Investigating the X-ray counterparts to unidentified sources in the 1000-orbit INTEGRAL/IBIS catalogue

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ABSTRACT

The latest INTEGRAL/IBIS all-sky survey lists 219 hard X-ray sources whose nature is still unknown. We report on our ongoing campaign aimed at identifying these high-energy emitters by exploiting the focusing capabilities of the X-ray Telescope (XRT, 0.2–10 keV) on board Swift, which allow an enhancement of the source localisation to arcsec level, thus facilitating the identification of the likely counterpart. By cross-correlating the list of the unidentified IBIS sources included in the latest IBIS catalogue with Swift/XRT archival data, we found a set of 14 objects, not yet reported in the literature, for which XRT data were available. We found no detection in only one case, a single X-ray association in 9 sources, and 2/3 associations in the remaining objects. We then made use of multi-waveband archives to search for counterparts at other wavelengths of these XRT detections and exploited X-ray spectral information in an attempt to determine their nature and association with the IBIS object. As a result of our analysis, we identified a single counterpart for 13 sources, although in some cases its nature/class could not be assessed on the basis of the information collected. More specifically, we found that SWIFT J0924.2−3141 and SWIFT J1839.1−5717 are absorbed AGN, while SWIFT J0800.7−4309 and 1SWXRT J230642.8+550817 are Cataclysmic Variable binary systems. Finally, we found that IGR J14059−6116 is likely associated with the Fermi source 3FGL J1405.4−5021. In the case of XMMSL1 J030715.5−311636 no XRT counterpart was detected. In all the other cases, optical/infrared spectroscopy is necessary to classify properly each X-ray counterpart and confirm their association with the INTEGRAL/IBIS detection.

Key words: gamma-ray: general – X-ray: general

1 INTRODUCTION

Over the last decade, our knowledge of the soft gamma-ray sky (>10 keV) has been significantly revolutionised thanks to the results obtained by IBIS (Ubertini et al. 2003) on board INTEGRAL (Winkler et al. 2003) and the Burst Alert Telescope (BAT, Barthelmy et al. 2005) on board Swift (Gehrels et al. 2004). Both telescopes operate in similar wavebands (around 20–200 keV) with a limiting sensitivity of about a mCrab and a point source location accuracy of the order of a few arcmin, depending on the source strength. Both instruments continue to survey the sky at high energies, thus providing an unprecedented sample of objects selected in the soft gamma-ray band. A significant fraction of these sources are still unidentified/unclassified, often because they lack coverage in the 2–10 keV energy range. The recent all sky INTEGRAL/IBIS survey (Bird et al. 2016) lists 939 soft gamma-ray selected sources of which 219 are still unassociated/unidentified. The identification process is crucial if one wants to gain an insight into the nature of the sources that populate our Universe at soft gamma-ray energies. To this aim, a refined localisation, attainable by exploiting the capability of current focusing X-ray telescopes, is necessary to pinpoint and classify their optical counterparts. Furthermore, information in the X-ray band can help to characterise these sources in terms of spectral shape, flux, absorption properties and variability.

In this paper, we present the results of our ongo-
ing campaign focused on identifying the still unknown integral/ibis sources. To this aim, we searched for X-ray archival data acquired with XRT on board the Swift satellite available before the end of June 2016, finding a set of 14 objects for which low energy data can provide X-ray information. Most of these sources are on the Galactic plane except for five objects (XMMSL1 J030715.5–545536, IGR J09242.4–3141, 1RXS J145559.4+120124, IGR J18074+3827, and SWIFT J1839.1–5717), which are instead located at high (above 20 degrees) Galactic latitudes.

The paper is structured as follows: in Sect. 2 we present the XRT data reduction and analysis and the criteria adopted to search for the likely counterparts to the IBIS sources. Sect. 3 is devoted to the discussion of the results for each individual source. Conclusions are drawn in Sect. 4.

2 SWIFT/XRT DATA REDUCTION AND ANALYSIS

The log of all X-ray observations taken into account in this work is shown in Table 1 where we report for each individual IBIS source, the observation ID, as well as the date and the on-source exposure time of each XRT pointing. The XRT data of the 14 selected sources were reduced by means of the XRTDAS standard data pipeline package (xrtpipeline v. 0.13.2) to produce screened event files. All data were extracted only in the Photon Counting (PC) mode that ensures a source fine positioning.

We then, for each IBIS source, summed together all the available XRT pointings using XSELECT v. 2.4c to enhance the signal-to-noise ratio and thus facilitate the detection of candidate counterparts. As a following step, we analysed the XRT images in the 0.3–10 keV energy band by means of XIMAGE v. 4.5.1 in search of X-ray detections above 3σ confidence level (c.l.) within both the 90% and 99% IBIS error circles. Furthermore, we checked the XRT images in the 3–10 keV band to select those sources with the hardest spectra (i.e. those with detection above 3 keV), since these are most likely to be the counterparts to the IBIS objects. For this reason, throughout the paper we will restrict our discussion to these sources, providing details on weaker X-ray detections only when possibly relevant. We estimated the X-ray positions using the task xrtcentroid v. 0.2.9. In the XRT images we plot the 90% and 99% IBIS positional uncertainties (black and black-dotted circles, respectively) and the 90% Swift/BAT error circle (black-dashed-dotted circle) when available. To visualise better the X-ray counterparts, in most cases we smoothed the images. Therefore, the presence of grains and/or features inside the XRT field of view are undoubtedly spurious; in some cases the poor quality of the XRT images is due to the low exposure.

For spectral analysis, source events were extracted within a circular region with a radius of 20 pixels (1 pixel ~2.36 arcsec) centred on the source position, while background events were extracted from a source-free region close to the X-ray source of interest. The spectra were obtained from the corresponding event files using the XSELECT v. 2.4c software and generally binned using GR PPHA to 20 counts per energy bin so that the χ² statistic could be applied. For sources with fewer counts (typically around 50–60), data were binned to 1 count per energy bin and the Cash statistic (Cash 1979) was adopted. We used version v.0.14 of the response matrices and created individual ancillary response files arf using xrtmkarf v.0.6.3.

