Optical and near-infrared observations of new INTEGRAL Galactic Sources

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Abstract

The INTEGRAL satellite has discovered many sources, the nature of most being still unknown. Only a multi-wavelength approach, including optical and near-infrared observations, may allow to constrain their nature. Several of these sources, apparently located in the Norma arm, share common X-ray properties, in particular a huge intrinsic absorption, probably by cold matter. The best studied source is IGR J16318−4848, for which we summarize here our optical/near-infrared observations, and for which we propose an identification as a High mass X-ray binary, the massive component being an sgB[e] star. There are indications that other sources in the Norma arm are binary systems with massive and rare stars, surrounded by complex envelopes or cocoons.

Key words: stars: circumstellar matter—stars: emission-line, Be—X-rays: binaries

1 Introduction

INTEGRAL has proved to work exceptionally well since its launch. Compact objects, the Galactic centre itself, unidentified high energy sources, new transient sources and unexpected discoveries in the highly variable γ-ray universe, are among the scientific objectives of INTEGRAL.
Indeed, after the usual period of in–flight calibrations, it started to discover several new sources (~ 33), among them $\sim 40\%$ have been identified to probable High-Mass X-ray binaries (HMXBs). Three of them, namely IGR J16318−4848, IGR J16320−4751 and IGR J16479−4514, deserve particular attention

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since they appear to be located very close to each other (three of them are within $\approx 1^\circ$) in the Norma arm of the Galaxy (Figure 1). This is a a star–forming region [Georgelin & Georgelin, 1976,Russeil, 2003]. According to the $\log N - \log S$ of X-ray binaries in the Milky Way [Grimm et al., 2002], the distribution of HMXBs is peaked close to star forming regions, identified by H II nebulae and warm molecular clouds. Therefore, the most probable hypothesis is that the new INTEGRAL sources could be HMXBs, as suggested by [Revnivtsev, 2003,Rodriguez et al., 2003,Walter et al., 2003]. It is worth noting however that IGR J16358 − 4726, although also in the Norma am, is probably a Low-Mass X-ray binary [Patel et al., 2004].
Using the SOFI in the NIR (near-infrared) and EMMI in the visible, both being instruments on the NTT (New Technology Telescope) at La Silla, we were able in 2003 to make a comprehensive photometrical and spectrometric study of IGR J16318−4848 [Filliatre & Chaty, 2004]. An observation campaign on the other sources of the Norma arm was recently performed and suggests that all these sources share common characteristics (Chaty et al., in prep). In this contributed paper, we summarise our conclusions on IGR J16318−4848, and present the preliminary indications that the other sources may share common features with IGR J16318−4848, that we can consider as the prototype of a possible new class of X-ray binary being unveiled by INTEGRAL.

2 The case of IGR J16318−4848

IGR J16318−4848 [Courvoisier et al., 2003] was the first new source discovered by INTEGRAL. The X-ray spectroscopy made using XMM-Newton revealed a very high absorption column density : $N_{\mathrm{H}} > 10^{24}\,\mathrm{cm}^{-2}$, which renders the source invisible below 2 keV [Matt & Guainazzi, 2003,Walter et al., 2003]. This amount of absorption is unusual in Galactic sources. Relatively bright and highly absorbed sources like IGR J16318−4848 could have escaped detection in past X-ray surveys and could still contribute significantly to the Galactic hard X-ray background. The fact that the Galactic hard X-ray background in the 20–200 keV band is dominated by sources has been recently demonstrated by [Lebrun et al., 2004].
We carried out photometrical observations in the optical and NIR, and spectroscopic observations in the NIR between 0.95 and 2.52 μm. We confirm the already proposed NIR counterpart with a 2MASS object [Walter et al., 2003] and for the first time extended detection into optical. With SOFI, we obtained a spectrum between 0.95 μm and 2.52 μm, at an average resolution of 950. Together with archival observations, the continua of these spectra allowed us to construct the Spectral Energy Distribution (SED) over 10 decades in wavelength (Figure 2). This SED has two components, consistent with a X-ray binary ; for the low energy component (radio to optical), we showed that the

SED is compatible with a black body continuum with $T > 10^4\,\mathrm{K}$, with an absorption of $A_V = 17.4$, significantly greater than the interstellar absorption in this direction, estimated to $A_V = 11.8$ obtained by using measurements of the hydrogen column density [Dickey & Lockman, 1990].
This indicates a strong intrinsic absorption that is confirmed by the study of the lines on the spectrum, shown on Figure 3. The spectrum displays around 80 lines, most of them being emission lines, some of them having P-Cygni profiles. Some iron forbidden lines are also present. The study of the lines has shown that there is a dense circumstellar material around the source, possibly enshrouding both the mass donor and the compact object, and with a stellar wind component. The data favour a high absorption and a high temperature, as foreseen by the SED. This points to a hot early-type star observed through a dense absorbing material. Moreover, the presence of forbidden lines and the fact that almost all the lines are in emission point towards a B[e] star, with a striking similarity with the companion star in CI Cam [Clark et al., 1999]. Therefore, we have proposed sgB[e] as a tentative identification for the massive companion of IGR J16318−4848, making of this source the second HMXB with an sgB[e] after CI Cam. There is evidence that the circumstellar material of an sgB[e] is concentrated in a disk [Hubert & Jaschek, 1998], with a rarefied polar wind. As already proposed by [Hynes et al., 2002] in the case of CI Cam, it is possible that the X-ray outburst is caused by the passage of the compact object in the disk, perhaps near the periastron.

