OPTICAL TO MID-INFRARED OBSERVATIONS REVEALING THE MOST OBSCURED HIGH-ENERGY SOURCES OF THE GALAXY.

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ABSTRACT

A new type of sources has been discovered by *INTEGRAL*. These sources are in the course of being unveiled by means of multi-wavelength optical, near- and mid-infrared observations. Among the high-energy binary sources, two distinct classes are appearing. The first class is constituted of intrinsically obscured high-energy sources, of which IGR J16318-4848 seems to be the archetype. The second class is populated by the so-called supergiant fast X-ray transients, with IGR J17544-2619 being the archetype. We report here on multi-wavelength observations of sources from these two classes, focusing on optical to mid-infrared observations. We show that in the case of the obscured sources IGR J16318-4848 and IGR J16195-4945, our observations suggest the presence of absorbing material (dust and/or cold gas) enshrouding the whole binary system. We then discuss the nature of these two different types of sources.

Key words: *INTEGRAL*; IGR J16195-4945; IGR J16318-4848; IGR J17544-2619; near-infrared; mid-infrared.

1. INTRODUCTION

INTEGRAL has performed a detailed survey of the galactic plane and the ISGRI detector on the IBIS imager has discovered many new sources, most of all reported in Bird et al. (2006)[1]. Many of these new sources are concentrated in a direction tangent to the Norma arm of the Galaxy (see e.g. Chaty & Filliatre 2005 and Tomsick et al. 2004), a region of our Galaxy which is rich in star forming regions. The most important result of the *INTEGRAL* observatory to date is probably the discovery of many new high energy sources exhibiting common characteristics which previously had rarely been seen. Most of them are high mass X-ray binaries (HMXBs) hosting a neutron star orbiting around an O/B companion, in some cases a supergiant star. They then divide into two classes. Some of the new sources are very obscured, exhibiting a huge intrinsic and local extinction. The archetype, and certainly the best example, is the extremely absorbed source IGR J16318-4848 (Filliatre & Chaty, 2004). The other sources are HMXBs hosting a supergiant star, exhibiting fast and transient outbursts: an unusual characteristic among HMXBs. They are therefore called Supergiant Fast X-ray Transients (SFXTs, Negueruela et al., 2006).

Since high-energy observations are not enough in order to reveal the nature of the newly discovered sources, one needs to perform multi-wavelength observations. Indeed, the difficulty is that even if *INTEGRAL* can provide a position for these sources which is already very accurate for this energy range ($\sim 2'$), the localisation is not accurate enough in order to pinpoint the source at other wavelengths. So the first stage is to observe in the low energy part of the high energy domain, for example with *XMM-Newton* or *Chandra*. These satellites can give arcsecond position accuracy. At this stage, the hunt for the optical counterpart of the source is open. However, once again, there is a difficulty, due to the high level of absorption in this region of the Galaxy, close to the galactic plane. One has then to observe in the near-infrared (NIR) domain in order to begin to reveal these sources at these wavelengths. Furthermore, since there is a strong absorption, there must obviously be some absorbing matter... It is only by observing at mid-infrared (MIR) wavelengths that one can characterise the nature of this absorbing matter, and determine if it is made of cold gas, or dust, or anything else...

We first report here on multi-wavelength observations of the two archetypes described above, and give results on MIR observations of newly discovered *INTEGRAL* sources belonging to both classes, in Section 2. We then discuss these results and conclude in Section 3.

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[1] Updated informations about these sources are reported in http://isdc.unige.ch/ rodrigue/html/igrsources.html

2. OBSERVATIONS AND RESULTS

In order to study the newly discovered *INTEGRAL* sources, it is necessary to perform multi-wavelength observations in the optical, NIR and MIR domains. The multiwavelength observations that we describe here were performed at the European Southern Observatory (ESO), in 3 domains:

- optical observations ($400 - 800$ μm) with the EMMI instrument, on the 3.5m New Technology Telescope (NTT) at La Silla,
- NIR observations ($1 - 2.5$ μm) with the SOFI instrument, on the NTT,
- and MIR observations ($5 - 20$ μm) with the VISIR instrument on Melipal, the 8m third Unit Telescope (UT3) of the Very Large Telescope (VLT) at Paranal.

These observations have been done using two different modes: Target of Opportunity (ToO) and Visitor modes. They include photometry and spectroscopy on 15 *INTEGRAL* sources in order to identify their counterparts, the nature of the companion star, derive the distance, and finally characterise the presence, the temperature, and the composition of their circumstellar medium.