For objects with more than one pointing, we first checked variability by analysing each single observation, then performed the spectral analysis of the average spectrum; this approach may provide further information that could be used as a possible filter on counterparts. For the spectral analysis, in the first instance, we adopted a basic model consisting of a simple power law passing through Galactic absorption in the source direction (Kalberla et al. 2005). If this baseline model was not adequate to fit the data, we then introduced extra spectral components as required.

3 RESULTS

To investigate the nature of each potential counterpart, we browsed various on-line archives such as NED (NASA/IPAC Extragalactic Database), HEASARC (High Energy Astrophysics Science Archive Research Center) and SIMBAD (Set of Identifications, Measurements, and Bibliography for Astronomical Data) in search of radio, infrared, optical, and UV counterparts within the XRT positional uncertainty. When relevant, we also discuss the association with objects reported in the ROSAT and XMM-Newton Slew catalogues (Voges et al.1999; Saxton et al. 2008).

In Table 2 we list the 14 IBIS sources analysed here together with their coordinates and relative uncertainty (90% c.l.) as listed in Bird et al. (2016). For each of these gamma-ray emitters, we then report the coordinates and relative uncertainties (at 90% c.l.) of all sources detected by XRT within the 90% and 99% IBIS positional uncertainties, the count rate in both the 0.3–10 and 3–10 keV energy range, the number of X-ray observations analysed and the total on-source exposure time. For each IBIS source, in Table 3 we report those XRT objects for which an optical and IR counterpart was found; references for the databases used are reported at the end of Table 3.

The results of the spectral analysis are shown in Table 4 where we report the Galactic column density in the source direction (Kalberla et al. 2005) and the best-fit parameters (intrinsic column density, power law photon index, χ² or C-stat versus degrees of freedom and 2–10 keV flux). Spectra and data-to-model ratio are shown for only those sources treated with the χ² statistic.

In the following, we discuss each integral/ibis source (as reported in Bird et al. 2016) and briefly analyse the overall properties found for each candidate counterpart.

3.1 XMMSL1 J030715.5–545536 (Detected as a persistent source)

This is the only IBIS source for which XRT follow-up observations do not reveal the presence of X-ray sources in the region surrounding the high-energy emitter. However, within

1 More information for these two catalogues are available at: https://heasarc.gsfc.nasa.gov/W3Browse/rosat/rassbbsc.html; https://heasarc.gsfc.nasa.gov/W3Browse/xmm-newton/xmmimglcat.html.
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Table 1. Log of the Swift/XRT observations used in this paper.

| IBIS source ID | Obs. Date | Exposurea (s) |
|----------------|-----------|---------------|
| XMMSL1 J030715.5−545536 | Mar 03, 2016 | 3277 |
| SWIFT J0800.7−4309 | Dec 08, 2010 | 692 |
| SWIFT J0924.2−3141 | Apr 02, 2013 | 2600 |
| IGR J14059−6116 | Oct 04, 2011 | 3114 |
| 1RXSJ 145959.4+120124 | Mar 02, 2013 | 2695 |
| IGR J15038−6021 | May 12, 2013 | 331 |
| IGR J16447−5138 | Mar 04, 2014 | 399 |
| IGR J17508−3219 | Mar 18, 2016 | 399 |
| IGR J18007−4146 | Mar 20, 2016 | 3016 |
| IGR J18074+3827 | Mar 06, 2016 | 4207 |
| XMMSL1 J182831.8−022901 | Nov 09, 2012 | 148 |
| SWIFT J1839.1−5717 | Oct 17, 2008 | 7675 |
| IGR J20310+3835 | Dec 04, 2012 | 108 |
| 1SWXRT J230642.8+550817 | Sep 01, 2010 | 592 |

The 90% IBIS positional uncertainty there is an XMM-Newton Slew source (XMMSL1 J030715.5−545536) that is detected at around 2σ c.l. in the 0.2−12 keV energy band with a flux of $1.5 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$. The XRT upper limit in the same energy range is ∼$1.2 \times 10^{-14}$ erg cm$^{-2}$ s$^{-1}$, which indicates significant flux variability over the period covered by the XMM-Newton Slew (November 2010) and XRT (March 2016) pointings. Within the restricted positional uncertainty of the XMM-Newton Slew detection (5.1 arcsec), we do not find any optical or IR counterpart. We note that 4% of the sources in the clean Slew Survey catalogue are expected to be spurious from statistical considerations (see Saxton et al. 2008), which suggests that this possibility cannot be totally discounted. Alternatively, an X-ray source is present inside the IBIS positional uncertainty but variable over time, more strongly at lower than at higher...
energies given the persistent nature of the source within the INTEGRAL database used by Bird et al. (2016). If so, and considering the source high Galactic latitude ($b = -53^\circ$), this X-ray detection could be an AGN maybe of the blazar type. Only X-ray monitoring of the source can provide some clues on its nature, while spectroscopy of the only possible X-ray counterpart can confirm or not its association with the gamma-ray source.

### 3.2 SWIFT J0800.7–4309

(Detected as a persistent source)

This source is also unclassified in the 70-month Swift/BAT survey (Baumgartner et al. 2013). The observations performed with XRT show the presence of three X-ray sources within the 90% IBIS/BAT positional uncertainty (see Ta-
Figure 1. XRT 0.3–10 keV image of the region surrounding SWIFT J0800.7−4309. Three X-ray sources are detected within the 90% IBIS and BAT positional uncertainties (black circle and black-dashed-dotted circle, respectively).

Figure 2. XRT spectrum of SWIFT J0800.7−4309 source #1 fitted with our basic model (upper panel); residuals to this model are in units of σ (lower panel).

Table 2 and Figure 1, two of which (source #1 and #2) are still detected above 3 keV.

In more detail, for source #1, which is the brightest object even above 3 keV (15.2σ c.l.), we found a single optical and IR counterpart within its error circle (see Table 3). Recent optical follow-up observations (Rojas et al. 2016) indicate that this is a Cataclysmic Variable binary system source (CV). Our basic model (Γ ∼ 0.8 and 2–10 keV flux of ∼5 × 10^{-12} erg cm^{-2} s^{-1}, see Table 4) does not yield a good fit to the XRT data (χ^2/d.o.f. = 43.3/35), as an excess below 1 keV is clearly visible in the data-to-model ratio (see Figure 2). This feature, which is expected to be observed in CVs (see Landi et al. 2009 and references therein), can be modelled with a blackbody component. Unfortunately, the statistical quality of the X-ray data does not allow us to place any constraint on this component.

