly correlated to that of Γ as expected. This figure, however, shows that for $\Gamma \geq 0.5$, a value typical for most high energy sources, this source is significantly (intrinsically) absorbed as would be expected from a Sey 2. We note that, to obtain the 20–40 keV flux of 0.5 mCrab seen with *INTEGRAL* (Bird et al. 2007), a harder power-law ($\Gamma \sim 0.7$) is needed. Even in that case, significant absorption is implied by the fit. The 2–10 keV luminosity at $z = 0.0365$ is $5.6 \pm 0.5 \times 10^{42}$ erg/s, compatible with the luminosity of an AGN.

An absorbed power-law provides a good fit to the spectrum of source #2 ($C = 7.6$ for 15 bins). The spectrum is consistent with little or no absorption in this source. The absence of significant absorption in the spectrum of the source argues in favour of a nearby object. The extrapolated 20–40 keV flux is well below the *INTEGRAL* flux. A hard power-law with a photon index $\lesssim$0.35 would be needed to reach the 20–40 keV flux observed by *INTEGRAL*. These last points argue against an association of source #2 with the IGR source.

The X-ray spectrum of source #3 is well-fitted with an absorbed power-law ($C = 7.7$ for 14 bins). The quite steep power-law and the low flux obtained with the lower limit of Γ, may indicate that the spectrum is thermal. Replacing the power-law by a black-body also gives a good fit ($C = 7.5$ for 15 bins). Note that since the value of N_{H} is poorly constrained, it was frozen to the value of Galactic N_{H}. The black-body temperature is 0.2 ± 0.1 keV for a luminosity of $9 \times (D_{10}^2) \times 10^{32}$ erg/s, with D_{10} the distance in units of 10 kpc. The probable low value of the absorption and the bright IR and optical counterparts argue in favour of a nearby object. In that case, the rather flat SED, black-body shape and temperature of the X-ray spectrum indicate that this is probably a young stellar object (YSO), e.g. a T Tauri star. The softness of the source renders it difficult to reconcile the emission of this object with that at energies >20 keV. A very hard photon index of ~1.0 would be needed to be compatible with the 20–40 keV flux. Such a power-law slope is incompatible with the XRT spectrum. We conclude that this object is certainly not related to the IGR source.

As for the 2 previous objects, the X-ray spectrum of source #4 is well-fitted with an absorbed power-law ($C = 4.7$ for 15 bins). A quite absorbed source with a very steep power-law seems to be favoured here. We note, however, that a simple power-law (with no absorption) leads to more physical results for this source. As a compromise the value of absorption was frozen to the Galactic N_{H}. A $0.6^{+0.3}_{-0.2}$ keV black-body also fits the data well ($C = 6.2$ for 15 bins). In any case, the extrapolation of the spectra to the *INTEGRAL* range falls well below the 20–40 keV flux. A power-law with a value of the photon index incompatible with the XRT spectrum ($\Gamma \lesssim 0.5$) would be needed. This shows that this source and the IGR source are very probably not related.

To conclude, the broad band (counterpart and X-ray) analysis of the four *Swift* objects found within the IBIS error circle of IGR J15161−3827 leads us to conclude that the IGR source is very probably associated with the Liner/Sey 2 object LEDA 2816946.

IGR J15479−4529:

Based on the presence of a *ROSAT* source (also detected by *XMM-Newton*) within the IBIS error circle, Tomsick et al. (2004) suggested an association between 1RXS J154814.5−452845, and the IGR source. 1RXS J154814.5−452845 is a CV, more precisely an Intermediate Polar (IP) with a pulse period of 693 s and an orbital period of 562 mn (Barlow et al. 2006). The refined position we obtained with *Swift* is only 5″ from the *ROSAT* position (Haberl et al. 2002), indicating that the two positions are compatible. There is a single source listed in SIMBAD within 3′ of the XRT position. This source has several names, one of which is V ⋆ Ny Lup indicating that it is a variable star (Samus et al. 2004). Clearly the coincidence of the *Swift* and *ROSAT* sources renders their association likely. The fact that it is an IP, which are known hard X-ray emitters, strengthens the associations with the *INTEGRAL* source. We therefore confirm all suggested association, and the fact that IGR J15479−4529 is very probably an IP. A bright source is found within the XRT error circle with the *UVOT UVW2*-filter (Table 4). Its position is consistent with the 2MASS source. We note that this UV counterpart may show some variability from one pointing to the other, from $UVW2 = 14.0$ to 15.0, which further confirms the variable nature of the source.