2.1. IGR J16318-4848: the archetype of the obscured high-energy sources

We will first remind the main characteristics of this source in the high energy domain (mainly reported in Matt & Guainazzi 2003 and Walter et al. 2003), before describing the optical/NIR observations of this source. IGR J16318-4848 was the first source to be discovered by the ISGRI detector on the IBIS imager onboard *INTEGRAL*, on 29 January 2003 at the galactic coordinates $(l, b) \sim (336°, 0.5°)$, with an uncertainty radius of localisation of $2'$ (Courvoisier et al., 2003). ToO observations were then triggered with *XMM-Newton*, which allowed a more accurate localisation at $4''$. *XMM-Newton* observations showed that the source was exhibiting a strong absorption of $N_{\rm H} \sim 2 \times 10^{24}$ cm^{-2}, a temperature of kT $=$ 9 keV, and a photon index $\sim$ 2. In the high energy spectrum a strong Fe absorption edge was visible, altogether with Fe Kα, Kβ and Ni Kα fluorescence emission lines. The 15-40 keV flux was 50-100 mCrab, the luminosity (assuming that the source is located at 5 kpc) was $L_{5kpc} = 1 - 20 \times 10^{36}$ erg s^{-1}. The flux was highly variable (by a factor of 20), and no oscillation was detected. There were usually 10 hours between flares, and 2 to 3 days of inactivity were also observed. The lines and continuum were varying on a 1000 s timescale: this allowed to derive the size of the emitting region to be smaller than 3×10^{13} cm. These X-ray properties, signature of wind accretion, were reminiscent of other peculiar sources, such as CI Cam and GX 301-2.

The accurate localisation allowed us to look for the counterpart at other wavelengths; the results that we will now report come from Filliatre & Chaty (2004), and we refer to this paper for more details. ToO photometrical and spectroscopic observations in optical and NIR were triggered just after the discovery of the source, but the observations could not be performed before 23-25 February 2003. Walter et al. (2003) had reported the discovery of the optical and NIR counterpart, however, after an improved astrometry based on these new optical/NIR observations, Filliatre & Chaty (2004) showed that they had misidentified the optical counterpart. Two optical sources were present inside the *XMM-Newton* EPIC $4''$ uncertainty circle, but comparison with the USNO B1.0 plate R band showed that only one of the two sources varied. This independent and improved astrometry therefore allowed Filliatre & Chaty (2004) to discover the real optical counterpart, and to confirm the NIR counterpart proposed by Walter et al. (2003). The optical counterpart of the source is not seen in the B and V filters (B $> 25.4 \pm 1.0$; V $> 21.1 \pm 0.1$), and appears in the R, I and Z filters (R $= 17.72 \pm 0.12$; I $= 16.05 \pm 0.54$). The first striking fact in the optical/NIR observations was the extreme brightness of this source in the NIR: the magnitudes of the NIR counterpart were J $=$ 10.33 ± 0.14; H $=$ 8.33 ± 0.10 and Ks $=$ 7.20 ± 0.05. This source is too bright to perform photometrical observations with a 4m class telescope, even with an integration time of 1s! This shows the need to maintain small telescopes for such observations.

The second striking fact in the optical/NIR domain is the absorption in the optical of this source. By looking at the magnitude versus the optical/NIR (B, V, R, I, J, H, Ks) wavelengths of IGR J16318-4848 and neighbour objects in the field of view, it is obvious that the high energy source exhibits an unusually strong intrinsic absorption in the optical of $A_v = 17.4$ magnitudes, much stronger than the absorption along the line of sight as exhibited by the neighbour objects (absorption of $A_v = 11.4$ magnitudes), but still 100 times lower than the absorption in X-rays! This led Filliatre & Chaty (2004) to suggest that the material absorbing in the X-rays must be concentrated around the compact object, while there is some material absorbing in the optical/NIR which is concentrated around the whole system.

The NIR spectroscopy in the $0.95 - 2.5$ μm domain, shown in Figures 1, 2, and 3, revealed the third striking fact of this optical/NIR domain: the high energy source exhibits an unusual spectrum in NIR, very rich in many strong emission lines. The different lines allow us to characterise the medium around this object. We remind here the main characteristics:

- the strong H (Brackett, Paschen, Pfund) and HeI (P-Cygni profiles) lines emanate from a dense and ionised wind,
- the He II lines come from a highly excited region in the vicinity of the compact object,
- the forbidden [FeII] lines indicate the presence of shock heated material,
- the allowed FeII lines imply a medium with densities greater than $10^5 - 10^6$ cm^{-3},

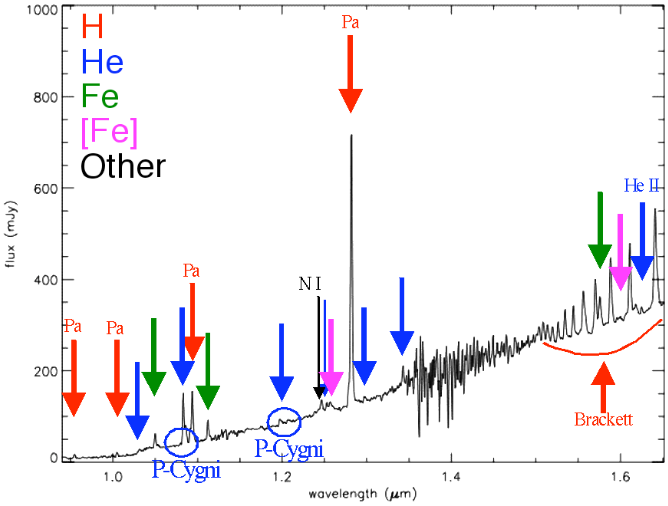

Figure 1. NIR spectrum (0.95-1.65 μm) of IGR J16318-4848, taken at ESO/NTT (Filliatre & Chaty, 2004).