A single optical and IR counterpart (see Table 3) was also found within the positional uncertainty of source #2, which is still detected above 3 keV but only at 3.4σ c.l. For this object, the XRT spectral analysis yields a 2–10 keV flux of ∼2 × 10^{-13} erg cm^{-2} s^{-1} and a photon index around 1.2 (see Table 4).

The X-ray brightness of source #1 and its optical classification argue in favour of its association with SWIFT J0800.7−4309, but optical spectroscopy of source #2 is required before its contribution to the soft gamma-ray emission can totally be disregarded.

3.3 SWIFT J0924.2−3141

(Detected as a persistent source)

Also this source is reported in the Swift/BAT 70-month survey (Baumgartner et al. 2013). XRT follow-up observations reveal the presence of two objects (see Figure 3 and Table 2) in the region surrounding this high-energy emitter. Their positions are compatible with either the 90% (#1) or the 99% (#2) IBIS positional uncertainties, but only source #1 is located within the 90% BAT error circle.

Source #1 is detected at 5.7σ c.l. both in 0.3–10 keV energy range and above 3 keV. The source is visible at 2.4σ c.l. up to 6.7 keV. Its optical/IR counterparts are listed in Table 3: both are associated with the galaxy 2MASX J09235371−3141305, classified as a Seyfert 1.8 at z = 0.042 in the Veron & Veron (13th edition) catalogue (2010). The XRT localization is also compatible with a NVSS radio source belonging to the NRAO VLA Sky Survey (NVSS; Condon et al. 1998), namely NVSS J092353−314126, listed with a 20 cm flux density of 4.4 ± 0.5 mJy. This source was proposed by Baumgartner et al. (2013) as the counterpart to SWIFT J0924.2−3141. Furthermore, Ricci et al. (2015), combining XRT and BAT spectra, have recently suggested that this may be a Compton thick AGN. The XRT data, although of poor statistical quality, require a double power-law model, with the primary component absorbed by an intrinsic column density and the secondary component, having the same photon index (frozen to 1.8) of the primary one, passing only through the Galactic absorption. The intrinsic N_H, albeit poorly constrained, is found to be around 8 × 10^{23} cm^{-2} and compatible with the Compton thick regime within uncertainties, while the 2–10 keV flux is ∼1.4 × 10^{-12} erg cm^{-2} s^{-1} (see Table 4).

Source #2, which lies just outside the 90% IBIS error circle but within the 99% one, is much brighter than object #1, as it is detected at around 126σ and 72σ c.l. in the 0.3–10 keV energy band and above 3 keV, respectively. Its XRT position is compatible with an USNO−A2.0 object; no IR counterpart has been found (see Table 3). Browsing the HEASARC archive, we find that this source was detected by various X-ray instruments like Chandra as CXO J092418.2−314217, BeppoSAX Wide Field Camera as SAXWFC J0924.3−3142.4, and ROSAT as the bright source 1RXS J092418.0−314212. It also coincides with an XMM-Newton Slew source (XMMSL1 J092418.4−314219), which is detected at 14.3σ c.l., with a 0.2–12 keV flux of

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\[ \sim 1.42 \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1}. \] Historically, the source may have also been observed by \emph{ARIEL V} and \emph{UHURU} with a 2–6 keV flux around \(8 \times 10^{-11}\) erg cm\(^{-2}\) s\(^{-1}\) and reported in the \emph{HEAO–1 A3} MC LASS catalogue (H0922–374), where it is classified as an X-ray binary in the Galaxy, due to the fact that the X-ray flux is by far too bright for an AGN of magnitude \(V \sim 21\). Furthermore, the X-ray/optical fluxes and ASM colours most likely resemble low luminosity ultra compact binaries. By fitting the average XRT spectrum with a simple power law, we found a photon index \(\Gamma \sim 1.4\) and a 2–10 keV flux of \(~2.4 \times 10^{-10}\) erg cm\(^{-2}\) s\(^{-1}\). The addition of a blackbody component provides a significant improvement of the fit \((\Delta \chi^2 = 40.0\text{ for two d.o.f. less})\), yielding a temperature \(kT \sim 1.1\) keV, a photon index of \(\sim 1.7\) and a 2–10 keV flux of \(~1.9 \times 10^{-10}\) erg cm\(^{-2}\) s\(^{-1}\) (see Figure 4). Analysing single XRT observations we find variability by a factor of 1.7 over a year time-scale and by a factor of 2 in comparison with the \emph{XMM-Newton} Slew flux measurement.

As can be seen in Figure 3, the XRT data are not able alone to discriminate between source \#1, located within the 90\% IBIS/BAT error circle, very hard but less bright and source \#2, 100 times brighter but located outside the 90\% IBIS positional uncertainty. Luckily, \emph{NuSTAR} has recently performed an observation of this sky region: although both sources are clearly visible in the 3–79 keV image, only source \#1 is present above 15 keV (see Figure 5)\(^2\) and is therefore the real counterpart of this IBIS/BAT detection. Source \#2 remains, however, an interesting object to study and one for which optical follow-up observations would be very useful. Fitting the \emph{NuSTAR} spectrum of source \#1\(^3\) with an absorbed power law provides a good fit \((\chi^2/d.o.f. = 58.76/56)\) to the data and the following best-fit parameters: a photon index of \(1.5 \pm 0.2\), a column density of \((5.9 \pm 1.7) \times 10^{23}\) cm\(^{-2}\) and a 2–10 keV flux of \(~1.3 \times 10^{-12}\) erg cm\(^{-2}\) s\(^{-1}\); this indicates that source \#1 is heavily absorbed, but not quite Compton thick.

\[3.4\] \emph{IGR J14059–6116}

\begin{flushleft}
(\textit{Detected in a 2198.6-day outburst from MJD = 52980.4})
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According to the bursticity method (see Bird et al. 2016 for details), this source was detected during activity in a set of data corresponding to roughly 2200 days over the period December 7, 2003 to December 14, 2009 (MJDs 52980.4 – 55179.04). XRT follow-up observations were instead carried out at a later time, more specifically during 2011 (October 4, 8 and November 1), 2012 (September 21) and 2015 (February 19 and April 27). It is therefore possible that the X-ray pointings missed the active phase seen by IBIS above 20 keV and observed the source in a more typical X-ray state. Despite this note of caution, the combined XRT image of this sky region (Figure 6) shows the presence of only one source whose position is compatible with the 99\% IBIS positional uncertainty (see Table 2).

