

## The nature of 19 X–ray sources detected with *INTEGRAL*

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Since its launch on October 2002, the *INTEGRAL* satellite has revolutionized our knowledge of the hard X–ray sky thanks to its unprecedented imaging capabilities and source detection positional accuracy above 20 keV. Nevertheless, many of the newly-detected sources in the *INTEGRAL* sky surveys are of unknown nature. The combined use of available information at longer wavelengths (mainly soft X–rays and radio) and of optical spectroscopy on the putative counterparts of these new hard X–ray objects allows pinpointing their exact nature. Continuing our long-standing program running since 2004, here we report the classification, through optical spectroscopy, of 19 more unidentified or poorly studied high-energy sources detected with the IBIS instrument onboard *INTEGRAL*.

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## 1. Introduction

One of the main objectives of the *INTEGRAL* [18] is a regular survey of the whole sky in the hard X-ray band. This makes use of the unique imaging capability of the IBIS instrument [17] which allows the detection of sources at the mCrab level with a typical localization accuracy of a few arcmin. The latest (4<sup>th</sup> one) IBIS catalogue published up to now by [3] shows that, among more than 700 sources detected above 20 keV, a substantial fraction ( $\sim 30\%$ ) had no obvious counterpart at other wavelengths and therefore could not yet be associated with any known class of high-energy emitting objects.

With the task of identifying them, our group started in 2004 an optical spectroscopy program which used data from ten telescopes worldwide up to now and which proved extremely successful, leading to the identification of about 150 *INTEGRAL* objects<sup>1</sup>, that is about three quarters of the unidentified sources sample of the first three IBIS catalogues.

It is found that more than half of the sources identified by us are Active Galactic Nuclei (AGNs), followed by X-ray binaries ( $\sim 30\%$ ) and Cataclysmic Variables (CVs;  $\sim 13\%$ ); see [13] and references therein.

Here we present the continuation of this follow-up and identification work on *INTEGRAL* objects with the use of data collected in more than one year, between March 2010 and May 2011.

## 2. Sample selection

Using the criterion applied in our past works (see [13] and references therein), we positionally cross-correlated the unidentified sources belonging to recently published IBIS surveys ([2, 3, 8, 14]) with available X-ray (*ROSAT*, *XMM-Newton*) and radio (NVSS, SUMSS, MGPS) on-line catalogues, and with archival X-ray observations (*Swift*, *Chandra*) to reduce the arcminute-sized source error circle to a radius of better than a few arcsec, thus pinpointing the putative optical counterpart.

This process eventually allowed us to select 19 new candidate counterparts to be observed through optical spectroscopy. The list of selected objects is reported in the first column of Table 1.

## 3. Caveats

While it is known [15] that the presence of a single, bright soft X-ray object within the IBIS error circle indicates that it is with a high probability the lower-energy counterpart of the corresponding *INTEGRAL* source, the same cannot be said with high confidence for radio objects (see however [11]). Thus, for the IBIS sources which were singled out using catalogues at wavelengths longer than soft X-rays, we caution the reader that the association with the selected optical object should await confirmation via a pointed observation with a soft X-ray satellite such as *XMM-Newton*, *Chandra* or *Swift*.

We also stress that in a few cases the putative soft X-ray (and optical) counterpart lies outside the nominal IBIS 90% confidence level error circle (but within the 99% one).

To remark the above uncertainties, we put an asterisk beside the source name in Table 1.

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<sup>1</sup>The list of *INTEGRAL* sources identified through optical and near-infrared spectroscopy can be found at <http://www.iasfbo.inaf.it/extras/IGR/main.html>

#### 4. Observations

In this work, 6 telescopes located in Northern and Southern Hemisphere observatories were used; moreover, a spectrum from the 6dF on-line archive [7] was also employed. In the following, the list of the telescopes used for the classifications reported in Table 1 is given:

- 1.5m telescope at CTIO, Chile;
- 1.5m “Cassini” telescope in Loiano, Italy;
- 1.8m “Copernico” telescope in Asiago, Italy;
- 2.1m telescope in San Pedro Mártir, Mexico;
- 3.58m Telescopio Nazionale Galileo, Canary Islands, Spain;
- 3.9m AAT telescope of the Anglo-Australian Observatory, Siding Spring, Australia (for the 6dF spectrum);
- 10.4m Gran Telescopio Canarias, Canary Islands, Spain.

