

## The soft X-ray counterpart of the newly discovered INTEGRAL source IGR J16195–4945

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**Abstract.** The INTEGRAL satellite, during its regular scanning observations of the Galactic plane, has discovered several new X-ray sources emitting above 20 keV. The nature of the great majority of them is still unknown. Here we report on the likely low energy counterpart, observed with ASCA in 1994 and 1997, of one of these sources, IGR J16195–4945. The ASCA source is faint ( $F_{2-10\text{ keV}} \sim 10^{-11}$  erg cm<sup>-2</sup> s<sup>-1</sup>), highly absorbed ( $N_{\text{H}} \sim 10^{23}$  cm<sup>-2</sup>) and has a rather hard spectrum (photon index  $\sim 0.6$ ). These spectral properties are suggestive of a neutron star in a High Mass X-ray Binary. Our analysis of all the public INTEGRAL data of IGR J16195–4945 shows that this source is variable and was in a high state with a 20–40 keV flux of  $\sim 17$  mCrab in two occasions in March 2003.

**Key words.** individual: IGR J16195–4945, AX J161929–4945 – X-rays: binaries

### 1. Introduction

Several hard X-ray (>15 keV) sources have been discovered with the INTEGRAL satellite (Winkler et al. 2003) during observations of the Galactic plane performed in the last two years (e.g., Courvoisier et al. 2003a; Walter et al. 2003; Rodriguez et al. 2003; Revnivtsev et al. 2003; see also Revnivtsev et al. 2004; Molkov et al. 2004; Tomsick et al. 2004; Bird et al. 2004, and references therein for an updated list). Observations at lower X-ray energies are available for a few of these sources and show that they are heavily absorbed ( $>10^{23}$  cm<sup>-2</sup>). The column densities are in some cases larger than the values expected from the interstellar matter along the line of sight, implying that the X-ray sources are embedded in a local absorbing gas (Walter et al. 2003; Patel et al. 2004).

The high absorption, together with the transient or variable nature of most of them, hampered their detection in previous X-ray surveys carried out at lower energy. However, searches in archival data show that some of the INTEGRAL sources are not new and do have faint X-ray counterparts below 10 keV (e.g. Rodriguez et al. 2003). The 2–10 keV X-ray spectra are power laws with photon index  $\sim 0.5$ –1, often with strong iron emission lines, as in the case of IGR J16318–4848 (Matt & Guainazzi 2003). The emerging picture of this class of sources is that they are mostly High Mass X-ray Binaries (HMXRBs). This is

indicated, in a few cases, by the identification of their optical/IR counterparts (e.g., Filliatre & Chaty 2004; Negueruela & Reig 2004) and/or by the discovery of pulsations (e.g., IGR J18027–2016/SAX J1802.7–2017, Augello et al. 2003; IGR J18410–0535/AXJ1841.0–0536, Halpern & Gotthelf 2004).

However, many new INTEGRAL sources, especially among the faintest ones (a few milliCrabs) still lack an identification and their nature is unknown. Thus, the study of their soft X-ray counterparts is an important step for unveiling their nature.

IGR J16195–4945 is one of the faint sources discovered with INTEGRAL during observations carried out between February 27 and October 19, 2003 (Walter et al. 2004). These authors reported it in a list of new sources, as a  $10\sigma$  detection in the 20–40 keV range, but without any information on its flux level. In the catalogue of Bird et al. (2004) IGR J16195–4945 is reported with a mean counting rate in the IBIS instrument of  $0.29 \pm 0.03$  counts s<sup>-1</sup> (20–40 keV) and an upper limit of 0.29 counts s<sup>-1</sup> (40–100 keV). These values correspond approximately to 3 and 4 mCrabs in the respective energy ranges.

We searched for possible lower energy counterparts of IGR J16195–4945, finding a faint X-ray source detected with the ASCA satellite in the 2–10 keV band. Here we report the analysis of all the ASCA observations and of the INTEGRAL public data of this source.