\(^2\) NuSTAR images were extracted starting from the event files available in the ASI/ASDC data archive available at:
http://www.asdc.asi.it/mta/index.php?mission=nustar.

\(^3\) For this spectral extraction, we follow the prescription used by Malizia et al. (2016) for other AGN observed by NuSTAR.

![Figure 3. 0.3–10 keV XRT image of the SWIFT J0924.2–3141 field. Two sources are detected by XRT: source \#1 and \#2 lie within the 90\% (black circle) and 99\% (black-dotted circle) positional uncertainties, respectively. While source \#1 is contained within the 90\% BAT error circle (black-dashed-dotted circle), source \#2 lies just outside it.](image)

![Figure 4. XRT spectrum of SWIFT J0924.2–3241 source \# 2 fitted with our basic model plus a black body component (upper panel); residuals to this model are in units of \(\sigma\) (lower panel).](image)
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Figure 5. NuSTAR images of the SWIFT J0924.2−3141 field. Left panel: image in the 3–79 keV energy band, where the two sources detected by XRT are clearly visible. Right panel: image in the 15–79 keV energy band, where only source #1 is still detected by NuSTAR.

has also been observed by Chandra on September 19, 2013: it is listed in the Chandra ACIS GSG Point-Like X-Ray Source Catalog (Wang et al. 2016) as CXOGSG J140514.4−611827 (only 1 arcsec uncertainty) with a 0.3–8.0 keV flux of $2.6 \times 10^{-13} \text{erg cm}^{-2} \text{s}^{-1}$, i.e. similar to the XRT one.

The detection of the XRT source inside the 3FGL error ellipse and its connection with the IBIS object is particularly interesting and worth investigating. Unfortunately, at this stage, the limited multi-waveband information prevents us from finding any secure clues on the nature of the source. The lack of a radio emission within the XRT positional uncertainty together with the allWISE colours ($W1 - W2 = 0.381$, and $W2 - W3 = 1.281$) of the IR counterpart, indicates that a blazar interpretation is unlikely (Masetti et al. 2013). Moreover, the source is located at low Galactic latitude ($b = +0.29$°), i.e. on the Galactic plane, and 3FGL J1405.4−6119 has already been reported as a pulsar candidate by Lee et al. (2012) and more recently by Saz-Parkinson et al. (2016).

Clearly, this remains an object of uncertain type, but its association with GeV emission is of particular interest and future dedicated high-energy observations and optical spectroscopy of the XRT source may shed light on its ultimate nature.

3.5 1RXS J145959.4+120124
(Detected in a 48.7-day outburst from MJD = 54640.7)

This is another IBIS source detected with the bursticity method; it was detected during a 49-day outburst starting from June 23, 2008. The XRT observations were instead performed on March (15 to 18) 2016. As shown in Figure 7, there is only one X-ray source within the IBIS 90% positional uncertainty; it is detected around 12σ and 5σ in the 0.3–10 and 3–10 keV energy range respectively. It has a counterpart in an XMM-Newton Slew object (XMMSL1 J145959.6+120131, 6.2" error radius) that is also reported in the ROSAT Bright source catalogue as 1RXS J145959.4+120124 (11" error radius). By XMM-Newton it is detected at 3.7σ c.l. in the 0.2–12 keV energy range with a flux of $5.32 \times 10^{-12} \text{erg cm}^{-2} \text{s}^{-1}$, 60% of which is above 2 keV$^4$. In the XMM-Newton Slew catalogue, the source is associated with HD 132658/TYCHO 922−865−1$^5$, a bright star of spectral type F5 D, whose location is also compatible with the positional uncertainty of the ROSAT detection.

The spectral analysis of the average XRT spectrum provides a photon index of $\sim 1.9$ and a 2–10 (0.2–12 keV) keV flux of $2.4 (5.0) \times 10^{-12} \text{erg cm}^{-2} \text{s}^{-1}$ (see Figure 8 and Table 4); the XRT flux ranges from 1.2 to 2.4× 10−12 erg cm−2 s−1. Therefore, spectral analysis of each single observation indicates variability by a factor of $\sim 2$ on a four-day time-

$^4$ XMM-newton Slew observation date is February 6, 2002.
$^5$ See more information at: http://www.astrostudio.org/xhip.php?hip=73397.
scale, while comparison of the average XRT flux with the \textit{XMM-Newton} Slew one indicates similar flux levels.

The X-ray source may also be associated with radio emission since a NVSS and FIRST (Faint Images of the Radio Sky at 20 cm, Helfand et al. 2015) source is listed nearby. The source, named NVSS J145959.4+120126/FIRST J145959.3+120125, has a 20 cm flux density of $6.5 \pm 0.4$ and $8.88 \pm 0.15$ mJy in the two catalogues, respectively. The NVSS image of this sky region is shown in Figure 9 where we plot the XRT, \textit{ROSAT}, and \textit{XMM-Newton} Slew error circles, as well as the position of the star HD 132658/TYCHO 922−865−1. Figure 9 emphasises that this is clearly a difficult case: on the one hand the star is formally outside the XRT positional uncertainty, but it is compatible with the \textit{ROSAT} and \textit{XMM-Newton} Slew error circles and it is spatially coincident with the radio source; on the other hand it is difficult to explain radio and soft gamma-ray emission from an F type class object. Alternatively, one must consider the possibility that the star is a chance association and that the true counterpart is a background object masked by the brightness of the star. In this case, the X-ray properties, the location of the source at high Galactic latitudes and the presence of radio emission suggest an extragalactic nature, i.e. a variable AGN behind HD 132658/TYCHO 922−865−1. Unfortunately, optical/IR follow-up observations cannot help in this case, since the bright star prevents the detection of objects nearby or behind it, thus making this case difficult to solve.