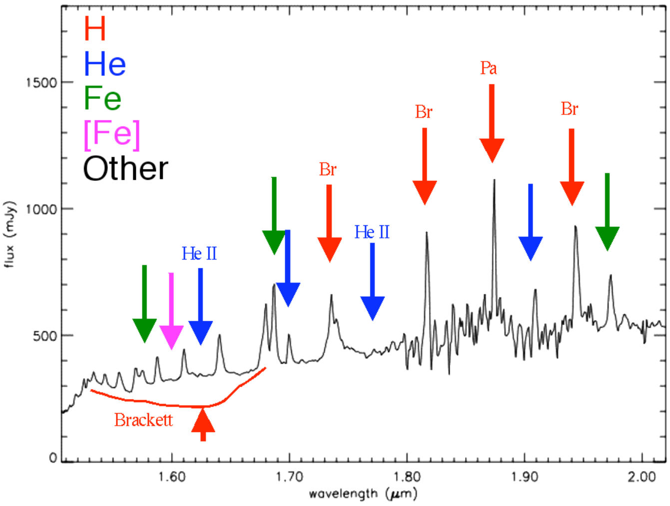

Figure 2. NIR spectrum (1.5-2.05 μm) of IGR J16318-4848, taken at ESO/NTT (Filliatre & Chaty, 2004).

- the NaI lines arise from cool and dense regions, shielded from both stellar and compact object radiation.

From these characteristics it is therefore clear that lines originate from different media (exhibiting various densities and temperatures), suggesting the presence in this high energy source of a highly complex and stratified circumstellar environment, and also the presence of an envelope and a wind. Only luminous post main sequence stars show such extreme environments, and then the companion star is most likely a sgB[e] star (or even an unclassified uncl/sgB[e] star because of its high luminosity). The system is therefore a high-mass X-ray binary system. As it was the case in the X-rays, the NIR characteristics are also reminiscent of the other peculiar high energy source CI Cam.

Filliatre & Chaty (2004) then built the multi-wavelength

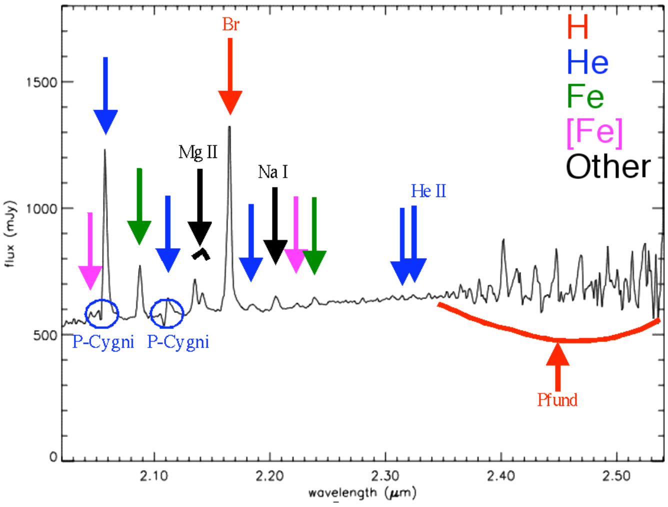

Figure 3. NIR spectrum (2.0-2.55 μm) of IGR J16318-4848, taken at ESO/NTT (Filliatre & Chaty, 2004).

Spectral Energy Distribution (SED) of this source, from radio to X-rays, including optical and NIR domains. They fitted a black-body representing the companion star to these observations, and derived the following parameters: $A_v = 17.5$ magnitudes, $L \sim 10^6 D^2_{6kpc} \times L_\odot$, $T = 20250$ K, $M = 30 M_\odot$ and $r/D = 5 \times 10^{-10}$, where A_v is the absorption in the V band and L, T, M, r and D are the companion star luminosity, temperature, mass, radius and distance respectively. These parameters imply a high luminosity, high temperature and massive star, therefore likely a supergiant, located at 6 kpc. The photometry, spectroscopy and fit of the SED therefore give results which are consistent between each other. Furthermore, by locating these parameters on a Hertzprung-Russel (or temperature–luminosity) diagram, one can see that this companion star is located at the edge of the blue supergiant domain, indicating that we are facing an extreme object even among those already extreme blue supergiant stars!

The SED can also allow us to try to derive the nature of the compact object. Indeed, a correlation in the black hole systems associated with low/hard X-ray emission has been found between X-ray and radio flux densities (Gallo et al., 2003). If the compact object of IGR J16318-4848 were a black hole, its 50-100 mCrab low/hard X-ray flux would lead to a 10 mJy radio flux. However, radio ATCA observation on 9 February 2003 did not detect any source up to 0.1 mJy, suggesting that the compact object is a neutron star. But we point out that we have to be cautious, since this correlation might not be so universal, see for instance Cadolle Bel et al. (2006).