Table 6. Spectral parameters obtained from the fits to the XRT spectra of IGR J15479−4529.

Pointing #	kT_{bb} (keV)	Γ	χ^2_ν (d.o.f.)	Flux (erg cm^{-2} s^{-1})
2	$0.12^{+0.03}_{-0.02}$	$0.9^{+0.06}_{-0.15}$	1.0 (59)	$2.1^{+0.2}_{-0.2} \times 10^{-11}$
4	$0.12^{+0.01}_{-0.01}$	$0.89^{+0.1}_{-0.09}$	1.0 (93)	$2.8^{+0.2}_{-0.2} \times 10^{-11}$
5	$0.11^{+0.01}_{-0.01}$	$0.9^{+0.1}_{-0.1}$	1.1 (58)	$3.3^{+0.3}_{-0.3} \times 10^{-11}$
6	$0.13^{+0.02}_{-0.01}$	$0.8^{+0.2}_{-0.2}$	0.8 (43)	$3.4^{+0.4}_{-0.5} \times 10^{-11}$

As the source may show some variability, we extracted a spectrum from each of the six pointings. Pointings #1 and #3 are quite short (<1 ks) so we do not consider them further. An unabsorbed power-law provides acceptable fits to pointings #2 and 4 (χ^2_ν between 1.3 for 61 d.o.f. and 1.6 for 95 d.o.f.), but not to pointings #5 and #6, where a significant excess is detected at soft X-rays. Haberl et al. (2002) also mention the need for a black-body to account for a soft excess in their *XMM* spectra. Adding a black-body to the power-law improves the fits greatly. We point out that Haberl et al. (2002) used a much more sophisticated model, but given the lower quality of our data, we only use the simple phenomenological models. However, since they report some absorption in the spectra we also included an absorption component. The resulting model is therefore `phabs*(bbody+powerlaw)` in the `XSPEC` terminology. When left free to vary, N_{H} tends toward very low values, although the 90% upper limit is (marginally) compatible with $\sim 0.14 \times 10^{22}$ cm^{-2} (Haberl et al. 2002). We therefore fixed N_{H} to this value in our fits. The results are reported in Table 6. The variations of the flux do not seem to be related to spectral changes, but they are more probably due to slight variations of the accretion rate.

IGR J18214−1318:

Tomsick et al. (2008a) recently reported a refined X-ray position with *Chandra* for this object. The accuracy of their position is 0.64″. The XRT position is 1.1″ away from the *Chandra* position, and the XRT error box (Table 2) contains the Chandra source. No counterpart is detected in any of the *UVOT* filters. We refer to Tomsick et al. (2008a) for the identification of counterparts. An absorbed power-law fits the XRT spectrum well ($\chi^2_\nu = 0.96$ for 83 d.o.f.). The value of N_{H} is higher than the Galactic value along the line of sight (Table 5), which confirms that there is intrinsic absorption in this source (Tomsick et al. 2008a). Our value of 3.5×10^{22} cm^{-2} is, however, significantly lower than the value of 11.7×10^{22} cm^{-2} obtained with *Chandra* observations (Tomsick et al. 2008a). Fixing N_{H} to the latter value does not lead to a good fit ($\chi^2_\nu = 2.4$ for 84 d.o.f.). This indicates that the variations of N_{H} are genuine for this source. This further argues in favour of an HMXB (possibly a supergiant system) since significant variability of N_{H} has been reported for several systems (e.g., Prat et al. 2008, in the case of IGR J19140+0951).

Note that the very hard spectrum may then indicate the presence of a pulsar.

IGR J19267+1325:
No X-ray source is found within the 3.7′ IBIS error circle. A bright X-ray source is, however, found 4.5′ away from the center of the IBIS error circle, and is, therefore, marginally compatible (within the 3σ error circle) with the *INTEGRAL* position. The *Swift* position is 1.7″away from the very recent 0.64″ *Chandra* position reported by Tomsick et al. (2008b). The positions given by the two satellites are therefore entirely compatible. Tomsick et al. (2008a) report the presence of a single IR and optical counterpart within the *Chandra* error circle of this object. We detect a single source in the UVOT detector (Table 4). It is well within the XRT and *Chandra* error circles (at 0.3″ from the best *Chandra* position).