3.6 IGR J15038−6021
\textit{(Detected as a persistent source)}

In this case, only one X-ray source is clearly visible inside the 90% IBIS error circle as listed in Table 2 and depicted in Figure 10. It is detected at 5σ and 3.3σ c.l., in the 0.3–10 and 3–10 keV energy range, respectively. Because of the poor quality of the XRT data, we can only infer a 2–10 keV flux of $\sim 1.6 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, by freezing the photon index to 1.8.

Two optical and one IR counterparts were found within the XRT positional uncertainty (see Table 3).

The hardness of this source in X-rays and the lack of other X-ray detections suggest that it is a likely association with IGR J15038−6021. Spectroscopy of both optical candidates are therefore encouraged to pinpoint which of the two is the true counterpart and assess its nature.

3.7 IGR J16447−5138
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3.8 IGR J17508−3219

Figure 10. XRT 0.3–10 keV image of the region surrounding IGR J15038−6021. Only one source is detected by XRT within the 90% IBIS error circle (black circle).

Figure 11. XRT 0.3–10 keV image of the region surrounding IGR J16447−5138. The only XRT detection lies at the border of the 90% IBIS positional uncertainty (black error circle).

Figure 12. XRT spectrum of IGR J16447−5138 fitted with our basic model plus intrinsic absorption (upper panel); residuals to this model are in units of σ (lower panel).

(_detected in a 35.7-day outburst from MJD = 54141.5)

This source was detected during an outburst lasting roughly 5 weeks starting from February 10, 2007; the XRT pointings were made at a much later time (March 4–6, 2016) and may be related to a more inactive state of the source.

The only X-ray object seen in the region surrounding the IBIS emitter is located at the border of the 90% IBIS error circle (see Figure 11). It is detected at 13.4σ and 7.1σ c.l. in the 0.3–10 and 3–10 keV energy range. The source is also reported as an XMM-Newton Slew object XMMSL1 J164433.3−513420 with a 0.2–12 keV flux of $1.30 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$.

The XRT spectrum is well modelled with an absorbed power law ($N_{\text{H, int}} < 0.6 \times 10^{22}$ cm$^{-2}$), yielding a photon index $\Gamma \sim 2.0$ and 2–10 keV flux of $\sim 3.9 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ (see Figure 12 and Table 4). The source shows flux variability by a factor of 1.5 over a two-day time-scale comparing closely Swift pointings. The XRT flux is also higher by a factor of 3.5 than the XMM-Newton Slew one in the same energy range. In Table 3 we report the only optical and IR counterpart to the XRT source.

We note that this object is on the Galactic plane and has been suggested to be a Young Stellar Object (YSO) by Marton et al. (2016) on the basis of its WISE and 2MASS photometric data. above 20 keV during flaring events, while coronal activity. However, we note that extragalactic sources, especially galaxies with ongoing star formation or active galactic nuclei, show similar infrared spectral shape to that of YSOs and may be variable over time; this leaves the final answer on which is the nature of this source to optical follow-up spectroscopic observations and eventually to X-ray monitoring campaigns.

(_detected as a persistent source)

In this case, two X-ray detections are revealed by XRT in the region surrounding IGR J17508−3219 as can be seen in Figure 13.

Source #1, which is located within the 90% IBIS error circle, is the weakest of the two, but also the only one detected above 3 keV (at 3.1σ c.l., see Table 2). In Table 3 it has a single infrared counterpart (GLIMPSE G357.6922−02.7203), which is not seen at optical wavelengths; because of the low statistical quality of the X-ray data the spectral parameters are poorly constrained. The fit with our basic model yields a flat photon index around 0.6 and a 2–10 keV flux around $8 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$; fix-
and Table 4. IGR J18007+3827

Figure 13. XRT 0.3–10 keV image of the region surrounding IGR J17508−3219. Two sources are detected by XRT: source #1 and #2 lie within the 90% and 99% IBIS positional uncertainty (black and black-dotted circles), respectively.

Figure 14. XRT 0.3–10 keV image of the region surrounding IGR J18007+4146. XRT detects only one source that is located within the 90% IBIS positional uncertainty (black circle).

3.9 IGR J18007+3827

(Detected as a persistent source)

For this INTEGRAL emitter, only one X-ray source is detected within the 90% IBIS positional uncertainty (see Figure 14 and Table 2). It is detected at 9.5σ and 5.5σ c.l. in the 0.3–10 and 3–10 keV energy range, respectively.

Within the XRT error box we also found an XMM-Newton Slew object (XMMSSL1 J180042.8−414651) that is detected at 2.7σ c.l. with a 0.2–12 keV flux of 1.78×10−12 erg cm−2 s−1. Another XMM-Newton Slew object (XMMSSL1 J180042.8−414656) was found at 8.4 arcsec from the XRT centroid. It is detected at 2.6σ c.l. with a 0.2–12 keV flux of 2.79×10−12 erg cm−2 s−1. The distance between the two XMM-Newton Slew detections is only 6 arcsec, whereas their respective error radii are 3.6 and 4.1 arcsec: this strongly suggests that they are probably the same source seen in different periods (observing times 2010–10–06 and 2013–03–08 for the first and second XMM-Newton Slew objects, respectively) and both are associated with the single XRT detection. If the two XMM-Newton Slew objects are the same object, then the observed fluxes indicate that the source may be variable on yearly timescales.

Our XRT baseline model provides a flat photon index ($\Gamma = 1$) and a 2–10 keV flux of $2.7 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ (see Figure 15 and Table 4); the extrapolation of the XRT flux to the 0.2–12 keV energy range yields a flux of $3.8 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$, higher than those shown by the XMM-Newton Slew detections.

Within the XRT positional uncertainty we find two possible counterparts (see Table 2); optical spectroscopy of both of them is necessary to disintangle which of the two is the real counterpart and assess its nature.

3.10 IGR J18074+3827

(Detected in a 447.2-day outburst from MJD = 53275.0)

In this case the source detection by IBIS is optimised over a period of around 15 months starting from September 26, 2004, while the only XRT pointing was carried out much later, at the beginning of June 2016.

In the region surrounding IGR J18074+3827 there is only one X-ray source that lies within the 90% IBIS positional uncertainty (see Figure 16). It is revealed at 3.3σ in the 0.3–10 keV energy range, but not above 3 keV. The XRT error circle is compatible with that of an XMM-Newton Slew source (XMMSSL1 J180752.6+382240, error radius of 3.4 arcsec), which is detected at 2.1σ c.l. with a 0.2–12 keV flux of $1.55 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$.

