Chin. J. Astron. Astrophys. Vol. 5 (2005), **Suppl.**, 104–109
(*http://www.chjaa.org*)

Chinese Journal of
Astronomy and
Astrophysics

INTEGRAL reveals a new class of obscured high mass X-ray binaries: focus on IGR J16318−4848 †

Sylvain Chaty[1,2] ⋆ and Philippe Filliatre[2]

[1] Université Paris 7 Denis-Diderot, 2 place Jussieu, F-75251 Paris Cedex 05, France
[2] Service d'Astrophysique DSM/DAPNIA/SAp, CEA-Saclay, Bat. 709, L'Orme des Merisiers F-91 191 Gif-sur-Yvette, Cedex, France

Abstract The X-ray source IGR J16318−4848 is the first source discovered by INTEGRAL on 2003, January 29, exhibiting a very high column density. On 2003, February, 23–25 we triggered a Target of Opportunity (ToO) program using the EMMI (optical) and SOFI (near-infrared, NIR) instruments on the New Technology Telescope of the European Southern Observatory (NTT/ESO La Silla). We discovered the optical counterpart and confirmed the NIR candidate. NIR spectroscopy revealed a large amount of emission lines, including forbidden iron and P-Cygni profiles. We show that the source is a High Mass X-ray binary (HMXB) at a distance between 0.9 and 6.2 kpc, the mass donor being an early-type star, probably a sgB[e] star, surrounded by a dense and absorbing circumstellar material. This would make the second HMXB with a sgB[e] after CI Cam. Other sources, discovered by INTEGRAL near IGR J16318−4848 in the direction of the Norma arm, present the same characteristics. Such sources may represent a different evolutionary state of X-ray binaries previously undetected with the lower energy space telescopes; if it is so, a new class of strongly absorbed X-ray binaries is being unveiled by INTEGRAL.

Key words: stars: circumstellar matter — emission-line — Be–X-rays: binaries — IGR J16318−4848

1 INTRODUCTION

IGR J16318−4848 was the first source discovered by the INTEGRAL IBIS/ISGRI imager (Ubertini et al. 2003, Lebrun et al. 2003). The source was detected on 2003 January 29 in the energy band 15–40 keV with a mean 20–50 keV flux of $6 \times 10^{11}\,\mathrm{erg\,cm^{-2}\,s^{-1}}$, 0.5° south from the galactic equator (Courvoisier et al. 2003). The source was thereafter regularly observed for two months. No X-ray counterpart could be found in the ROSAT All Sky Survey (Voges et al. 1999). It was observed by XMM-Newton on 2003 February 10, which detected a single X-ray source within the INTEGRAL error box using the EPIC PN and MOS cameras giving the most precise position to date: $\alpha = 16^{\mathrm{h}}31^{\mathrm{m}}48\overset{\mathrm{s}}{.}6$, $\delta = -48°49'00''$ with a $4''$ error

† Based on observations collected at the European Southern Observatory, Chile (# 70.D-0340).

⋆ E-mail: chaty@cea.fr

box (Schartel et al. 2003). X-ray spectroscopy revealed a very high absorption column density: $N_{\rm H} > 10^{24}\,{\rm cm}^{-2}$ (Matt & Guainazzi 2003, 2004, Walter et al. 2003), which renders the source invisible below 2 keV. 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 in the 10–200 keV band. The high column density prompted counterpart research in NIR: within the EPIC error box, a possible counterpart was proposed by Foschini et al. (2003) using the Two Micron All Sky Survey (2MASS) with the following magnitudes: $J = 10.2$, $H = 8.6$, $K_s = 7.6$ with an uncertainty of ± 0.3 mag (Walter et al. 2003). On the other hand, no radio emission at the position of the source was detected with a 1σ upper limit of 0.1 mJy both at 4.8 and 8.6 GHz (Walter et al. 2003).

In the course of a ToO program at ESO dedicated to look for counterparts of high energy sources newly discovered by satellites including INTEGRAL (PI S. Chaty), we carried out on 2003, February, 23-25 photometric observations in the optical and NIR, and spectroscopic observations in the NIR with EMMI and SOFI instruments on ESO/NTT. The goals were to search for likely counterparts within the EPIC error box, to get informations about the environment and the nature of the source, especially about the mass donor. In the following, we describe briefly our observations and report our main results (see Filliatre & Chaty 2004 for more details).