An absorbed power-law provides an acceptable, although not perfect, fit ($\chi^2_\nu = 1.7$ for 18 d.o.f.) to the XRT spectrum. The value of the absorption is below the Galactic value on the line of sight, and we obtain an upper limit consistent with the value of 2.1×10^{22} cm^{-2} obtained with *Chandra* (Tomsick et al. 2008b). Landi et al. (2007) mentioned the presence of black-body emission in the spectrum. We added such a component in our spectral fits (both with and without absorption), but in no case did it provide a noticeable improvement over the absorbed power-law fit. The extrapolated 20–40 keV flux of $\sim 2.3^{+1.7}_{-1.1}$ mCrab is higher than the IBIS 20–40 keV flux of 0.7 mCrab reported by Bird et al. (2007). This may argue in favour of an association of this source with the *INTEGRAL* source, suggesting that it undergoes significant flux variations. The hard power-law index, low value of the absorption and position on the plane of the sky close to the Sagittarius arm would tend to suggest this object has a Galactic origin. Optical observations allowed Steeghs et al. (2008) to detect a possible counterpart within the *Chandra* error box of this source. Optical spectroscopy of this source permitted Steeghs et al. (2008) to further conclude that this source is a CV, probably containing a magnetic white dwarf (see also Butler et al., submitted to ApJ).

IGR J20286+2544:
Based on the presence of MCG+04-48-002 in the IBIS error circle of the *INTEGRAL* source Bassani et al. (2006) suggested an association between the two objects. Masetti et al. (2006a) added that although this Compton thick $z = 0.013$ Sey 2 was most probably the true counterpart to the IGR source, contribution from the nearby $z = 0.01447$ galaxy NGC 6921 could not be excluded. Our *Swift* mosaic image reveals 2 sources (Swift J202834.9+254359, source #1, and Swift J202828.7+254322, source #2), whose positions match those of the two galaxies. There are two possible USNO-B1.0 sources within the *Swift* position of source #1. Only one has well-estimated magnitudes in the *B* and *R* bands. As it is the closest in position to the 2MASX source (0.9″), it is the one we report in Table 4. Both sources are quite well-detected with the *UVOT* as extended sources in the *B*, *U*, *V*, *UVW*1 and *UVW*2 filters (Fig. 2). The UVOT counterpart to source #1 is not spontaneously found by `uvotdetect`, although it is clearly visible in Fig. 2. In this case, we used `uvotcentroid` to obtain an *estimate* of the source position[8], while the magnitudes at the best position of the source were obtained with `uvotsource`. The positions of all counterparts of source #2 are compatible with being within the extension of the 2MASX sources. We note, however, a large discrepancy between the *B* magnitude obtained by the *UVOT* (14.3) and that of the USNO-B1.0 source reported in Table 4. This may indicate that all *UVOT* magnitudes are overestimated, possibly because of the extension of the source.

As both sources are rather faint, we accumulated average spectra from the four pointings. The spectrum of source #1 is not well-fitted by an absorbed power-law ($C = 43$ for 14 bins). Significant residuals are found at low energy. Such soft excesses have been reported in a number of AGN (e.g., paper 1 and references therein). Adding an unabsorbed black-body greatly improves the fit ($C = 8.0$ for 14 d.o.f.). The black-body has a temperature of $0.4^{+0.2}_{-0.1}$ keV, and a 0.5–10 keV luminosity of $1.5^{+0.75}_{-0.5} \times 10^{40}$ erg/s assuming a distance $z = 0.013$. The other parameters are reported in Table 5. The source is strongly absorbed, but not Compton-thick. The extrapolated 20–40 keV flux is 4.5 times lower than the 20–40 keV IBIS flux of 2.6 mCrab reported by Bird et al. (2007).

As for source #1, a simple absorbed power-law does not provide a good description of the spectrum of source #2. It in particular gives negative values for the power-law index. Even fixing the latter to a fiducial value of 2 does not help. We used a similar model as for source #1, and this led to a good fit ($C = 11.7$ for 14 bins). The value of the photon index is poorly constrained (Table 5). In subsequent runs it was fixed to 2.0. Even in those cases, the source is highly absorbed and could be a Compton-thick object with $N_{\rm H} \sim 83 \times 10^{22}$ cm^{-2}. In this latter case, the extrapolated 20–40 keV flux is 8.2 times lower than the IBIS flux of IGR J20286+2544.