Now, the question which remains open is: what is the cause of this unusual absorption in the optical/NIR domain? In order to answer to this question, we recently obtained MIR observations with VISIR on VLT/UT3. We were therefore able to fit IGR J16318-4848 SED from optical to MIR wavelengths, including data from ESO/NTT, *Spitzer* (GLIMPSE survey) and VLT/VISIR (see Figure 4). We fitted the observations with a model of a companion star (taking usual parameters of a sgB[e]) and simple spherical dust component. More details on this fitting procedure are given in Section 2.3. We found for the parameters of the companion star a temperature of T$=23500\,$K, radius R$_{star}=20.4 R_{\odot}=15\times10^6\,$km, and a dust component with the following parameters: T $=900\,$K, radius R$=12 R_{star}=171\times10^6\,$km and A$_v=17.6\,$magnitudes. The derived distance was of D $=1.2$ kpc. The χ^2/dof of the fit was of 1884/56, a high value mainly due to the very small error bars in the MIR domain (more details about this work will be given in Rahoui and Chaty, in prep.). What is important in this result is that in the case of IGR J16318-4848 there is a need for an extra (e.g. dust) component. The extension of this dust component seems to suggest that it enshrouds the whole binary system, perhaps as would do a cocoon of dust.

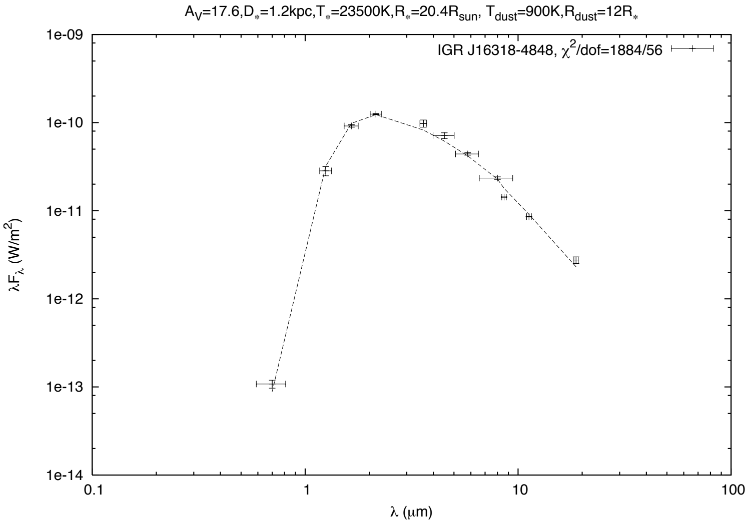

Figure 4. Optical to MIR SED of IGR J16318-4848, including data from ESO/NTT, VISIR on VLT/UT3 and Spitzer (GLIMPSE survey). The observations fitted with both a model of a companion star (taking usual parameters of a sgB[e]) and simple spherical dust component allowed us to derive the following parameters: i) for the companion star: temperature T $=23500K$ *and radius* $R_{star}=20.4R_{\odot}=15\times10^6$ *km; ii) for the dust component: temperature T* $=900K$*, radius R* $=12R_{star}=171\times10^6$ *km. The absorption we derived was* $A_v=17.6$ *magnitudes, and the distance D* $=1.2$ *kpc. The high* χ^2*/dof value of the fit (=1884/56) is mainly due to the very small error bars in the MIR domain. The main result given by this SED is that in the case of IGR J16318-4848 there is a need for an extra (e.g. dust) component in order to fit its SED.*

Let us now summarise briefly the nature of IGR J16318-4848. We are facing an HMXB system, located at a distance between 1 to 6 kpc, hosting a neutron star (probably) and an early-type supergiant B[e] star. It is therefore the second HMXB with a sgB[e] star, after CI Cam. The most striking facts are that i) the compact object seems to be surrounded by absorbing material and ii) the whole system itself seems to be surrounded by a dense and absorbing dusty circumstellar material envelope or cocoon, and by both cold and hot stellar wind components.

2.2. IGR J17544-2619: the archetype of the Supergiant Fast X-ray Transients

The Supergiant Fast X-ray Transients (SFXTs) is a class of sources identified among the recently discovered *INTEGRAL* sources. As their name indicates it, this class is constituted of high-energy transient sources, whose common characteristics are: they exhibit rapid outbursts, lasting only hours, a faint quiescent emission, their high energy spectra require a BH or NS accretor, and they host O/B supergiant companion stars. Among these sources, IGR J17544-2619 seems to be the archetype, since it exhibits all characteristics that are common to sources belonging to this SFXT class. We will now review high energy properties of IGR J17544-2619 before reporting optical/NIR observations.

IGR J17544-2619 is a bright recurrent transient X-ray source which has been discovered by *INTEGRAL* on 17 September 2003, at 3° from the Galactic centre (Sunyaev et al., 2003). *XMM-Newton* had observed the field of this source, and EPIC had detected an X-ray counterpart with mean 0.5-10 keV unabsorbed variable luminosity of $1.1-5.7\times10^{35}\,$erg$\,$s^{-1} for an assumed distance of 8 kpc (see González-Riestra et al. 2004). The EPIC spectra can be represented by a power-law model with variable photon indices of $1.42-2.25\pm0.15$. The 0.5-10 keV spectrum hardens with increasing intensity. This source has therefore a very hard X-ray spectrum, and exhibits a faint intrinsic absorption (10^{22} cm^{-2}). Its bursts last for hours, in-between bursts it exhibits long quiescence periods, and there is a long outburst period of 165 days (Negueruela et al., 2006). Furthermore, there is no radio emission up to an upper limit of 7.35 mJy at 0.61 GHz (Pandey et al., 2006). The nature of the compact object is probably a neutron star, as suggested by in't Zand (2005). Some of the high-energy properties of this source were similar to other *INTEGRAL* sources (such as IGR J16318-4848, IGR J16320-4851, IGR J16358-4726, see e.g. Chaty & Filliatre 2005). The question which rapidly arose concerning this source was then: is it another highly absorbed galactic X-ray binary? But the rapid outbursts of this source, quite unusual among the HMXBs, could even suggest that it was belonging to a new kind of X-ray binaries. It was therefore important to establish its nature, and once again, the optical and infrared observations will play here a crucial role in revealing this source.