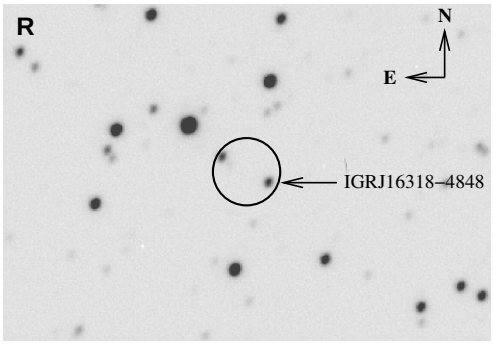

Fig. 1 EMMI R band image of the field of view of IGR J16318−4848. We overplot the XMM error box of $4''$. The scale is given by the error box. The most likely candidate is at the south-west border of the circle as indicated by the arrow.

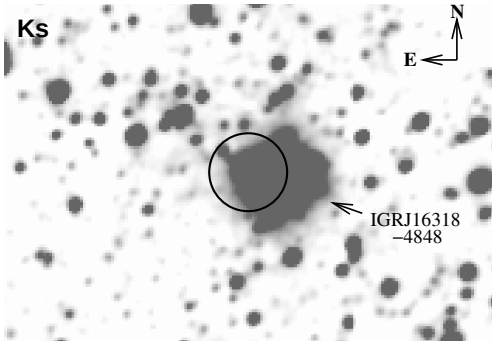

Fig. 2 Ks band image of the same field than in Figure 1.

2 OBSERVATIONS AND RESULTS

We discovered the optical counterpart and confirmed an already proposed NIR candidate (see Walter et al. 2003) by performing an independent astrometry, giving the following position for IGR J16318−4848: $\alpha = 16^{\rm h}31^{\rm m}48\overset{s}{.}3$ $\delta = -48°49'01''$. The optical/NIR images are shown in Figures 1 and 2. We obtained photometric measurements for the R, I and J bands, flux upper limits for B and V, flux lower limits for H and K_s: $Bb > 25.4 \pm 1$, $V > 21.1 \pm 0.1$, $R = 17.72 \pm 0.12$, $I = 16.05 \pm 0.54$ $J = 10.33 \pm 0.14$, $H < 10.35 \pm 0.15$ $K_s < 9.13 \pm 0.10$. We then derived the absorption towards the source along the line of sight: Av$\sim$ 17.4 magnitudes, greater than interstellar (11.8 mag, see Fig. 3) but 2 orders of magnitude lower than in X-rays. With the continua of our GBF (Grism Blue Filter) and GRF (Grism Red Filter) spectra, our photometric measurements and with X-ray, radio and archival data, we constructed a SED, shown in Fig. 4, covering 10 decades in wavelength. From this SED, we derived that the companion star must be a high luminosity, high temperature star: above 10 000 K. The absence of radio emission, contradictory with a photon index compatible with a black hole in the low/hard state, suggests that the compact object is a neutron star (see the correlation by Gallo et al. 2003). The $0.95 - 2.52$ μm NIR spectra, shown in Figures 4, 6 and 7, are highly unusual, very rich in emission lines (we identified 72), including forbidden iron and P-Cygni profiles. These spectra favor the existence of a highly complex, stratified and dense circumstellar environment, with stellar wind or enveloppe. Study of the spectral lines, of the SED and of the colour-magnitude diagram (CMD) suggest a sgB[e] star so the system would be a HMXB, probably hosting a neutron star, like CI Cam: this would make the second such system after CI Cam. The type of the companion star is consistent with the position on the CMD, computed for various absorption values and distances (see figure 8). The distance of the source is constrained between 0.9 and 6.2 kpc.

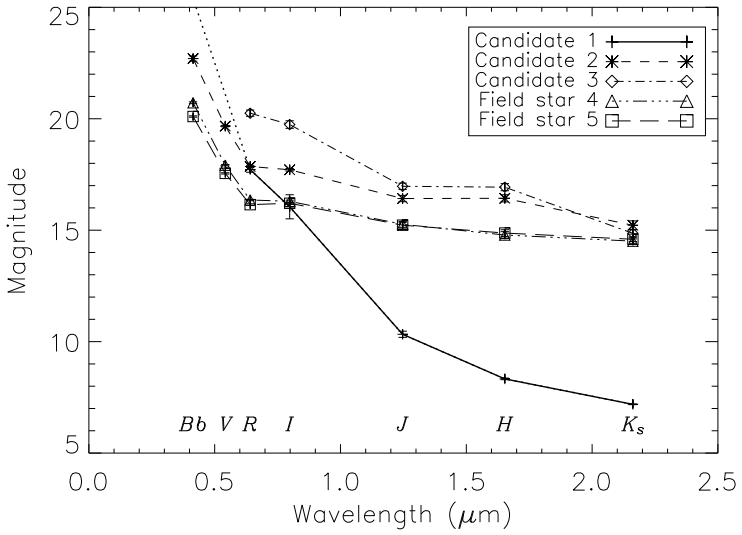

Fig. 3 Magnitudes of IGR J16318-4848 (called here candidate 1) and field stars versus the wavelengths. This plot shows the unusual colours of the candidate, mostly due to the absorption along the line of sight, much stronger towards the candidate (Av$\sim$ 17.4 magnitudes) than towards the other stars of the field of view (Av$\sim$ 11.8 magnitudes).