Although the flux of source #2 highly depends on the value of the photon index, our results indicate that IGR J20286+2544, the source seen by *INTEGRAL*, is probably a blend between Swift J202834.9+254359 and Swift J202828.7+254322, with a stronger contribution from the former. We also note that the high flux obtained by *INTEGRAL* may indicate significant variability in those sources. It has to be noted that the high absorption in source #2 would argue in favour of the source being a Sey 2, similar to source #1.

IGR J23206+6431:
This source was associated with 2MASX J23203662+6430452 by Bikmaev et al. (2008) based on the observation made with *Swift*. They did not provide any fine X-ray position, however. The position reported in Table 2 is fully compatible with that of the IR counterpart. They measured a value of $z = 0.0717$ from optical spectroscopy of this counterpart, and classified it as a Sey 1. The source is not detected by the *UVOT* *U*-filter with a 3σ lower limit $U > 21.1$.

An absorbed power-law fits the spectrum well ($\chi^2_\nu = 0.3$ for 8 d.o.f.). The 2–10 keV luminosity at $z = 0.0717$ is $5.4^{+1.3}_{-1.0} \times 10^{43}$ erg/s, which is typical for this type of object. The low value of the absorption is also compatible with the source being a Sey 1.

3.2. IGR J03184–0014

The position of the *Swift* source we found is 4.4′ away from the best IBIS position, and is, therefore, slightly outside the 4.0′ 90% IBIS error circle reported in Bird et al. (2007). Given the compatibility of the 3σ error circles of both the *INTEGRAL* and *Swift* sources, we first consider the possibility that the two

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[8] `uvotcentroid` obtains mean coordinates by running a series of Monte-Carlo simulations of the source's pixel distribution on a 20 × 20″ sub-image centred on the best position

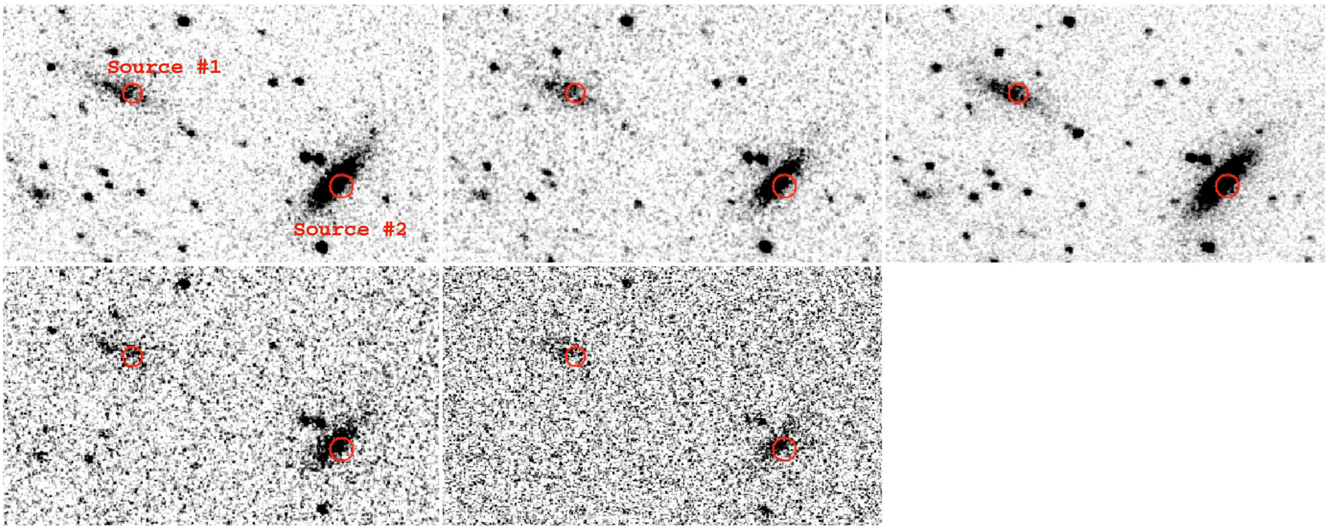

Fig. 2. *From top to bottom and left to right* 2.9′×1.7′ $B, U, V, UVW1, UVW2$ images of the field of IGR J20286+2544. The circles represent the *Swift* error circles for the two possible counterparts.

sources are associated. Its IR counterpart has a well-measured magnitude in the K_s band only. There is no USNO-B1.0 source within the *Swift* error circle with $V \gtrsim 21$. The UVOT telescope observed the field in the $UVW1$ filter. The `uvotdetect` tool did not yield a detection of a source within the XRT error circle. The presence of a bright $UVW1 = 13$ source at 23.8″ from the candidate counterpart renders, however, the detection of a possible counterpart difficult (the source is so bright that part of its flux is within the XRT error circle). Keeping this caveat in mind, we can roughly estimate a 3σ upper limit $UVW1 > 21.95$ based on the faintest source detected (at a confidence level greater than 3σ) with `uvotdetect`.