Given the poor quality of the XRT data, we can only infer a 2–10 keV flux of $\sim 1 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$, by freezing the photon index to 1.8; comparison with XMM-Newton Slew detection indicates strong X-ray variability. This suggests that XRT pointed at the source during a
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Table 3. Optical/IR associations with XRT candidate counterparts discussed in the text.

| XRT source                  | Optical/IR source† | Distance† (arcsec) | Magnitudes |
|-----------------------------|--------------------|--------------------|------------|
| SWIFT J0800.7–4309          |                    |                    |            |
| #1 USNO-A2.0 U0450.05566063 | 2.28               |                    |            |
| 2MASS J08003998–431076       | 2.22               |                    |            |
| allWISE J080039.96–431107.2  | 2.34               |                    |            |
| #2 USNO-A2.0 U0450.05571649  | 3.66               |                    |            |
| allWISE J080045.83–439939.3  | 1.86               |                    |            |

| SWIFT J0924.2–3141          |                    |                    |            |
| #1 USNO-A2.0 U0525.11601717 | 1.62               |                    |            |
| 2MASS J0925373–3141308       | 1.68               |                    |            |
| allWISE J092531.73–314130.9  | 1.68               |                    |            |
| #2 USNO-A2.0 U0525.1161506   | 1.32               |                    |            |

| IGR J14059–6116             |                    |                    |            |
| #1 2MASS J1405141–6118282   | 3.78               |                    |            |
| G311.6718+100.3053           | 3.84               |                    |            |
| allWISE J140514.40–611827.7  | 3.90               |                    |            |

| IGR J15038–6021             |                    |                    |            |
| #1 USNO-B1.0 0926–0547603   | 3.18               |                    |            |
| USNO-B1.0 0926–0547602      | 3.36               |                    |            |
| 2MASS J15041611–601225      | 1.32               |                    |            |

| IGR J16447–5138             |                    |                    |            |
| #1 USNO-B1.0 0384–0622801   | 3.18               |                    |            |
| 2MASS J1644324–5134311      | 3.42               |                    |            |
| allWISE J164433.25–513431.2 | 3.48               |                    |            |

| IGR J17508–3219             |                    |                    |            |
| #1 USNO-B1.0 0576–0768321   | 4.50               |                    |            |
| 2MASS J17505721–3219488     | 4.26               |                    |            |
| G357.6922–00.7203           | 2.40               |                    |            |

| IGR J18007–4146             |                    |                    |            |
| #1 USNO-B1.0 0482–0651082   | 1.38               |                    |            |
| USNO-B1.0 0482–0651086      | 1.92               |                    |            |
| 2MASS J18064247–4144666     | 2.16               |                    |            |
| allWISE J180642.66–414468.9 | 1.50               |                    |            |

| IGR J18074–3827             |                    |                    |            |
| #1 USNO-A2.0 U1275.09785770 | 5.52               |                    |            |
| 2MASS J18075291–3822384     | 4.74               |                    |            |
| allWISE J180752.92–382238.5 | 4.50               |                    |            |

| XMMSS1 J182831.8–022901     |                    |                    |            |
| #1 UGPS J182831.01–022906   | 1.2                |                    |            |
| UGPS J182831.03–022908.3    | 1.86               |                    |            |

| SWIFT J1839.1–5717          |                    |                    |            |
| allWISE J183905.95–571505.1 | 3.42               |                    |            |

| IGR J20310–3835             |                    |                    |            |
| #1 UGPS J203055.29–383347   | 3.06               |                    |            |
| UGPS J203055.30–383347      | 3.12               |                    |            |

| 1SWXRT J203064.28–550817    |                    |                    |            |
| #1 USNO-A2.0 U1425.1406199  | 3.66               |                    |            |
| 2MASS J20306426+5508200     | 3.36               |                    |            |
| allWISE J203064.67–550820.1 | 3.18               |                    |            |

† The catalogs are the Two Micron All Sky Survey (2MASS, Skrutskie et al. 2006), the United States Naval Observatory (USNO-B1.0 and USNO– A2.0, Monet 1998,2003), the Wide-field Infrared Survey Explorer all sky survey (WISE, Wright et al. 2010) or, if available, allWISE (available at: http://vizier.u-strasbg.fr/viz-bin/VizieR?source=II/528), the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE, Churchwell et al. 2009), and the UKIRT Infrared Deep Sky Survey (UKIDSS) Galactic Plane Survey (UGPS, Lucas et al. 2008).
‡ Angular distance from the XRT centroid.

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period of quite low flux, while INTEGRAL and XMM-Newton observed it during a much brighter flux state. Within the XRT positional uncertainty we find a single optical/infrared counterpart that is also reported as a bright UV source (GALEX J180752.91+382238.9 with Near and Far UV magnitudes of 17.9 and 17.6, respectively). The UV detection and the source location, well above the Galactic plane ($b = \sim +24.6^\circ$), argue for an extragalactic nature, but unfortunately there is no radio counterpart associated with the optical-UV/IR counterpart nor are its WISE colours compatible with an AGN nature for the source. Using the 2MASS magnitudes to compute the free reddening parameter $Q = (J–H)–1.7(H–K_s)$ to create a $Q/K_s$ diagram (Neguerela & Schurch 2007), we find that the source falls in the region of late type stars (Reig & Milonaki 2016) casting doubts on its detection above 20 keV. Furthermore, the lack of emission above 3 keV and the variability seen mostly at X-ray energies further complicate the issue and provide indication that the XRT/XMM-Newton Slew source may not be the correct association to the INTEGRAL object.

Clearly, optical spectroscopy of the only X-ray counterpart found together with further observations at time of strong X-ray emission can shed light and eventually help to classify this source.

