A&A 468, L21–L24 (2007)
DOI: 10.1051/0004-6361:20077439


Astronomy & Astrophysics

Letter to the Editor

# INTEGRAL high energy detection of the transient IGR J11321–5311

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Received 8 March 2007 / Accepted 14 April 2007

**ABSTRACT**

*Context.* The transient hard X-ray source IGR J11321−5311 was discovered by INTEGRAL on June 2005, during observations of the Crux spiral arm. To date, this is the only detection of the source to be reported by any X/$\gamma$-ray mission.

*Aims.* To characterize the behaviour and hence the nature of the source through temporal and spectral IBIS analysis.

*Methods.* Detailed spectral and temporal analysis has been performed using standard INTEGRAL software OSA v.5.1.

*Results.* To date, IGR J11321−5311 has been detected only once. It was active for ∼3.5 h, a short and bright flare lasting ∼1.5 h is evident in the IBIS light curve. It reached a peak flux of ∼80 mCrab or $2.2 \times 10^{-9}$ erg cm$^{-2}$ s$^{-1}$ (20–300 keV), corresponding to a peak luminosity of $\sim 1.1 \times 10^{37}$ erg s$^{-1}$ (assuming a distance of 6.5 kpc). During the outburst, the source was detected with a significance of $\sim 18\sigma$ (20–300 keV) and $\sim 8\sigma$ (100–300 keV). The spectrum of the total outburst activity (17–300 keV) is best fitted by the sum of a power law ($\Gamma = 0.55 \pm 0.18$) plus a black body ($kT = 1.0^{+0.2}_{-0.3}$ keV), with no evidence for a break up to 300 keV. A spectral analysis at Science Window level revealed an evident hardening of the spectrum through the outburst. The IBIS data were searched for pulsations with no positive result.

*Conclusions.* The X-ray spectral shape and the flaring behaviour favour the hypothesis that IGR J11321−5311 is an Anomalous X-ray Pulsar, though a different nature can not be firmly rejected at the present stage.

**Key words.** gamma rays: observations – X-rays: general – X-rays: individuals: IGR J11321-5311 – X-rays: binaries – X-rays: bursts – gamma rays: theory

## 1. Introduction

The IBIS instrument (Ubertini et al. 2003), on board the INTEGRAL satellite (Winkler et al. 2003), is playing a key role in detecting many transient hard X-ray sources, thanks to its large field of view, good sensitivity and spatial resolution. The new hard X-ray transient IGR J11321−5311 was discovered by IBIS on June 2005 during a deep observation of the Crux spiral Arm (Krivonos et al. 2005). It was active for a few hours with average fluxes of ∼30 mCrab (17–60 keV) and ∼90 mCrab (60–200 keV). Subsequently, the flux diminished below ∼3 mCrab (17–60 keV). So far, the INTEGRAL detection is the only one to be reported and no further informations or study at different wavelengths are available. Here we report for the first time on detailed spectral and timing analysis of the IBIS data for IGR J11321−5311, aimed at understanding the origin of its hard X-ray emission.

## 2. INTEGRAL results

The reduction and analysis of the ISGRI data have been performed using the INTEGRAL Offline Scientific Analysis (OSA) v.5.1. INTEGRAL observations are typically divided into short pointings (Science Windows, ScWs) of ∼2000 s duration. Throughout the paper, uncertainties are given at a 90% confidence level.

IGR J11321−5311 was detected by IBIS in 4 consecutive ScWs in the energy range 20–300 keV. Figure 1 shows a sequence of significance maps around these ScWs. The source was not detected in the first ScW, then it was detected during the next 4 consecutive ScWs with a significance, from left to right, equal to $12\sigma$, $8\sigma$, $5\sigma$ and $4\sigma$, respectively. Finally, in the last ScW the source was undetectable. Summing the 4 ScWs in a mosaic, IGR J11321−5311 is detected at $\sim 18\sigma$ level in the energy band 20–300 keV and $\sim 8\sigma$ in 100–300 keV. The position of IGR J11321−5311 as taken from the mosaic is RA = 11 32 15.72, Dec = −53 11 41, error radius = 1.′5 (90% confidence). The source is located off the Galactic plane ($b$ = 7.°85), in the direction of the Crux spiral arm tangent. We can assume an approximate distance to the source of ∼6.5 kpc.