Pellizza et al. (2006) managed to get optical/NIR ToO observations only one day after the discovery of this source. We report here their main results, and refer to Pellizza et al. (2006) for more details on the study of the optical/NIR counterpart of this source. Inside the *INTEGRAL* $2'$ uncertainty radius circle of IGR J17544-2619,

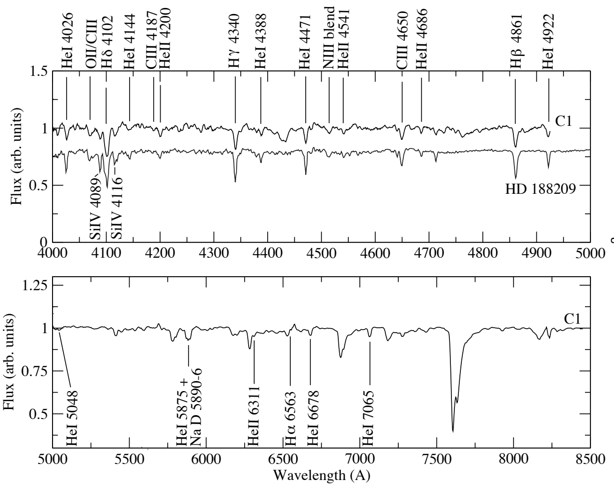

Figure 5. Optical spectrum of IGR J17544-2619 showing the identified lines, among which Pellizza et al. (2006) found strong HI, HeI and HeII lines typical of an O-type star. **Upper panel:** *Blue spectrum of IGR J17544-2619 (upper curve) and the standard O9Ib star HD 188209. The high degree of similarity between them supports their classification of IGR J17544-2619 as an O9Ib star.* **Lower panel:** *Spectrum of IGR J17544-2619 between 5000 Å and 8500 Å.*

there is a ROSAT source (1RXS J175428, with 23″ uncertainty radius) which is in fact not connected with IGR J17544-2619. *XMM-Newton* observations have allowed to accurately localise the source with a $4''$ uncertainty radius circle. But even in such a small circle, there were 5 optical candidate counterparts inside: a bright candidate (called C1 in Pellizza et al. 2006) identified in USNO and 2MASS, three very faint candidates (C2, C3 and C5), probably foreground dwarf stars, and finally an extended object (C4), likely a high-z galaxy. Pellizza et al. (2006) have shown that the C1 candidate had to be the counterpart of IGR J17544-2619, and confirmed it by an astrometry including *Chandra* observations. Indeed, these observations allowed to localise this source even more accurately, with a $0.4''$ uncertainty error circle.

Spectroscopy was thereafter performed on the C1 candidate, and the spectrum is shown in Figure 5, characteristic of a blue supergiant of spectral type O9Ib, with a mass of $25-28M_{\odot}$ and temperature of T $\sim$ 31000 K: the system is therefore an HMXB. The spectrum also exhibits $H\alpha$ P-Cygni profiles, suggesting the presence of a stellar wind at a velocity of 265±20 km/s. If this is confirmed, it is unusually mild for O stars (this value is for instance smaller than the wind velocity of 400 km/s in IGR J16318-4848 reported in Filliatre & Chaty 2004). The derived distance was of 3-4 kpc.

In order to better characterise the nature of the emission of this source, and to answer to the question of the presence of dust around this type of sources, we recently obtained MIR observations with VISIR on VLT/UT3. We were therefore able to fit IGR J17544-2619 SED from optical to MIR wavelengths, including data from ESO/NTT, *Spitzer* (GLIMPSE survey) and VISIR on VLT/UT3 (see Figure 6). We fitted the observations with a model of a companion star (taking usual parameters of an O9Ib star) allowing us to derive the following parameters for the companion star: temperature T $=$ 30500 K and radius R$_{star}$ $= 21.9R_{\odot} = 15\times10^6$ km. The absorption we derived was A$_v$ $=$ 5.9 magnitudes, and the distance D $=$ 3.9 kpc. The χ^2/dof value of the fit is 84/48 (more details about this work will be given in Rahoui and Chaty, in prep.). The main result given by this SED is that in the case of IGR J17544-2619 there is no need for any extra (e.g. dust) component in order to fit its SED, and only a stellar component is necessary.