3.11 XMMSL1 J182831.8–022901 (also 3PBC J1828.7–0227)

(Detected as a persistent source)

This source is also reported in the Palermo 66-month Swift/BAT catalogue as 3PBC J1828.7–0227⁶. XRT detects only one source which lies within the 90% IBIS error circle, but just outside the 90% BAT positional uncertainty (see Figure 17). It is seen at 11.6σ and 8.9σ c.l. in the 0.3–10 and 3–10 keV, respectively (see Table 2). The XRT position is compatible within respective uncertainties with the location of the XMM-Newton Slew detections XMMSL1 J182831.8–022901 and XMMSL1 J182831.4–022914, which are detected at 2.7 and 2.3 σ c.l. in the 0.2–12 keV energy range with a flux of $1.5 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ and $2.3 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ respectively. Both detections correspond to a single source seen by XMM-Newton at different epochs (September 23 and October 12, 2012) and possibly varying over time.

This X-ray source has only a couple of possible IR counterparts (see Table 3).

Our basic power law model does not provide a good fit to the XRT data, which require additional intrinsic absorption ($N_{\text{H,intr}} \sim 1 \times 10^{22}$ cm$^{-2}$). The photon index turns out to be around 1.2 and the 2–10 keV (0.2–12 keV) flux is $\sim 4.6(5.9) \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ (see Table 4 and Figure 18), which suggests some variability (by a factor of 2.6) if compared to the XMM-Newton Slew ones.

The location of XMMSL1 J182831.8–022901 on the Galactic plane ($b = 3.95^\circ$) indicates that we may be dealing with either a Galactic source (i.e. some type of X-ray binary) or an AGN hidden behind the Galactic plane. Only IR spectroscopy of the likely counterparts can disintangle which is the correct association and eventually unveils its nature.

3.12 SWIFT J1839.1–5717

(Detected as a persistent source)

This source is also listed in the 70-month Swift/BAT catalogue (Baumgartner et al. 2013) and it is one of the few objects in our sample located off the Galactic plane ($b = \sim -20.95^\circ$). XRT follow-up observations indicate the presence of two X-ray sources whose positions are compatible with the 90% IBIS/BAT error circles (see Figure 19 and Table 2).

Source #1 is the brightest of the two X-ray detections

Figure 15. XRT spectrum of IGR J18007–4146 fitted with our basic model (upper panel); residuals to this model are in units of \( \sigma \) (lower panel).

Figure 16. XRT 0.3–10 keV image of the region surrounding IGR J18074+3827. Only one source is found by XRT within the 90% IBIS positional uncertainty (black circle).
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Table 4. Swift/XRT spectral analysis results of the averaged spectra. Frozen parameters are written in square brackets; errors are given at the 90% confidence level.

| Source | $N_{H}^{\text{(Gal)}}$ (10$^{22}$ cm$^{-2}$) | $N_{H}^{\text{(int)}}$ (10$^{22}$ cm$^{-2}$) | $\Gamma$ | $\chi^2$/d.o.f. | $C - \text{stat}$/d.o.f. | $F_{\text{(2–10 keV)}}$ (10$^{-11}$ erg cm$^{-2}$ s$^{-1}$) |
|--------|----------------------------------|----------------------------------|--------|--------------|----------------|-----------------|
| SWIFT J0800.7–4309  
#1 | 0.353 | – | 0.83 ± 0.11 | 43.3/35 | – | 0.50 ± 0.02 |
| SWIFT J0924.2–3141  
#1$^a$ | 0.133 | 81.8$^{+56.8}_{-38.5}$ | [1.8] | – | 86.8/71 | 0.17 ± 0.06 |
| #2$^b$ | 0.132 | – | 1.69 ± 0.11 | 221.3/213 | – | 19.5 ± 0.26 |
| IGR J14059–6116  
#1 | 1.84 | – | [1.8] | – | 52.4/38 | 0.03 ± 0.005 |
| 1RXSJ 145959.4+120124  
#1 | 0.0232 | – | 1.89 ± 0.23 | 12.0/9 | – | 0.24 ± 0.02 |
| IGR J15038–6021  
#1 | 1.26 | – | [1.8] | – | 4.0/7 | 0.16 ± 0.03 |
| IGR J16447–5138  
#1 | 0.387 | < 0.6 | 1.96$^{+0.58}_{-0.48}$ | 10.7/9 | – | 0.39 ± 0.03 |
| IGR J17508–3219  
#1$^c$ | 0.452 | – | 0.64$^{+0.71}_{-0.78}$ | – | 27.5/25 | 0.08 ± 0.02 |
| #2 | 0.452 | 1.15$^{+1.55}_{-0.86}$ | [1.8] | – | 28.5/25 | 0.07 ± 0.02 |
| IGR J18007–4146  
#1 | 0.120 | – | 1.02 ± 0.30 | 5.9/6 | – | 0.27 ± 0.03 |
| IGR J18074+3827  
#1 | 0.0273 | – | [1.8] | – | 18.5/18 | 0.010 ± 0.002 |
| XMMSL1 J182831.8–02290  
#1 | 0.512 | 1.53$^{+1.34}_{-0.98}$ | 1.21$^{+0.75}_{-0.66}$ | 5.3/6 | – | 0.46 ± 0.03 |
| SWIFT J1839.1–5717  
#1 | 0.0726 | 2.06$^{+0.36}_{-0.33}$ | 1.57 ± 0.21 | 71.7/63 | – | 0.84 ± 0.02 |
| IGR J20310+3835  
#1$^c$ | 1.04 | – | 0.14$^{+0.68}_{-0.75}$ | – | 44.2/58 | 0.18 ± 0.02 |
| #2 | 1.04 | 5.58$^{+7.62}_{-3.56}$ | [1.8] | – | 45.8/57 | 0.12 ± 0.02 |
| 1SWXRT J230642.8+550817  
#1 | 0.311 | – | 1.00 ± 0.47 | – | 44.3/52 | 0.67 ± 0.09 |

$^a$ In this case, the best-fit model requires a second power law component, having the same photon index of the primary absorbed power law, and passing only through the Galactic column density;  
$^b$ In this case, the best-fit model includes a black-body component ($kT = 1.09 ± 0.09$ keV) to account for the excess observed below 2 keV;  
$^c$ For this source, we report the results of the spectral analysis obtained both by leaving the photon index to vary and by freezing it to 1.8 (see text).

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Figure 17. XRT 0.3–10 keV image of the region surrounding XMMSL1 J182831.8–022. The only X-ray detection is located inside the 90% IBIS positional uncertainty (black circle). The 90% BAT (black-dashed-dotted circle) positional uncertainty partially overlaps the IBIS one, but does not include source #1.