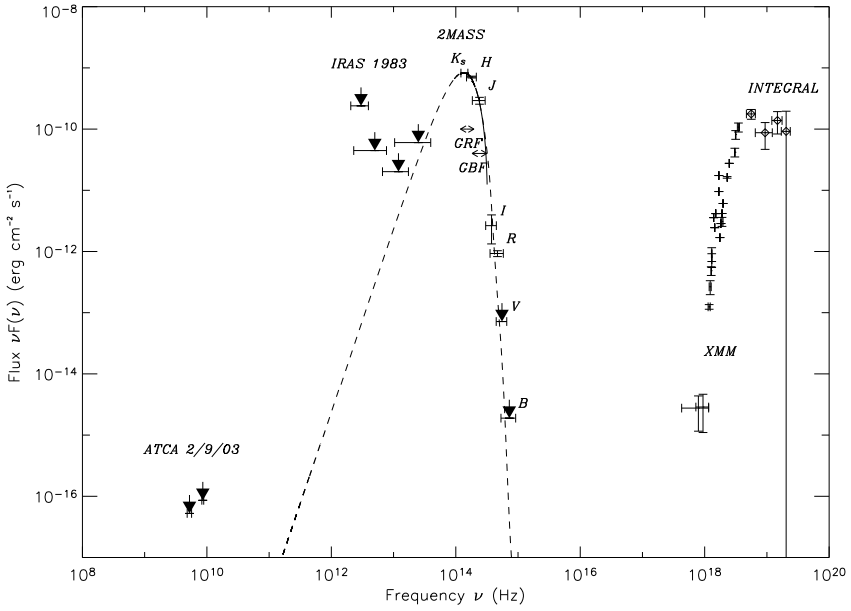

Fig. 4 Observed SED of IGR J16318-4848 in (ν, $\nu F(\nu)$) units, including the results of our photometry, our rescaled continuum GBF and GRF spectra, and INTEGRAL, XMM, IRAS and ATCA results. The B and V data are upper limits only. The dashed curve corresponds to an absorbed black body, representing well the data.

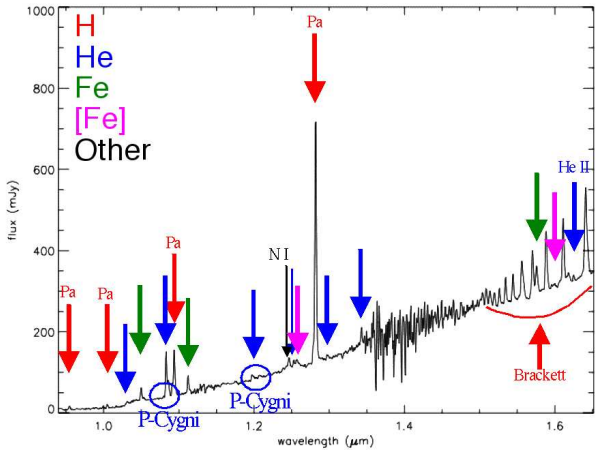

Fig. 5 NIR GBF spectrum (0.95–1.65 μm).

2.1 A new class of obscured binaries?

This source shows many unusual features, the first being its strong intrinsic absorption. Interestingly, among the ten sources that INTEGRAL has discovered near this source, in the line of sight of the Norma arm of our Galaxy, this feature is common (at least in the X-rays), to the three sources discussed by Revnivtsev (2003): IGR J16318−4848, IGR J16320–4751

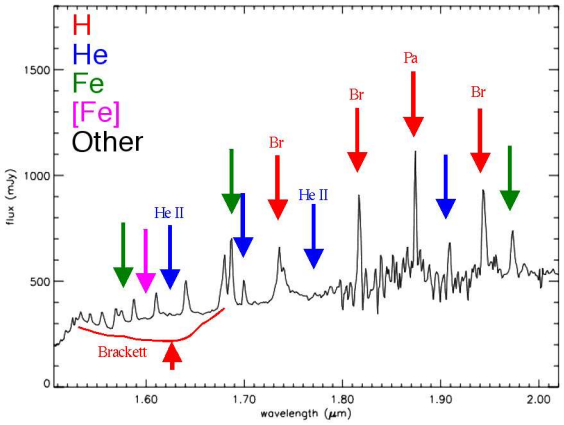

Fig. 6 NIR GRF spectrum (1.5–2.05 μm).