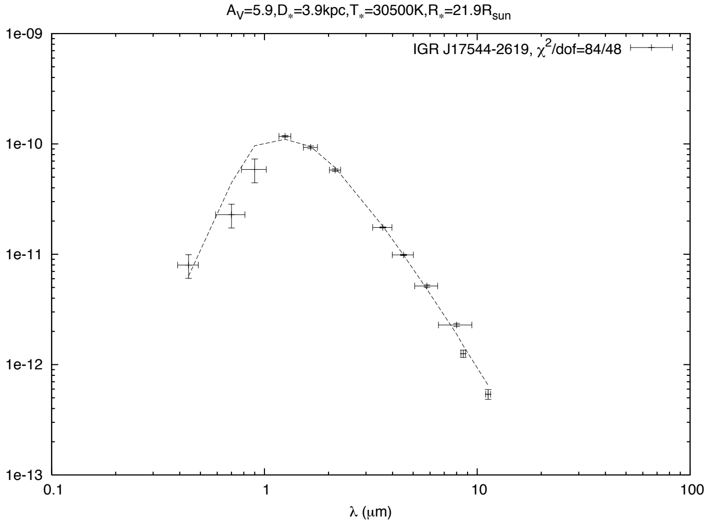

Figure 6. Optical to MIR SED of IGR J17544-2619, including data from ESO/NTT, VISIR on VLT/UT3 and Spitzer (GLIMPSE survey). The observations were fitted with a model of a companion star (taking usual parameters of an O/B star) which allowed us to derive the following parameters for the companion star: temperature T $=$ *30500 K and radius* $R_{star} = 21.9R_{\odot} = 15\times10^6$ *km; The absorption we derived was* $A_v = 5.9$ *magnitudes, and the distance* $D = 3.9$ *kpc. The* χ^2*/dof value of the fit is 84/48. The main result given by this SED is that in the case of IGR J17544-2619 there is no need for any extra (e.g. dust) component in order to fit its SED, and only a stellar component is necessary.*

Let us now summarise the nature of IGR J17544-2619. It is a HMXB at a distance of 3-4 kpc, constituted by a supergiant of spectral type O9Ib (Mass of $25-28M_{\odot}$), with a mild stellar wind and a compact object which is likely a neutron star, without any absorbing material.

2.3. MIR observations of *INTEGRAL* sources

Apart from the two sources described above, we also observed other newly discovered *INTEGRAL* sources. The optical and NIR results will be presented in Chaty et al. (in prep.). We report here the main results about MIR observations (more details about this work will be given in Rahoui and Chaty, in prep.). The MIR observations were performed on 2005/2006 at Paranal UT3-VISIR, and we present the results in Table 1. From this Table one can see that we detected in the MIR domain 9 *INTEGRAL* sources out of 14. We fitted the optical to MIR emission of these sources by an absorbed blackbody representing the stellar emission. The free parameters of the fit were the absorption in the V-band, the system distance and the companion star blackbody temperature and radius. The absorption at wavelengths λ was computed using $\frac{\mathrm{A}_\lambda}{\mathrm{A}_V}$ ratios given in Rieke & Lebofsky (1985) for optical bands and MIR wavelengths above 8 μm. For wavelengths from 1.25 to 8 μm, we used the analytical expression given in Indebetouw et al. (2005). Fits were optimised by minimising the χ^2.

For most of the sources the SEDs were accurately fitted, showing that the MIR emission has a stellar origin, and corresponds to the Rayleigh-Jeans tail of the blackbody stellar spectrum. However, in the case of IGR J16318-4848 (as described above) and IGR J16195-4945, the fitted fluxes were too low compared to the observed MIR fluxes. We therefore had to add the blackbody emission of a spherical dust cloud centred on the companion star, in order to improve the fits in the MIR domain, considering their high fluxes at these wavelengths. Only in these two cases, dust cloud blackbody temperature and radius were also free parameters of the fits.

We already showed the fit of IGR J16318-4848 in Figure 4. We show the fit of IGR J16195-4945 SED from NIR to MIR wavelengths, including data from ESO/NTT and *Spitzer* (GLIMPSE survey) in Figure 7. We fitted the observations with a model of a companion star (taking usual parameters of an O/B star) and simple spherical dust component. We found a temperature of T $=$ 23100 K, radius $\mathrm{R}_{star} = 22.6 R_\odot = 15 \times 10^6$ km for the parameters of the companion star, and a dust component with the following parameters: T $=$ 950 K, radius $\mathrm{R} = 6.1 R_{star} = 95 \times 10^6$ km and $\mathrm{A}_v = 15.4$ magnitudes. The derived distance was of D $=$ 8.4 kpc. The χ^2/dof of the fit was of 17/42, which shows the good quality of the fit. What is important in this result is that in the case of IGR J16195-4945, as for IGR J16318-4848, there is the need for an extra (e.g. dust) component. Again, as for IGR J16318-4848, the extension of this dust component seems to suggest that it is enshrouding the whole binary system, perhaps as would do a cocoon of dust.