The *Swift* spectrum extracted from the single pointing available has 19 cts. An absorbed power-law is a good representation of the spectrum ($C = 10.4$ for 14 bins). As the value of the absorption is very poorly constrained ($<1.3 \times 10^{22}$ cm^{-2} at 90% confidence if left free to vary) we fixed it to the Galactic value along the line of sight. The spectral parameters are reported in Table 5. A fit with a black-body instead of the power-law also provides a good description of the data although statistically worse ($C = 12.0$ for 14 bins). The black-body has a temperature of $1.0^{+0.7}_{-0.3}$ keV, and a luminosity of $1.5^{+1.5}_{-0.7} \times 10^{33}$ erg/s at a distance of 10 kpc. The extrapolated 20–40 keV flux (3.5×10^{-13} erg cm^{-2} s^{-1}) is ~100 times below the IBIS flux reported in Bird et al. (2007). We, therefore, conclude that this source (Swift J031818.0−001748) and IGR J03184−0014 are probably not related.

Given the faintness of the source, it is quite difficult to unveil its true nature. The fact that it is well-detected in the K band only, and that it has no counterpart in the optical and UV bands either points to a very distant object or a faint Galactic source. If we assume the source is an AGN, with a luminosity of 6×10^{42} erg/s (the luminosity of the faintest AGN detected in Paper 1), this implies a distance $z = 0.144$. The only source that was farther than this in paper 1 (IGR J09523−6231) was not significantly detected in the IR, but had, on the other hand, a well detected U-band counterpart compatible with the emission from the accretion disc of the AGN. The absorption on the line of sight for the latter object was also much higher than in the case of IGR J03184−0014, which suggests that, if IGR J03184−0014 was an AGN it would probably be detected with the UVOT. We conclude that it is unlikely that this object is an AGN. In the case of a Galactic object, the spectral parameters, while being very poorly constrained, may be compatible with the source being either an active star, a CV, or a neutron star X-ray Binary. At 8 kpc, the 2–10 keV power-law luminosity would be 1.1×10^{34} erg/s. These again point towards the *Swift* and *INTEGRAL* sources not being related.

3.3. IGR J05319−6601

A weak source is found in the XRT ~20 ks mosaic image at a position consistent with that of IBIS (Götz et al. 2006). The XRT position is also consistent with that of RX J0531.8−6559. There are no IR or optical counterparts reported in the 2MASS, 2MASX, USNO-B1.0 catalogues with $K_s \gtrsim 16.2$, and $V \gtrsim 21$. There are no sources detected in the *UVOT* U, V, $UVM2$ and $UVW2$ filters compatible with the XRT position. As in the case of IGR J03184−0014, the presence of a bright UV source at ~10″ from the centre of the XRT error box renders the estimate of upper limits difficult due to possible contamination at the position of IGR J05319−6601. In a similar manner as for the previous source, we can estimate $U > 19.43$, $V > 19.33$, $UVW1 > 19.81$, and $UVM2 > 14.87$.

An absorbed power-law is a good representation of the *Swift* spectrum ($C = 7.4$ for 14 bins). As the value of the absorption is very poorly constrained ($<2.7 \times 10^{22}$ cm^{-2} at 90% confidence if it is left free to vary), we fixed it to the Galactic value along the line of sight. The spectral parameters are reported in Table 5. A fit with a black-body instead of the power-law also provides a good description of the data ($C = 6.53$ for 14 bins). The black-body has a temperature of $0.8^{+0.4}_{-0.3}$ keV, and a luminosity $6.6/D_{10}^{2}{}^{+4.5}_{-2.9} \times 10^{32}$ erg/s, where D_{10} is the distance in units of 10 kpc. The extrapolated 20–40 keV flux (based on the power-law model) is within 9.6×10^{-15}–1.9×10^{-13} erg cm^{-2} s^{-1} , which is more than 40 times lower than the IBIS 20–40 keV flux of 0.9 mCrab reported in Götz et al. (2006). We note, however, that during a second observing campaign, the same team did not