Figure 2 shows the 20–300 keV ISGRI light curve of the outburst shown in Fig. 1. We assume the beginning of the first ScW during which the source was detected as being the start time of the outburst and similarly the burst stop time to be the end of the last ScW during which the source was detected. As we can note from the light curve, initially the source is not detected, the $2\sigma$ upper limit (ScW level) is ∼11 mCrab or $3 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$ (20–300 keV). Then it became detectable at 21:59:49 UTC (27 June 2005) reaching in only ∼1 h a peak flux of ∼80 mCrab or $\sim 2.2 \times 10^{-9}$ erg cm$^{-2}$ s$^{-1}$ (20–300 keV). For the assumed distance, the corresponding peak luminosity is $\sim 1.1 \times 10^{37}$ erg s$^{-1}$ (20–300 keV). Subsequently, the flux gradually decreased and then the source became undetectable on 28 June 2005 at 01:22:33 UTC, with the same upper limit as above. The duration of the total outburst activity was ∼3.5 h, during which the flare lasted ∼1.5 h. Figure 3 shows the light curve in two different energy bands (20–100 keV and 100–300 keV)

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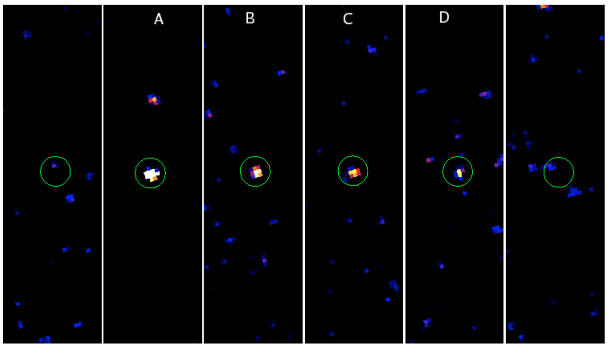


**Fig. 1.** ISGRI ScWs significance image sequence (20–300 keV) of the outburst from IGR J11321−5311 detected on June 2005. The source (encircled) was not detected in the first ScW, then it was detected during the next 4 consecutive ScWs with a significance, from left to right, equal to $12\sigma$, $8\sigma$, $5\sigma$ and $4\sigma$, respectively. Finally, in the last ScW the source was not detected.