## 2. ASCA observations and analysis

The sky coordinates of IGR J16195–4945 are RA =  $16^{\text{h}}19.4^{\text{m}}$ , Dec =  $-49^{\circ}43'08''$  (J2000) with an uncertainty of  $3'$  (Bird et al. 2004). Our search in public archives of previous X-ray missions resulted in only one object consistent with this position: the source AX J161929–4945, observed in 1994 and 1997 during the ASCA survey of the Galactic Ridge (Sugizaki et al. 2001; RA(J2000) =  $16^{\text{h}}19^{\text{m}}29^{\text{s}}$ , Dec =  $-49^{\circ}45.5'$ ,  $1'$  error radius). Sugizaki et al. (2001) report that AX J161929–4945 is a hard (or severely absorbed) source, not detected below 2 keV.

No ROSAT counterparts can be found in the RASS catalog, consistent with a very high absorption.

The region of sky containing AX J161929–4945 was observed three times during 1994–1997 (see Table 1). The ASCA satellite (Tanaka et al. 1994) provides simultaneous data in four co-aligned telescopes, equipped with two solid state detectors (SIS) and two gas scintillation proportional counters (GIS). However, since AX J161929–4945 was observed at a relatively high off-axis angle, only the GIS instruments, which has a larger field of view ( $44'$  diameter), provide useful data.

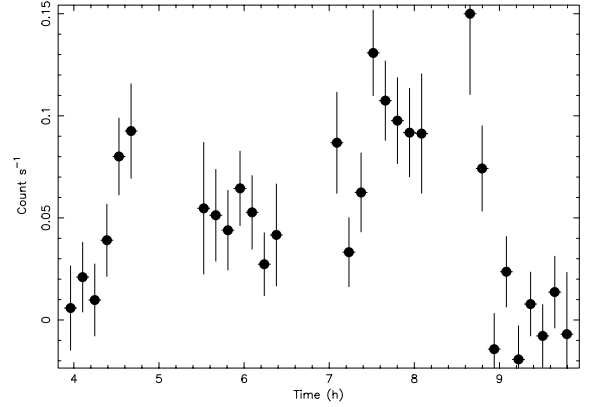
We reduced and analyzed the GIS data of the three observations, obtaining for AX J161929–4945 the background subtracted count rates reported in Table 1. These values, which include the vignetting correction to account for the instrumental response at different off-axis angles, give evidence for long-term temporal variability between 1994 and 1997, the source being  $\sim 2.5$  times brighter in 1997. In Fig. 1 we show the light curve of the 1997 observation, where a variability on shorter timescales of hours is clearly evident.

Only the 1997 observation provides enough statistics for a meaningful spectral analysis. The source spectrum in the 1–10 keV range is well fit by an absorbed power law model with photon index  $\Gamma = 0.6^{+0.8}_{-0.5}$  and a relatively high value of  $N_{\text{H}} = 12^{+8}_{-4} \times 10^{22} \text{ cm}^{-2}$  (reduced  $\chi^2 = 1.12$ , with 28 d.o.f.). The observed flux is  $1.6 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$ , which becomes  $2.4 \times 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$  (2–10 keV) after correcting for the absorption. There is no evidence for  $K_{\alpha}$  iron lines, with a 90% level upper limit on the equivalent width of  $EW < 270 \text{ eV}$  for a narrow line at 6.7 keV, and  $EW < 470 \text{ eV}$  for a narrow line at 6.4 keV. We tried to fit the spectrum with other simple models (blackbody, thermal bremsstrahlung, cut-off powerlaw) but they were not adequate: the blackbody, although formally acceptable (reduced  $\chi^2 = 1.22$ , with 28 d.o.f.), resulted in a very high temperature,  $kT$ , of  $\sim 3 \text{ keV}$ , leaving structured residuals. Both the bremsstrahlung and the cut-off power law resulted in an unconstrained cut-off (or temperature) at high energy.

A search for periodic pulsations in the 0.1–1000 s range using the data of the 1997 observation gave negative results.