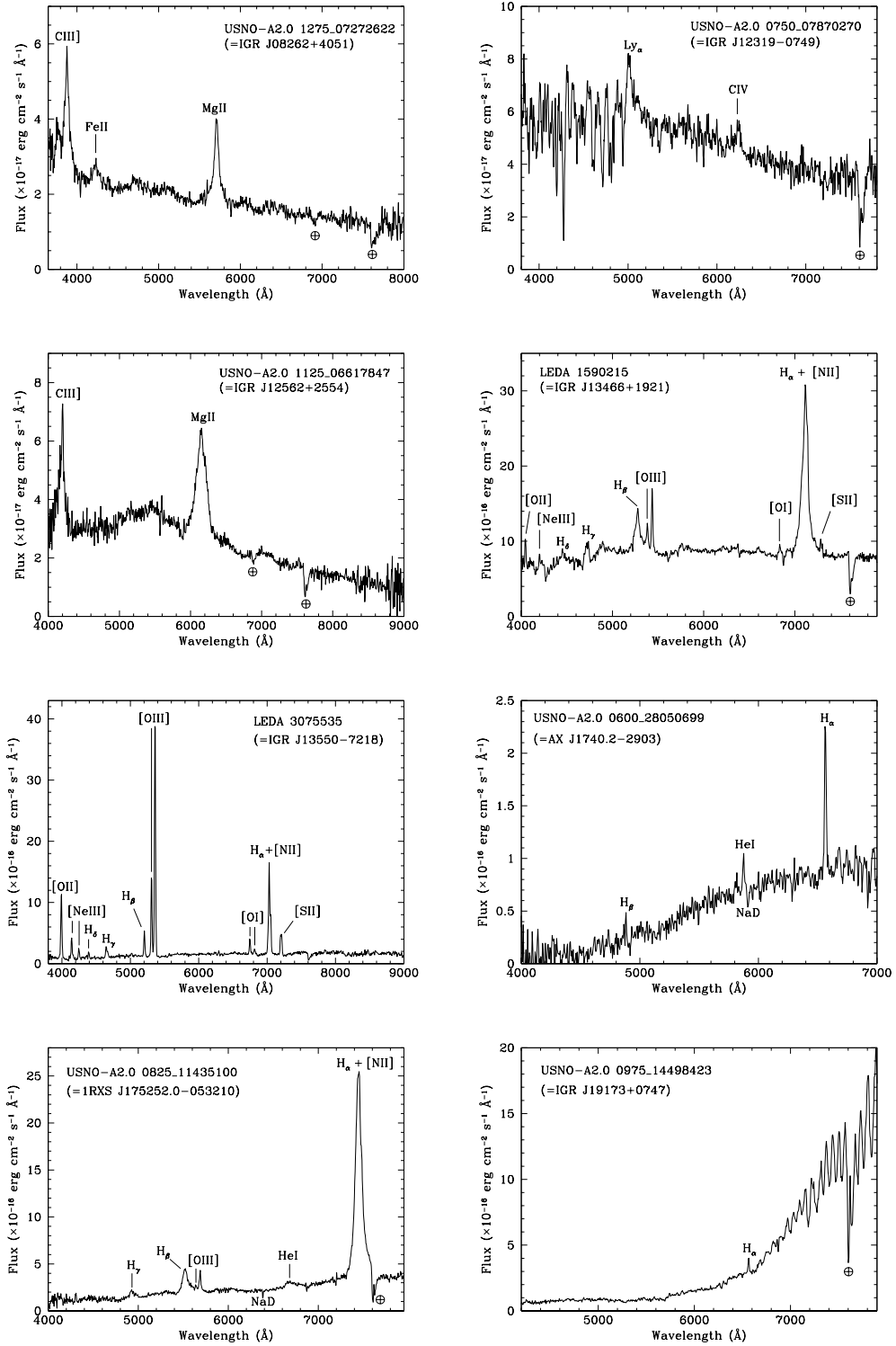
#### 5. Results

Table 1 reports, for each selected source, the corresponding classification obtained through optical spectroscopy, its redshift and the name of the telescope with which the observation was performed; in Fig. 1 the spectra of the optical counterparts of some of these 19 selected IBIS sources are shown.