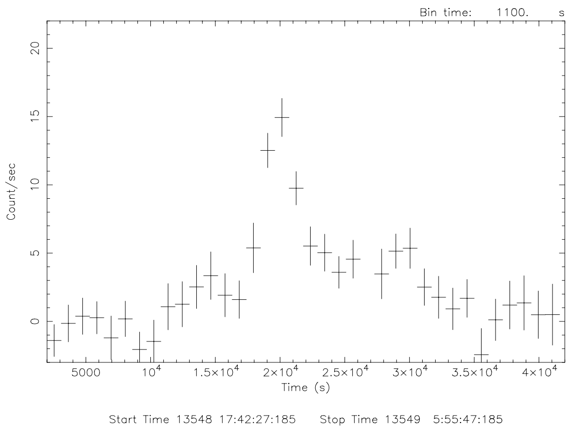


**Fig. 2.** ISGRI light curve (20–300 keV) of the outburst from IGR J11321−5311 on June 2005.

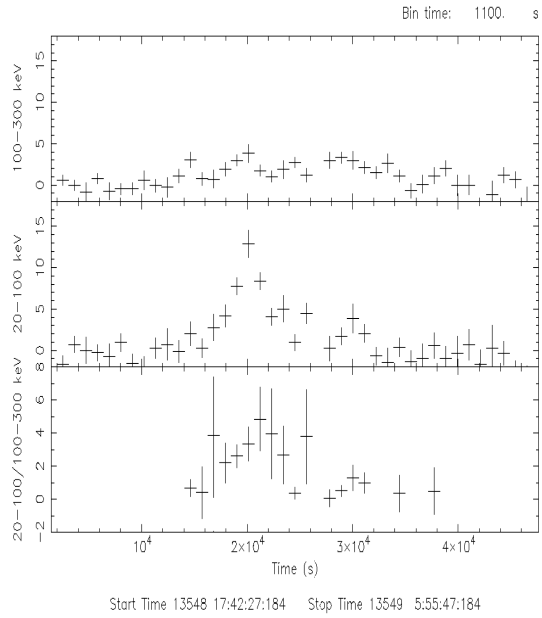


**Fig. 3.** ISGRI light curves of IGR J11321−5311 in the energy bands 20–100 and 100–300 keV. In the lower panel, the ratio of the two light curves is shown.

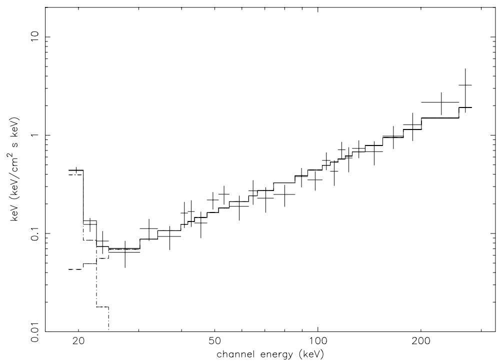


**Fig. 4.** Unfolded power law plus black body spectrum (17–300 keV) of IGR J11321−5311 extracted during its total outburst activity.

and their ratio 20–100/100–300 keV. The latter suggests a possible spectral evolution of the source during the outburst.

In order to search for pulsations, a time resolved ISGRI light curve with barycentric correction (1 s binning) was produced in the 20–100 keV band, using the OSA ii-light tool. However no clear signal was detected using the Lomb-Scargle periodogram method. Using a Monte-Carlo approach, it was possible to assess the data quality of the fine timing light curve and our sensitivity to periodic signals. Simulated light curves were generated which had the same sampling and statistical properties of the data but which had a sinusoidal modulation of ~10 s introduced. The results of the Monte-Carlo simulations found that to detect 100% pulsed emission a signal strength ~3 times stronger than that of the data was required; 50% pulsed emission required a signal ~9 times stronger. The implication of the Monte-Carlo results is that the statistical quality of the ISGRI data is insufficient to detect pulsations, and we cannot rule out their presence.

The spectrum (17–300 keV) extracted from the sum of the four ScWs (A, B, C and D in Fig. 1) during which the source was detected cannot be fitted by a single power law ($\chi^2_\nu$ = 4.7, d.o.f. 48). The presence of an additional component below ~25 keV is clearly evident. The fit did not improve by adding another power law component ($\chi^2_\nu$ = 4.95, d.o.f. 46), whereas it improved significantly by adding a black body ($\chi^2_\nu$ = 0.8, d.o.f. 46); the inclusion of this component was found to be significant at a confidence level greater than 99.99% using a F-test. In this case the best fit parameters are $\Gamma = 0.55 \pm 0.18$ and $kT = 1.0^{+0.2}_{-0.3}$ keV. The unfolded power law plus black body spectrum is displayed in Fig. 4. The spectrum does not show any break up to ~300 keV. For the assumed distance, a radius of the emitting black body region equal to $R$ = 7.7 km can be inferred, which is compatible with the typical value (10 km) of a neutron star. The flux of the black body component is ~$3.8 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$, accounting for ~14% of the total flux. IGR J11321−5311 was unfortunately outside the narrower JEM–X FOV so that it is not possible to add any information at lower energies. A spectral analysis at ScW level has also been performed, searching for a possible spectral evolution during the outburst, as highlighted in Fig. 3. Spectra extracted from ScW A and B (see Fig. 1) are very similar, both being best fitted by a power law plus a black body model (17–300 keV) with almost identical values of the best fit parameters. It was therefore reasonable to extract a spectrum from the sum of the two ScWs A+B to get a better model fit to the data. In this case, the best fit parameters of the power law plus black body best fit ($\chi^2_\nu$ = 0.8, d.o.f. 46) are $\Gamma = 1 \pm 0.17$ and $kT = 0.9^{+0.44}_{-0.25}$ keV. The best fit parameters concerning the spectrum extracted from the sum of ScW C+D (see Fig. 1) are $\Gamma = -0.36^{+0.18}_{-0.44}$ and $kT = 1.0^{+0.3}_{-0.3}$ keV ($\chi^2_\nu$ = 0.55, d.o.f. 46). The spectrum of IGR J11321−5311 during the final part of its