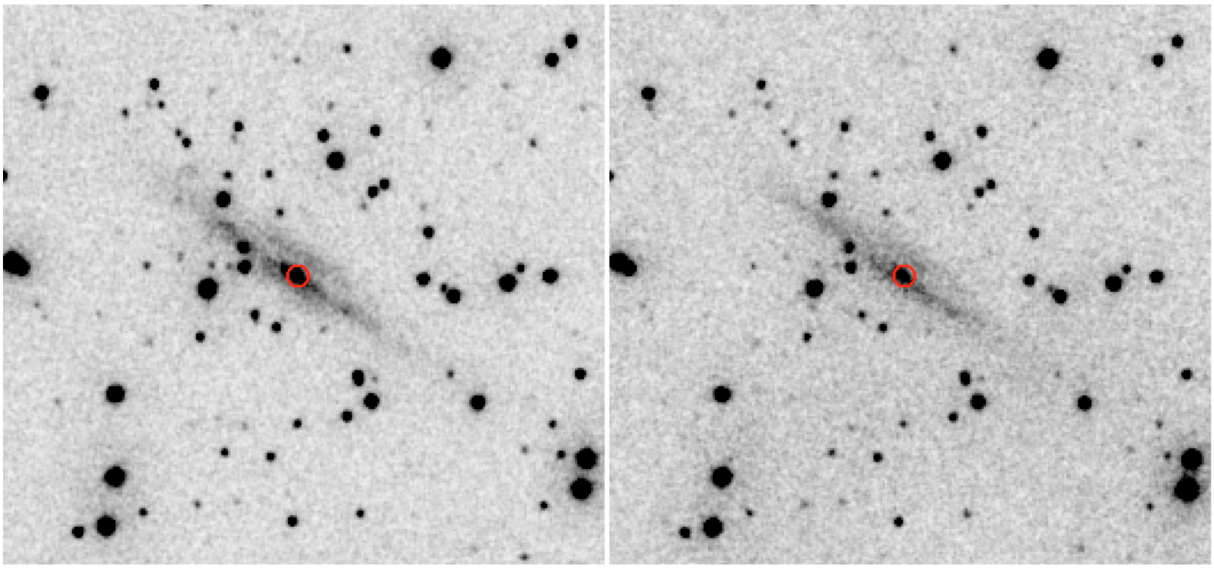

Fig. 3. 4.3′×4.1′ U (*left*) and UVW1 (*right*) UVOT images of the field around IGR J09025−6814. The best X-ray position is represented by the circle.

detect the source with *INTEGRAL*, which may indicate significant variability.

Götz et al. (2006) suggested the IGR source may be an X-ray binary in the LMC. In fact this assumption is in good agreement with the fact that no counterparts are reported in any of the optical and IR catalogues which may be due to the large distance to the source. Assuming the source is at the distance of the LMC, the 2–10 keV luminosity is $1.6^{+0.5}_{-0.3}\times10^{34}$ erg/s, which is therefore compatible with this hypothesis.

3.4. IGR J09025−6814

A very weak XRT excess is found within the IBIS error circle. The XRT position contains a 2MASX source (Table 3). It also contains two USNO-B1.0 sources. The one that is reported in Table 4 is the closest to the position of the 2MASX source (1.1″ away). It also has well-defined B and I magnitudes while the second source does not. The 2MASX source is reported in the NED database as ESO 60-24/NGC 2788A, a $z = 0.013$ galaxy. The detection of the source at X-ray energies with *INTEGRAL* and *Swift* suggests it is an AGN. The X-ray position falls right on the nucleus of the Galaxy as can be seen in the *UVOT U* and *UVW*1 images of the field (Fig. 3).

The XRT source is too weak to study any possible variability. We therefore extracted an averaged spectrum from the four pointings. An absorbed power-law seems to be a good representation of the spectrum. If we allow all parameters to be free to vary, they are, however, very poorly constrained ($C = 23$ for 14 bins, $N_{\rm H} < 52\times10^{22}$ cm^{-2} and $-2.5 < \Gamma < 3$). In order to try and have a more constraining range of values, we refitted the spectrum forcing $\Gamma \geq 0.$. An equally good fit is obtained with $C = 24$ for 14 bins. The values are reported in Table 5. The source may be intrinsically absorbed, and this may point towards a Sey 2 object, as intrinsic absorption is expected in this case. As the source is a Sey candidate, and to obtain a reasonable estimate of its flux, we fixed the power law photon index to 2.0. The 2–10 keV unabsorbed flux is $2.7^{+1.7}_{-1.5}\times10^{-12}$ erg cm^{-2} s^{-1}, which translate into a 2–10 keV luminosity of $8.7^{+1.7}_{-1.5}\times10^{41}$ erg/s. This value lies in the usual range for Seyfert galaxies.