As one can see from Table 1, most objects (14 out of 19) are AGNs, with a large majority (12) of Type 1 (i.e. broad-line) ones. Among them, 5 lie at large ( $z > 0.5$ ) redshift: this confirms the trend that new, deeper IBIS surveys are able to detect more distant AGNs. In particular, we were able to identify IGR J12319–0749 (at  $z = 3.12$ ) as the second most distant object ever detected by *INTEGRAL* up to now after the blazar IGR J22517+2218, which lies at redshift  $z = 3.668$  ([1] and references therein).

Within our AGN identifications we moreover refine the classifications of IGR J06523+5334 and IGR J19491–1035 made by [5] and [9], respectively. We also confirm the double Seyfert 2 nature of source IGR J03249+4041 first suggested by [10].

Only 5 of our identifications are instead of Galactic nature: two of them are (likely magnetic) CVs, one is a Symbiotic Star, one is a magnetic flare star (possibly of RS CVn type), and one is a High-Mass X-ray Binary (HMXB). We confirm the CV nature of sources RX J0525.3+2413 and AX J1740.2–2903 as first proposed by [16] and [6], respectively; we also note that the spectra of these two objects (along with that of the HMXB IGR J19173+0747) appear substantially reddened. We further stress that the optical spectrum of AX J1740.2–2903 (left panel of third row from top in Fig. 1) allows us to exclude the possibility that it is a Symbiotic X–ray binary as proposed by [4], as in this case we would have seen the optical spectral continuum typical of a late-type giant star (see e.g. [12]).



**Figure 1:** Optical spectra of the counterparts of 8 objects belonging to the sample of 19 *INTEGRAL* sources identified in this work and listed in Table 1. These data allowed us to securely determine the nature and the redshift of these objects through inspection of their absorption and emission spectral features. The spectra are not corrected for the intervening Galactic absorption. For each spectrum the main spectral features are labeled. The symbol  $\oplus$  indicates atmospheric telluric absorption bands.

**Table 1:** The sample of 19 *INTEGRAL* objects identified in this work together with their classification, redshift and telescope with which the identification was obtained. The asterisks indicate sources for which an X-ray position either is still not available or lies outside the 90% IBIS error circle (see Sect. 3).

Object name	Class	redshift	Telescope
IGR J03184–0014*	Sy1.9	0.330	GTC
IGR J03249+4041	double Sy2	0.049	SPM
RX J0525.3+2413	CV	0	SPM
IGR J05255–0711*	QSO	0.634	TNG
IGR J06073–0024*	QSO	1.028	TNG
IGR J06523+5334	Sy1.2	0.301	SPM
IGR J08262+4051	QSO	1.038	TNG
IGR J12319–0749	Blazar	3.12	TNG
IGR J12562+2554*	QSO	1.199	GTC
IGR J13466+1921	Sy1.2	0.085	SPM
IGR J13550–7218	Sy2	0.071	CTIO
IGR J14385+8553*	Sy1.5	0.081	Asiago
IGR J17197–3010*	Symbiotic	0	SPM
AX J1740.2–2903	CV	0	SPM
1RXS J175252.0–053210	Sy1.2	0.136	SPM
IGR J18371+2634*	RS CVn?	0	Loiano
IGR J19173+0747	HMXB	0	SPM
IGR J19491–1035	Sy1.2	0.024	6dF
IGR J20450+7530	Sy1	0.095	Loiano

## 6. Conclusions

Here we presented the precise identification of a set of 19 sources of unknown or uncertain nature and which were detected by IBIS onboard *INTEGRAL*. We found that nearly three quarters of them have an extragalactic nature, with redshifts in the range 0.024–3.12, while the remaining ones are Galactic sources. It is noteworthy that the majority of the latter ones are (possibly magnetic) CVs or Symbiotic stars.

These preliminary results further confirm the *INTEGRAL* capabilities of detecting AGNs and hard X-ray emitting CVs.

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