We have to point out that we are more cautious in our conclusions about IGR J16195-4945 than with IGR J16318-4848, since i) the former was not detected with VISIR, but only with SPITZER, and ii) the ESO/NTT optical magnitudes seem to be those of a blended object (see Tomsick et al. 2006 and Tovmassian et al. 2006). However, both sources seem to be very similar, since they exhibit the same temperature ($\sim$ 23000 K) and are highly obscured sources: they both exhibit absorption of $\mathrm{A}_V \sim 17$ magnitudes in the optical, and their column density derived from X-ray observations is respectively $N_\mathrm{H} = 2.1 \times 10^{24}$ cm^{-2} for IGR J16318-4848 and $N_\mathrm{H} \sim 10^{23}$ cm^{-2} for IGR J16195-4945. In fact, the case of IGR J16195-4945 is extremely interesting, since it would look very much like IGR J16318-4848 if it were located at the same distance (our fits suggest that IGR J16195-4945 is 7 times more distant than IGR J16318-4848). Therefore, the parameters derived from our fits suggest that IGR J16195-4945 should not be visible in optical, and this result is consistent with the conclusion by Tovmassian et al. (2006) that the optical source observed in Tomsick et al. (2006) is not the *INTEGRAL* source but a foreground object.

Another important point is that the fits are very dependent on the absorption correction used, and the sources which exhibit a high absorption seem to be better fitted with the absorption correction given in Indebetouw et al. (2005) than the one of Rieke & Lebofsky (1985), probably because the former has been calibrated using more recent MIR data taken from *Spitzer* observations. In summary, if the observations and the fits leave no place to any doubt about the presence of dust around IGR J16318-4848, the situation is less clear for IGR J16195-4945, even if the parameters derived by fitting the observations suggest its presence.

Therefore, in two cases only, concerning the sources IGR J16318-4848 and IGR J16195-4945, the presence of cold dust is required by the fits. In this context, IGR J16318-4848 proves once again that it is an extraordinary source among other *INTEGRAL* sources, and that there is much more absorbing material around this source than around the others. Therefore IGR J16318-4848, and probably also IGR J16195-4945, remain exceptional cases, which might probably deserve to constitute a class by themselves!

3. DISCUSSION AND CONCLUSIONS

Now, the question which remains is: "what are these sources?". 80% of these newly discovered *INTEGRAL* sources are HMXBs, hosting compact objects (probably neutron stars) orbiting around O/B supergiant secondaries. These systems are wind accretors, and exhibit a more or less substantial extra absorption. Obscured sources and SFXTs share similar properties, however, they are not the same type of sources, mainly because this excess in absorption does not seem to have the same origin in both classes of sources. For instance, the excess of absorption is caused by two different phenomena in the case of the highly obscured sources, such as IGR J16318-4848. Indeed, in this case, the observations from high energy to MIR domains suggest that there is some absorbing material concentrated around the compact object, and also some dust, cold gas, or even a cocoon of dust, enshrouding the whole binary system. On the contrary, in the case of SFXTs, such as IGR J17544-2619, the presence of the absorbing material seems concentrated around the compact object only, and MIR observations show that there is no need of any other absorbing material around the whole system.

Table 1. Summary of MIR observations of newly discovered INTEGRAL sources. We give in this Table the name of the sources, their coordinates, their type (SFXT or OBS –obscured source–), their spectral type (SpT), the reference (Ref) about the spectral type, and their MIR magnitudes in the PAH1 ($8.59\ \mu m$), PAH2 ($11.25\ \mu m$) and Q2 ($18.72\ \mu m$) filters. The classification as SFXT is still subjective, since we miss some accurate observations on a long-term scale for most of the sources. The spectral types come from optical/NIR spectroscopy, reported in the following references: c: Chaty et al. in prep., f: Filliatre & Chaty (2004), i: in't Zand et al. (2006), n1: Negueruela et al. (2005), n2: Negueruela et al. (2006), p: Pellizza et al. (2006), t: Tomsick et al. (2006), z: Zurita Heras et al. (2006).

Sources	α (J2000)	δ (J2000)	Type	SpT	Ref	PAH1	PAH2	Q2
IGR J16195-4945	16 19 32.20	-49 44 30.7	OBS	OB	t	< 6.12	< 7.83	< 50.25
IGR J16207-5129	16 20 46.26	-51 30 06.0			t	22 ± 1.4	9.4 ± 1.0	< 53.37
IGR J16318-4848	16 31 48.60	-48 49 00.0	OBS	sgB[e]	f	409 ± 2.4	322 ± 3.26	172 ± 14.9
IGR J16320-4751	16 32 01.90	-47 52 27.0		OB	c	12.1 ± 2.67	6.3 ± 1.84	
IGR J16358-4527	16 35 53.80	-47 25 41.1				< 6.84		
IGR J16418-4532	16 41 51.00	-45 32 25.0	SFXT			< 5.83		
IGR J16465-4507	16 46 35.50	-45 07 04.0	SFXT	B0.5I	n1	8.69 ± 1.77	4.7 ± 0.9	
IGR J16479-4514	16 48 06.60	-45 12 08.0	SFXT	OB	c	12 ± 1.3	7 ± 1.7	
IGR J17252-3616	17 25 11.40	-36 16 58.6		OB	z	6 ± 0.6	2 ± 0.4	
IGR J17391-3021	17 39 11.58	-30 20 37.6	SFXT	O8Iab(f)	n2	70.2 ± 1.61	46.5 ± 2.64	
IGR J17544-2619	17 54 25.28	-26 19 52.6	SFXT	O9Ib	p	36 ± 2.77	20.2 ± 2.07	
IGR J17597-2201	17 59 45.70	-22 01 39.0				< 6.12		
IGR J18027-2016	18 02 42.00	-20 17 18.0		sgOB	c	< 6.00		
IGR J19140+0951	19 14 04.23	+09 52 58.3		OB?	c	35 ± 1.4	19 ± 1.4	