3.5. IGR J16287−5021

The XRT position is well within the 4.4′ IBIS error circle, and is compatible with the very recent *Chandra* position reported by Tomsick et al. (2008b) (the *Chandra* positional accuracy is 0.64″. The *Swift* position is 3.6″ away from the *Chandra* position). There are no infrared and optical counterparts reported in the 2MASS, 2MASX, USNO-B1.0 catalogues. There is no source within the XRT error circle in the *UVOT UVM*2-filter image with $UVM2 > 20.0$.

The XRT spectrum is well-fitted by an absorbed power-law ($C = 8.5$ for 14 bins). The value of the absorption is not very well-constrained (Table 5), but may indicate little intrinsic absorption. Following Tomsick et al. (2008b), we also fitted the data with a non-absorbed power-law. The fit has a worse C-statistic value of 19.5 for 14 bins, which indicates that absorption is required in the fit. A good fit is also obtained when fixing $N_{\rm H}$ to the Galactic value along the line of sight ($C = 9.15$ for 14 bins). The spectrum is then much harder (0.4 ± 0.4) and is not consistent with the very hard photon index of -0.9 ± 0.4 obtained with *Chandra* (Tomsick et al. 2008b). Such a hard spectrum may indicate that the source is an HMXB.

3.6. IGR J17353−3539

As for the previous sources, a single X-ray source is found within the ∼ 3′ IBIS error circle. Our best position is within 3.1″ of 1RXH J173523.7−354013, indicating that the two sources are the same. Note that the position of 1RXH J173523.7−354013 reported in SIMBAD is at ∼9″ from the position reported in the online *ROSAT* catalogue[9]. In addition to the 2MASS source listed in Table 3, the XRT error circle also contains two USNO-B1.0 objects. Both have positions that are compatible with the position of the IR source. The closest (at 0.2″ from the 2MASS source) is the one reported in Table 4. No source is detected in the *UVM*2 and *UVW*1 filters of the UVOT telescope.

Since we see some variability, we extracted spectra from all pointings and analysed them separately. We report here only the

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[9] `http://www.xray.mpe.mpg.de/cgi-bin/rosat/src-browser`

two extreme cases, as the others have parameters that are intermediate between those two. An absorbed power-law fits both spectra well (χ^2_ν = 0.75 and 0.88 for 16 and 34 d.o.f., respectively). The value of $N_{\rm H}$ is consistent with the Galactic value on the line of sight, which indicates the object is not highly intrinsically absorbed. The position of the source towards the Galactic Bulge may indicate a Galactic source. We note that the absence of a UV counterpart with the presence of a possible optical counterpart is also more compatible with a Galactic source as, in case of an AGN, the optical would be also completely absorbed, while a Galactic stellar component could have significant emission in optical and not in the UV domain (see, e.g., paper 1). The compatibility of $N_{\rm H}$ with the Galactic value may indicate that the source lies at a significant distance. The 2–10 keV luminosity of the highest state (Table 5) is 14.4 ± 0.1 /$D_{10}^2 \times 10^{34}$ erg/s (where D_{10} is the distance in units of 10 kpc), which, combined with the spectral shape, may indicate the source is an HMXB.

3.7. IGR J17476–2253

A single bright X-ray source is found within the IBIS error circle. A single source is reported in the 2MASS catalogue (Table 3), while 2 USNO-B1.0 sources are found in the XRT error circle. The latter two are at, respectively, 1.7 and 2.9″ from the 2MASS source, and we consider the first (reported in Table 4) as just marginally compatible. The second is very probably not related to the IR source. No source is found in the $UVM2$-filter image of the UVOT telescope.