## 3. Discussion

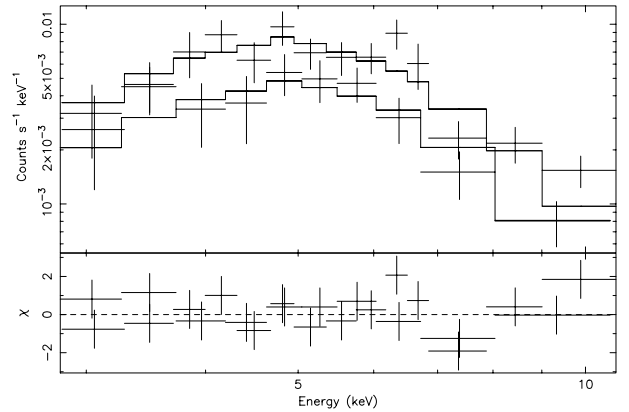
It is very likely that AX J161929–4945 is the low energy counterpart of IGR J16195–4945. Its spectral properties are similar to those of other highly absorbed sources which have been associated to the newly discovered INTEGRAL sources. Furthermore, based on the galactic  $\text{Log } N - \text{Log } S$  in the 2–20 keV energy band (Sugizaki et al. 2001), the chance



**Fig. 1.** Background subtracted light curve obtained from the sum of the two GIS instruments during the 1997 observation. Time is in hours from the beginning of the observation (3 Sep. 1997, 03:01:20). Bin size is 512 s. The source is variable and goes below the threshold of detectability at the beginning and at the end of the observation.

**Table 1.** Summary of the ASCA observations of AX J161929–4945. The count rates are corrected for the vignetting.

Start date (UT)	GIS exp. time (ks)	Count rate ( $10^{-2} \text{ cts s}^{-1}$ )	Off-axis angle
01 Sep. 1994	4.0	$6.3 \pm 0.7$	$14'$
02 Sep. 1994	7.2	$7.0 \pm 1.1$	$21'$
03 Sep. 1997	12.6	$17.3 \pm 0.8$	$21'$

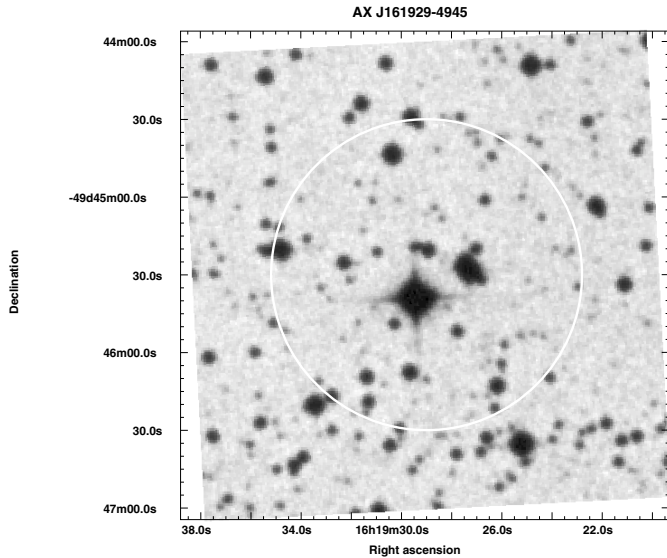


**Fig. 2.** Best fit power law spectrum of AX J161929–4945 obtained with the GIS2 and GIS3 instruments. The residuals in units of standard deviations are shown in the lower panel.

probability of finding a source brighter than  $\sim 10^{-11} \text{ erg cm}^{-2} \text{ s}^{-1}$  in the  $3'$  radius error box is  $\sim 2.4 \times 10^{-3}$ .

Extrapolating the 2–10 keV best fit power law to higher energy, we obtain a 20–40 keV flux of  $1.2 \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1}$ . This is higher than the average flux of  $\sim 3 \text{ mCrab}$  reported for IGR J16195–4945 (Bird et al. 2004). However the latter is an average value derived from all the INTEGRAL data taken over the period between 2003 February 28 and October 10.

To investigate in more detail the variability properties of the source, we analyzed all the INTEGRAL observations of this region of the sky which are currently public. We restricted our analysis to the data of the IBIS instrument



**Fig. 3.** *R*-band image of the error region of AX J161929–4945 obtained from the ESO-R survey scanned on the Precision Measuring Machine at the US Naval Observatory, Flagstaff Station. The circle has a radius of 1'. North is to the top, East to the left. The brightest star in the error circle is HD 146628 ( $V = 10.08$ ).