We can therefore try to distinguish the nature of both classes by speculating on the geometry of these systems:

- The highly obscured sources (for which the archetype is IGR J16318-4848) are characterised by the presence of absorbing material both around the compact object and around the whole binary system. Their characteristics might be explained by the presence of a compact object (neutron star or black hole) orbiting within the dense wind surrounding the companion star.
- The SFXTs (for which the archetype is IGR J17544-2619) are characterised by fast X-ray outbursts, and the presence of a supergiant companion star. Their characteristics might be explained by the presence of a compact object (neutron star or black hole) located on a wide orbit around the companion star, and it is probably when the compact object penetrates the envelope of the star that outbursts are caused.

Therefore the X-ray transient or persistent nature of these sources might be related to the geometry of these systems. Obviously the confirmation of this view will probably be given by the knowledge of their orbital periods. Many questions are still open, and most of them are related to the presence of the MIR excess in these sources. For instance, no radio emission has been detected in any of these systems, while it is commonly detected among high energy binary systems, therefore it seems that there is something special here again with these sources. One possibility is that the dust might prevent the triggering of the jets. But in order to answer to this question, we will need to better characterise the dust, its temperature, composition, geometry, extension around the system, etc... And also, we need to investigate where this dust or cold gas comes from... But probably the most important question is: is this unusual circumstellar environment due to stellar evolution OR to the binary system itself? We are now facing a dominant population of high energy binary systems born with two very massive components. These systems are probably the primary progenitors of NS/NS or NS/BH mergers. There is therefore the possibility that they are related with short/hard gamma-ray bursts, and also that they might be good candidates of gravitational wave emitters.

To summarise, a new population of sources has been recently revealed by *INTEGRAL*, and it appears that a careful study of this new population might provide hints on the geometry of high energy binary systems, and a better understanding of the evolution of these systems. Our final word will be that, because they are obscured, the "Norma arm" sources can only be studied in the high-energy and infrared domains. A joint study with multiwavelength high-energy, optical, NIR, MIR (and radio) observations is therefore necessary, especially during bursts of these sources.

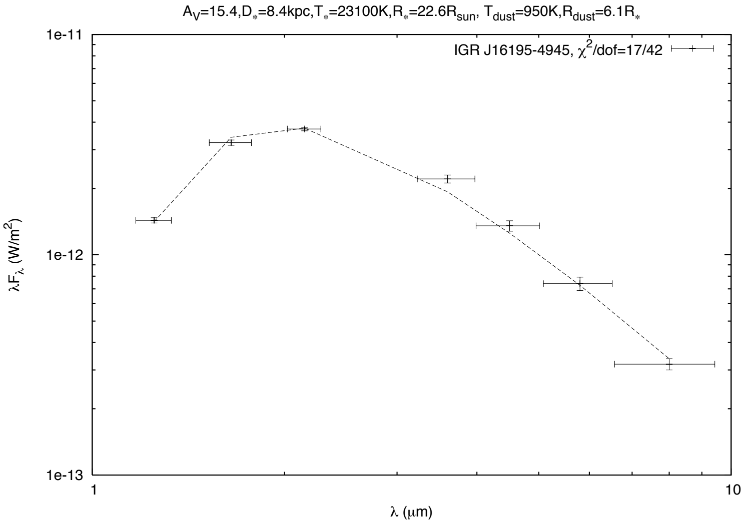

Figure 7. NIR to MIR SED of IGR J16195-4945, including data from ESO/NTT and Spitzer (GLIMPSE survey). The observations fitted with both a model of a companion star (taking usual parameters of an O/B star) and simple dust component allowed us to derive the following parameters: i) for the companion star: temperature $T = 23100$ *K and radius* $R_{star} = 22.6 R_\odot = 15 \times 10^6$ *km; ii) for the dust component: temperature* $T = 950K$*, radius* $R = 6.1 R_{star} = 95 \times 10^6$ *km. The absorption we derived was* $A_v = 15.4$ *magnitudes, and the distance* $D = 8.4$ *kpc. The* χ^2*/dof value of the fit is 17/42. The main result given by this SED is that in the case of IGR J16195-4945, as for IGR J16318-4848, there is a need for an extra (e.g. dust) component in order to fit its SED.*

ACKNOWLEDGEMENTS

Based on observations collected at the European Southern Observatory, Chile (observing proposals ESO N° 70.D-0340, ESO 71.D-0073, 075.D-0773 and 077.D-0721). SC is grateful to Leonardo Pellizza and Jérôme Rodriguez for a careful rereading of the manuscript. SC would like also to thank the organisers for the opportunity to report on these exciting results on newly discovered *INTEGRAL* sources, and also for a very nice organisation of this workshop, fruitful to arise scientific discussions and new ideas.
Болшое спасибо, Пока!

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