3 The other sources in the Norma arm

The NIR properties of the counterpart of IGR J16318−4848 lead to the identification to a somewhat unusual object. It is worth noting that other sources discovered by INTEGRAL share common properties both in NIR and in high energy. It has been noted by [Rodriguez et al., 2003] that IGR J16320−4751 have strong intrinsic photoabsorption as IGR J16318−4848 and is probably also a high-mass binary. In few cases, an identification of the counterpart has been proposed, pointing towards high-mass stars : IGR J16195−4945 is associated to a BIa star, IGR J16207−5129 to an A1IVe star [Tomsick et al., 2004], IGR J17391−3021=XTE J1739−302, IGR J16465−4507 [Smith, 2004] and IGR J17544−2619 [Gonzalez-Riestra, 2004] to blue supergiant stars. Identifications in the infrared were made with 2MASS : in all cases the counterparts appear only slightly dimmer in the K band than IGR J16318−4848, and with less reddened colours along to a smaller hydrogen column density still indicating a dense surrounding material [Smith, 2004].
All this suggests that INTEGRAL is therefore in the course of revealing not only one but various new classes of high mass binary systems. The unusual

properties of the proposed counterparts call for further observations including spectroscopy in the NIR to study in details the circumstellar environment, as we did for IGR J16318−4848. We are currently analysing recent optical/NIR observations of INTEGRAL sources made in July 2004 with the NTT.

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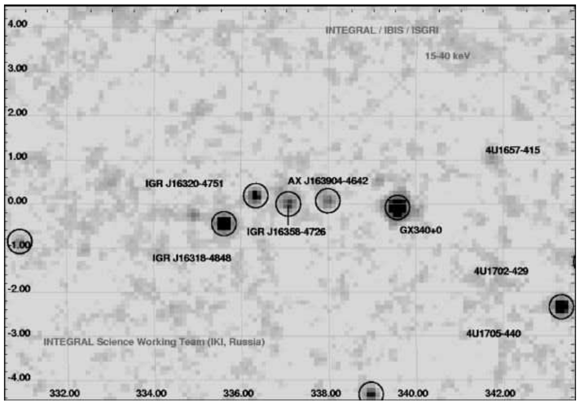

Fig. 1. Mosaic of IBIS/ISGRI images of the Norma Galactic arm ($15-40$ keV) with the first three new sources discovered by *INTEGRAL*. The fourth is not displayed since it was recently discovered (Molkov et al. 2003). From ESA's *INTEGRAL* web page. The image has been made by the *INTEGRAL* Russian team. Galactic coordinates (l,b) are shown.

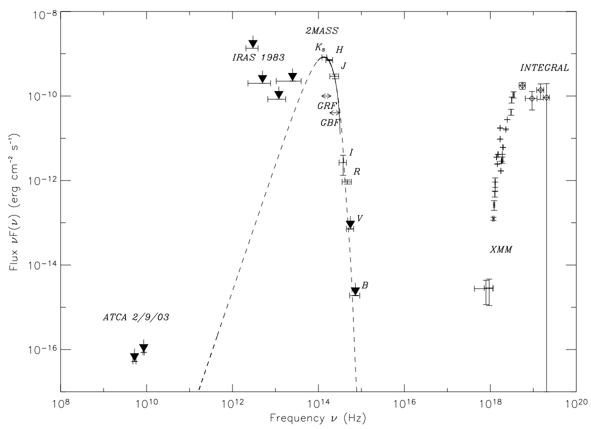

Fig. 2. Observed SED in (ν, $\nu F(\nu)$) units. The dashed curve corresponds to a fit by an absorbed black body, representing well the data. The results of INTEGRAL, XMM, IRAS and ATCA are also shown.

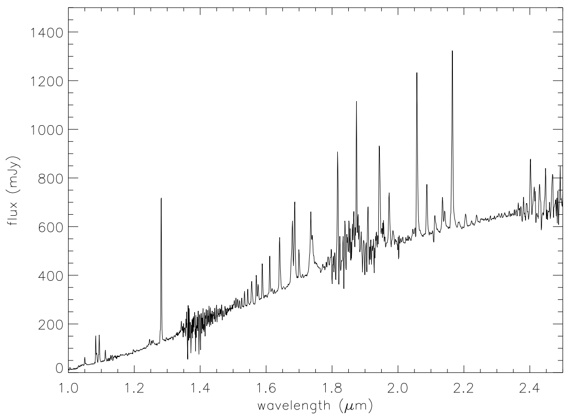

Fig. 3. The spectrum of IGR J16318−4848. The identification of the lines can be found in [Filliatre & Chaty, 2004].