REVEALING THE NATURE OF NEW UNIDENTIFIED INTEGRAL SOURCES

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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. However, 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 (and with which we identified more than 100 INTEGRAL objects) here we report the classification, through optical spectroscopy, of 25 unidentified high-energy sources mostly belonging to the recently published 4th IBIS survey.

**Keywords**: Galaxies: Seyfert; quasars: emission lines; X-rays: binaries; Stars: novae, cataclysmic variables; Techniques: spectroscopic; X-rays: individuals

1. Introduction

One main objective of the INTEGRAL hard X-ray satellite is the regular survey of the whole sky at high energies (above 20 keV). This makes use of the unique imaging capabilities of the IBIS instrument [1] which permits the detection of sources at the mCrab level with a typical localization accuracy of 2-3 arcmin above 20 keV. A substantial fraction of the remaining objects (∼30%; see e.g. Ref. 2) had no obvious counterpart at other wavelengths and therefore cannot be associated with any known class of high-energy emitting sources.

To this aim, since 2004 our group has been actively performing a successful observational campaign for the optical identification of these unidentified objects: up to now we identified more than 100 INTEGRAL sources and found that about half of them are Active Galactic Nuclei (AGNs), mostly located in the nearby Universe (at redshift z ≲ 0.1; see Ref. 3 and references therein).

Here we present the continuation of this work with the use of the new INTEGRAL detections of unidentified sources reported in the recently published 4th IBIS survey [2].

2. Sample selection

Using the criterion applied to our past works (see e.g. Ref. 3), we positionally cross-correlated the 208 unidentified objects belonging to the 4th IBIS survey [2] with X-ray (ROSAT, XMM-Newton), radio (NVSS, SUMSS, MGPS) and far-infrared (IRAS) catalogues – available online using SIMBAD [a] – and with archival X-ray observations (Swift, Chandra). This was made in order to reduce the source error circle

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and pinpoint the putative optical counterpart. A few cases in which a catalogued emission-line optical object is present in the IBIS error box were also considered. We also included in our sample the source IGR J01054−7253, not included in the 4th IBIS survey but recently discovered during an INTEGRAL key programme observation, and for which an arcsec-sized X-ray position obtained with Swift is available in the literature.

This allowed us to pick out, and perform optical spectroscopy on, 25 candidate counterparts. The list of selected objects is reported in the 1st column of Table 1.

3. Caveats

While it is known 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 for radio and far-infrared sources, or for optically peculiar objects. Thus, for the IBIS sources which were selected 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. To stress this issue, when needed, we put an asterisk beside the source name in Table 1.

4. Observations

In this work, 6 telescopes located in Northern and Southern Hemisphere observatories were used; moreover, spectra from the 6dF and SDSS on-line archives were also employed. In the following, the list of the telescopes used for the classification 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;
- 1.9m “Radcliffe” telescope at SAAO, South Africa;
- 2.1m telescope in San Pedro Mártir, Mexico;
- 2.5m telescope at Apache Point Observatory, New Mexico, USA, for the SDSS spectra;
- 3.5m NTT telescope at ESO-La Silla, Chile;
- 3.9m AAT telescope of the Anglo-Australian Observatory in Siding Spring, Australia, for the 6dF spectra.

5. Results

Table 1 reports, for each selected object, the corresponding classification obtained through optical spectroscopy, the object redshift and the name of the telescope used for the identification; Fig. 1 reports the spectra of the optical counterparts of some of these 25 selected IBIS sources.
Fig. 1. Optical spectra of the counterparts of 8 objects belonging to the sample of 25 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 ⊕ indicates atmospheric telluric absorption bands.
Table 1. The sample of 25 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 is still not available (see Sect. 3).

| Object name       | Class   | redshift | Telescope |
|-------------------|---------|----------|-----------|
| IGR J00158+5605   | Sy1.5   | 0.168    | SPM       |
| IGR J00465−4005   | Sy2     | 0.201    | CTIO      |
| IGR J01054−7253   | HMXB    | 0        | SAAO      |
| IGR J01454+6437*  | Sy2     | 0.034    | Asiago    |
| IGR J02086−1742   | Sy1.2   | 0.129    | SPM       |
| IGR J05253+6447   | likely Sy2 | 0.071 | Loiano    |
| 1RXS J080114.6−462324 | CV     | 0        | NTT       |
| MCG +04−26−006    | LINER   | 0.020    | SPM       |
| IGR J1248.2−5828  | Sy1.9   | 0.028    | SAAO      |
| IGR J13187+0322*  | QSO     | 0.606    | SDSS      |
| IGR J14301−4156*  | Sy2/LINER | 0.039  | 6dF       |
| IGR J15311−3737   | Sy1     | 0.127    | SAAO      |
| IGR J15549−3739*  | Sy2     | 0.019    | 6dF       |
| IGR J16287−5021   | LMXB    | 0        | NTT       |
| IGR J16327−4940*  | HMXB    | 0        | SAAO      |
| 1RXS J165443.5−191620 | CV     | 0        | SPM       |
| IGR J18311−3337*  | Sy2     | 0.066    | 6dF       |
| IGR J19077−3925   | Sy1.9   | 0.073    | 6dF       |
| IGR J19113+1533*  | HMXB    | 0        | SPM       |
| IGR J19118−1707*  | Sy2/LINER | 0.024  | 6dF       |
| PKS 1916−300      | Sy1.5/1.8 | 0.167  | 6dF       |
| IGR J19552+0044   | CV      | 0        | Loiano    |
| 1RXS J2111336.1+542226 | CV     | 0        | SPM       |
| 1RXS J211928.4+333259 | Sy1.5/1.8 | 0.051  | SPM       |
| 1RXS J213944.3+595016 | Sy1.5    | 0.114    | SPM       |

As one can see from Table 1, most objects (17, i.e., 68%) have an extragalactic origin, and are nearly equally divided into Type 1 and Type 2 AGNs (9 and 8 cases, respectively). Six of them (5 of Type 1 and only 1 of Type 2) have \(z > 0.1\), indicating that this new, deeper IBIS survey is able to detect more distant AGNs. Only 32% (8 sources) of our identifications are instead of Galactic nature. Interestingly, half of them are (likely magnetic) Cataclysmic Variables (CVs): these identifications increase by 13% the number of hard X-ray emitting CVs detected with INTEGRAL up to now (see Ref. 9).

6. Conclusions

We here presented the identification of a first set of 25 sources of unknown or uncertain nature, 24 of which belonging to the 4\(^{th}\) IBIS survey. We found that 2/3 of them have an extragalactic nature, with redshifts in the range 0.019–0.606, while the remaining ones are Galactic sources. It is noteworthy that the majority of the latter ones are (possibly magnetic) CVs.
These preliminary results further confirm the INTEGRAL capabilities of detecting AGNs and hard X-ray emitting CVs. We also stress that with this work we already reduced by 12\% the number of unidentified sources of the 4th IBIS survey, bringing it from 208 to 184.

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