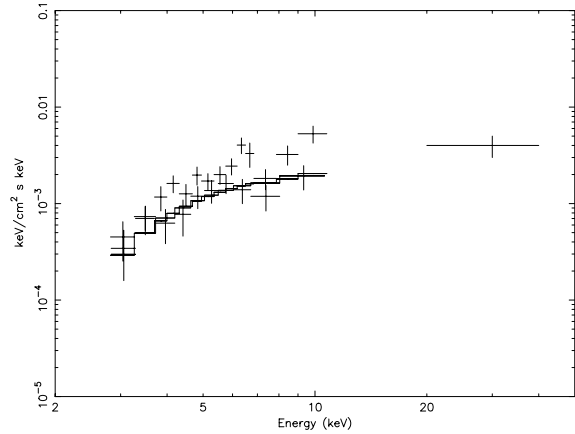
**Table 2.** Summary of the two INTEGRAL observations where a significant detection for IGR J16195–4945 has been obtained. IBIS/ISGRI count rates are in the 20–40 keV energy band.

INTEGRAL obs.	Start time (UT)	ISGRI rate ( $s^{-1}$ )
004700970010	05 Mar. 2003 08:15:35	$1.78 \pm 0.45$
005000770010	14 Mar. 2003 00:30:54	$1.60 \pm 0.43$

(Ubertini et al. 2003) for observations pointed at less than  $5^\circ$  from the source position. This selection resulted in 56 observations obtained in March–April 2003, with an approximate total net exposure time of  $\sim 100$  ks. The INTEGRAL data have been reduced with the standard procedure using version 4 of the ISDC Offline Scientific Analysis software (OSA, Courvoisier et al. 2003b).

Only in 2 observations of  $\sim 1.7$  ks each (see Table 2), the IBIS/ISGRI detection significance was above  $3\sigma$  in the 20–40 keV energy band, at a flux level of  $\sim 17$  mCrab. IGR J16195–4945 was never detected above 40 keV. These flux values are more in line with those measured by ASCA (see Fig. 4 for the broad-band non-simultaneous spectrum). The source is clearly variable at soft and hard X-ray energies, and only during the brightest flares it was above the INTEGRAL sensitivity.

An *R*-band image of the error region of AX J161929–4945 is shown in Fig. 3. The brightest star in the error circle is HD 146628 ( $B = 10.52$ ,  $V = 10.08$ ). Different spectral types and possible distances for this star are reported in literature: it is classified as a B-type supergiant (B1/B2Ia sp. type, HD catalogue, Cannon & Pickering 1918–1924), located at about 7 kpc (distance calculated assuming canonical relations reported in Allen et al. 2000), or as a O-type main sequence star at  $\sim 2$  kpc (O9V sp. type,  $M_V = -4.54$ ,  $A_V = 2.78$ ,



**Fig. 4.** Broad band  $Ef(E)$  spectrum obtained with the ASCA best-fit together with the IBIS/ISGRI flux measured for IGR J16195–4945 in the energy band 20–40 keV (see Table 2).

Kilkenny 1993). A distance of few kpc implies a 2–10 keV luminosity of  $\sim 10^{35}$  erg  $s^{-1}$ , still compatible with being a galactic X-ray binary. A bright 2MASS infrared source is positionally coincident with HD 146628 ( $J = 8.575 \pm 0.026$ ,  $H = 8.412 \pm 0.042$  and  $K = 8.377 \pm 0.031$ ).

The total Galactic absorption in this direction is  $N_H \sim 2 \times 10^{22}$   $cm^{-2}$  (Dickey & Lockman 1990). As expected, the optical absorption derived for HD 146628 ( $A_V = 2.78$ , Kilkenny 1993) corresponds to a lower column density value ( $N_H \sim 5 \times 10^{21}$   $cm^{-2}$ ; Predehl & Schmitt 1995). The fact that this value is smaller than that measured for the ASCA source does not rule out the possible association of HD 146628 with the X-ray source, if we admit that the latter, maybe enshrouded by a dense local envelope, is intrinsically much more absorbed than its companion. Indeed, this is also suggested by the fact that the absorption of AX J161929–4945 is even larger than the total Galactic absorption in this direction.

The fact that AX J161929–4945 has been always detected with ASCA GIS both in 1994 and in 1997 suggests a persistent, although quite variable, nature for the high energy emission. All the source properties, the hard spectrum, the strong absorption, the temporal variability are strongly suggestive of a neutron star in a High Mass X-ray Binary.

Follow-up observations at X-rays are needed to improve the source position in order to establish if the star is really physically related to the high energy source.

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