The XRT spectrum is well-fitted with an absorbed power-law (C = 4 for 15 bins). The value of the absorption is not well-constrained, and it may indicate that some intrinsic absorption occurs in this source. We, however, note that it is marginally compatible with the Galactic value along the line of sight. Fixing $N_{\rm H}$ to the Galactic value also provides a good description of the spectrum (C = 11.2 for 15 bins). In this case, the photon index is harder ($\Gamma = 1.2 \pm 0.4$). In this latter case, the 20–40 keV extrapolated flux is in good agreement with the 20–40 keV *INTEGRAL* flux of 1.3 mCrab (Bird et al. 2007). This may further argue in favour of an association between the *Swift* and *INTEGRAL* sources, although the flux obtained when all parameters are left free to vary is lower than that obtained with *INTEGRAL*. We, in addition, note that an absorbed black-body also gives a good representation of the data. It has a temperature of $0.9^{+0.1}_{-0.2}$ keV and a luminosity of 6×10^{34} erg/s at 10 kpc. Bird et al. (2007) tentatively classify this source as an AGN. We do not find strong evidence of this possibility, as the spectral parameters are also compatible with a Galactic X-ray binary. Here again, the position towards the Galactic bulge may favour a Galactic source. We note that the absence of a UV counterpart with the presence of a possible optical one is also more compatible with a Galactic source as, in case of an AGN, the optical would be also completely absorbed, while a Galactic stellar component could have significant emission in optical and not in the UV domain.

4. Summary and conclusions

In this paper, we reported the X-ray analysis of seventeen hard X-ray sources discovered by *INTEGRAL*. The refined X-ray positions provided by the *Swift* observations (Table 2) allowed us to pinpoint the possible IR and optical counterparts in most of the cases. Table 7 reports the conclusions of our analysis concerning the possible type of each of the seventeen sources. We confirm the associations and types previously suggested for five sources:

Table 7. Summary of the possible type for each counterpart of the seventeen sources, obtained through the analysis presented in this paper.

Name (IGR)	Type and Comment
J03184−0014	IGR and Swift sources not related
J03532−6829	z = 0.087 BL Lac
J05319−6601	probable XRB in LMC
J05346−5759	CV (not an IP?)
J09025−6814	AGN, poss. Compton thick, Sey 2(?)
J10101−5654	HMXB
J13000+2529	AGN
J13020−6359	HMXB with pulsar
J15161−3827 #1	AGN, Liner/Sey 2
#2	?
#3	YSO
#4	?
J15479−4529	CV/IP
J16287−5021	HMXB (?)
J17353−3539	HMXB (?)
J17476−2253	XRB (?)
J18214−1318	probable HMXB (sg star?)
J19267+1325	Galactic source
J20286+2544 #1	AGN, Sey 2
#2	AGN, Sey 2 (?)
J23206+6431	AGN, Sey 1

- IGR J03532−6829 is a BL Lac;
- IGR J05346−5759 and J15479−4529 are CVs, the latter is an IP;
- IGR J10101−5654 is very likely an HMXB;
- IGR J18214−1318 is a probable HMXB;
- IGR J13000+2529 and J23206+6431 are AGNs. The latter is a Sey 1;
- IGR J13020−6359 is an HMXB containing a pulsar.

In 2 cases, we detected several X-ray counterparts in the IBIS error circle. In these cases, the spectral analysis of each of those sources allowed us to suggest that Swift J151559.3−382548 is a probable Sey 2 AGN, which is the likely counterpart to IGR J15161−3827. In the case of IGR J20286+2544, the *Swift* error circle contains two AGNs, and the *INTEGRAL* source seems to be a blend of those two objects, although Swift J202834.9+254359 (=MCG+04-48-002) is brighter and therefore contributes more to the hard X-ray emission.

In one case (IGR J19267+1325), we do not detect any X-ray source within the IBIS error circle. A bright source, however, has a position that is marginally consistent, and, although it is slightly outside the IBIS error circle, our analysis leads us to suggest that both sources are related. We could not unambiguously unveil its true nature, although we favoured a Galactic source.
Of the six remaining source:

- IGR J05319−6601 is compatible with being an X-ray binary in the LMC;
- We identified IGR J09025−6814 with the nucleus of a galaxy, and provided the first identification of this source as an AGN and a possible Sey 2;

- We suggest that IGR J16287−5021, J17353−3539 and J17476−2253 are probable X-ray binaries and possibly HMXBs;
- We find an X-ray source slightly outside the IBIS error circle of IGR J03184−0014, but our analysis does not favour any association between the *Swift* and *INTEGRAL* objects.

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