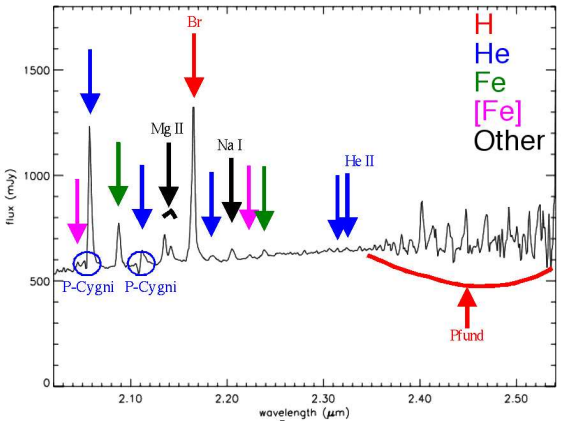

Fig. 7 NIR spectrum (2.0–2.55 μm).

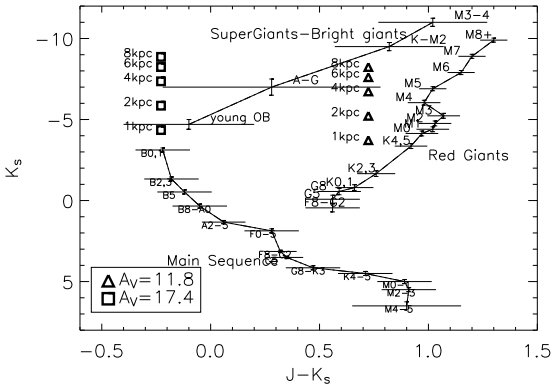

Fig. 8 Position on the CMD computed from template stars of Ruelas-Mayorga (1991), for distances from 1 to 8 kpc, and for two absorption values: $A_V = 17.4$ and $A_V = 11.8$.

and IGR J16358–4726, although the $N_{\rm H}$ column density is lower by an order of magnitude in the two latter systems (Rodriguez et al. 2003, Patel et al. 2004). Furthermore, recent X-ray (XMM) and NIR (ESO) observations suggest that many of these sources in the direction of the Norma arm share similar characteristics. Therefore, although a clear identification for the optical/NIR counterpart has been done only for IGR J16318−4848, and the type of the mass donor, as inferred from our study, has been considered up to now as very rare, it is likely that INTEGRAL has unveiled a new class of obscured high energy binaries. These objects, of which IGR J16318−4848 seems to be the prototype, will deserve much attention in the future, since they might help us to understand the evolution of high-energy binary systems.

Acknowledgements SC is thankful to the ESO panel who understood the utility of multi-wavelength ToO programmes to reveal the nature of high-energy sources, and to the ESO staff (especially Malvina Billeres), who conducted the observations.

References

Courvoisier T. J.-L., Walter R., Rodriguez J. et al., 2003, IAU circ., 8063
Filliatre P., Chaty S., 2004, ApJ, 616, 469
Foschini L., Rodriguez J., Walter R., 2003, IAU Circ., 8076
Gallo E., Fender R. P., Pooley G. G., 2003, MNRAS, 344, 60
Lebrun F., Leray J. P., Lavocat P. et al., 2003, A&A, 411, L141
Matt G., Guainazzi M., 2003, MNRAS, 341, L13
Matt G., Guainazzi M., 2004, this proceeding
Murakami H., Dotani T., Wijnands R., 2003, IAU Circ., 8070
Patel S. K. et al., 2004, ApJ, 602, L45
Revnivtsev M. G., 2003, Astronomy Letters, 29, 644
Rodriguez J., Tomsick J. A., Foschini L. et al., 2003, A&A, 407, 41
Ruelas-Mayorga R. A., 1991, RevMexAA, 22, 27
Schartel N., Ehle M., Breitfellner M. et al., 2003, IAU Circ., 8072
Ubertini P., Lebrun F., Di Cocco G. et al., 2003, A&A, 411, L131
Voges W. et al., 1999, A&A, 349, 389
Walter R., Rodriguez J., Foschini L. et al., 2003, A&A, 411, L427