Figure 18. XRT spectrum of XMMSL1 J182831.8–022 with our basic model plus intrinsic absorption (upper panel); residuals to this model are in units of $\sigma$ (lower panel).

Figure 19. XRT 0.3–10 keV image of the region surrounding SWIFT J1839.1–5717. Two sources are detected by XRT: source #1 is located within the 90% IBIS error circle (black circle), while source #2 lies at its border. Both sources are instead located within the 90% BAT positional uncertainty (black-dashed-dotted circle).

Figure 20. XRT spectrum of SWIFT J1839.1–717 fitted with our basic model plus intrinsic absorption (upper panel); residuals to this model are in units of $\sigma$ (lower panel).

(around 32.5$\sigma$ and 23.8$\sigma$ c.l. in the 0.3–10 and 3–10 keV, respectively) and also the only one still detected above 3 keV; it is positionally compatible with the allWISE source listed in Table 2.

Its X-ray spectrum requires intrinsic absorption ($N_{\text{H(int)}} \sim 2 \times 10^{22}$ cm$^{-2}$) and shows a photon index $\Gamma \sim 1.6$ and 2–10 keV flux of $\sim 4 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ (see Table 4 and Figure 20).

Thus, the XRT data univocally bring us to consider the association of source #1 with SWIFT J1839.1–5717 highly likely. Not only is it the brightest and hardest object detected in X-rays, but it is also listed in the WISE AGN catalogue by Secrest et al. (2015) since its WISE colours ($W1 - W2 = 1.84$ and $W2 - W3 = 3.47$) are typical of an IR-selected AGN. Furthermore, its location off the Galactic plane strengthens its extragalactic nature. Last but not least, its spectral behaviour suggests a type 2 AGN, i.e. the X-ray spectrum requires intrinsic absorption in excess to the Galactic one.
Figure 21. XRT 0.3–10 keV image of the region surrounding IGR J20310+3835. The two XRT detections (sources #1 and #2) are located within the within the 90% (black circle) and 99% (black-dotted circle) IBIS positional uncertainties, respectively. Source #1 also lies within the 90% BAT error circle (black-dashed-dotted circle).

3.13 IGR J20310+3835 (also 3PBC J2030.8+3833)  
(Detected as a persistent source)

This source is listed in the Palermo 66 month Swift/BAT hard X-ray catalogue as 3PBC J2030.8+3833. XRT detects two sources whose positions are compatible with either the 90% or 99% IBIS error circle (see Figure 21 and see Table 2), but only one is likely associated with the IBIS/BAT emitter.

Source #1, which is detected at 7.4σ c.l. in the range 0.3–10 keV, is the only one detected above 3 keV (6.2σ c.l. in the range 3–10 keV) and hence the hardest of the two; it is also the only source compatible with the BAT positional uncertainty. Only two IR counterparts were found for this XRT object (see Table 2).

By fitting the XRT data with our basic model we find a flat photon index ($\Gamma \sim 0.1$) and a 2–10 keV flux of $\sim 2 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$. If we freeze the photon index to 1.8, the data require an intrinsic column density $N_{H_{\text{intr}}} \sim 6 \times 10^{22}$ cm$^{-2}$; in this case the 2–10 keV flux is around $1 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ (see Table 4).

These findings, combined with the location of IGR J20310+3835 on the Galactic plane ($b = -0.49^\circ$), suggest again that we may be dealing with either a Galactic source or an absorbed AGN hidden behind the Galactic plane. Only IR spectroscopy of the likely counterparts can discriminate between these two options.

Figure 22. XRT 0.3–10 keV image of the region surrounding 1SWXRT J230642.8+550817. Only one X-ray source is detected by XRT within the 90% IBIS positional uncertainty (black circle).

4 SUMMARY AND CONCLUSIONS

In this paper, we report on the results of a work aimed at exploiting Swift/XRT archival data to search for candidate counterparts to a set of still unidentified sources listed in the latest INTEGRAL/IBIS survey (Bird et al. 2016). Only in one case, we were not able to provide an XRT association, although a possible X-ray counterpart was reported in the XMM-Newton Slew survey; in all other cases one or two likely associations were found. The more accurate position provided by XRT enabled us to pinpoint the optical, IR, and UV counterpart for most of these candidate associations. Moreover, for the brightest objects, i.e. those having a signal-to-noise ratio good enough to allow a reliable spectral analysis, we also characterised the X-ray spectrum, while for the fainter sources only a flux estimate in the 2–10 or 0.2–12 keV energy range is reported. When more than one XRT pointing were available and/or an association/s with XMM-Newton Slew survey were found, we also explored flux variability in the X-ray band. All the information gathered helped us to propose, for each IBIS source, the most likely counterpart and discuss its nature. For SWIFT J0924.2–3142 we found that the high-energy emission, although most likely due to the contribution of two objects (a Seyfert 2 and a bright unclassified source) up to 15 keV, it is related only reported in Table 2. This source is also listed as an H$_{\alpha}$ emission line object in the INT/WFC Photometric H$_{\alpha}$ Survey (IPHAS, Witham et al. 2008). Indeed, it has recently been classified as a CV by Masetti et al. (in preparation), who will provide details on the optical spectrum in a forthcoming paper.

The XRT spectrum shows a flat photon index ($\Gamma \sim 1$) and a 2–10 keV flux of $\sim 7 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ (see Table 4). The source properties and its optical classification argue strongly in favour of its association with the newly reported IBIS object.
to the AGN above these energies. Optical follow-up observations of the proposed counterpart to SWIFT J0800.7−4309 and 1SWXRT J230642.8+550817 has led Rojas et al. (2016) and Masetti et al. (in preparation) to classify both of them as CVs. The properties found for one of the few IBIS objects detected off the Galactic plane (SWIFT J1839.1−5717) suggest it is most likely a type 2 AGN. Finally, we note that IGR J14059−6116 is likely associated with a GeV source (3FGL J1405.4−6119). In all other cases, follow-up optical/IR observations are necessary to help to classify the proposed counterparts and assess their ultimate nature.

As a final remark, we note that the results of this work confirms the key role played by follow-up observations with current X-ray telescopes and the importance of multi-waveband studies, in particular optical/infrared spectroscopy.

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