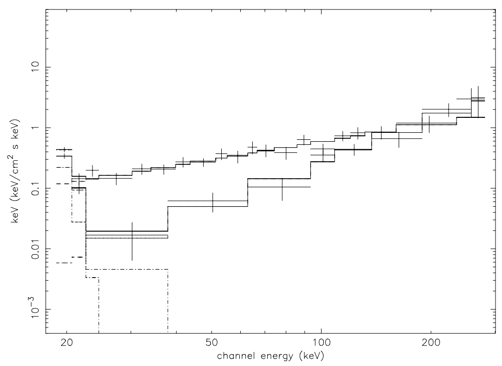


**Fig. 5.** Unfolded power law plus black body spectra (17–300 keV) of IGR J11321−5311 extracted from the sum of ScW A and B (*top*), C and D (*bottom*).

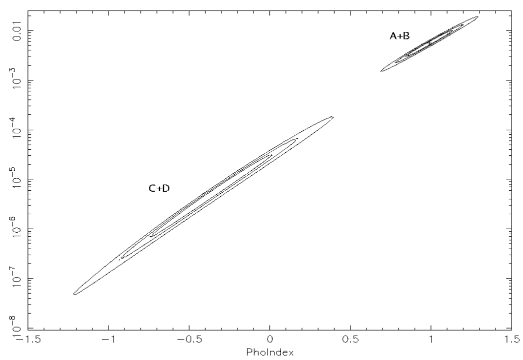


**Fig. 6.** Confidence contour levels for the photon index and the normalization constant of the power law model of the spectra extracted from the sum of ScW A+B and C+D.

outburst activity is much harder than that of the beginning of the outburst. This can be clearly noted in Fig. 5, which shows the two spectra extracted from the sum of ScW A+B and C+D, and in Fig. 6 which displays their confidence contour levels for the photon index and the normalization constant of the power law.

IGR J11321−5311 was not reported in the third IBIS catalog (Bird et al. 2007) although the region of the sky including the source was observed for a total of ∼1.15 Ms. It is worth pointing out that the third IBIS catalog input dataset did not include the INTEGRAL data pertaining the detection of the source discussed here, since they were not public at the time. It is therefore possible to infer a $2\sigma$ IBIS upper limit to the quiescent flux of IGR J11321−5311, equal to ∼0.5 mCrab or $3.4 \times 10^{-12}$ erg cm$^{-2}$ s$^{-1}$ (20–40 keV). Assuming again a distance of ∼6.5 kpc, the corresponding upper limit on the quiescent luminosity is $\sim 1.5 \times 10^{34}$ ergs$^{-1}$ (20–40 keV). Recently, *S*wift XRT performed two targeted observations of IGR J11321−5311 (exposure time of ∼2.5 and 3.3 ks), but no X-ray objects were detected inside the ISGRI error box (Landi et al. 2007). Moreover, the source has been targeted several times by the RXTE satellite, but detections were never reported. We can then conclude that IGR J11321−5311 spend a considerable fraction of its time in quiescence.

## 3. Discussion

We reported on spectral and timing analysis of the ISGRI detection of IGR J11321−5311 on June 2005, to date the only one reported in the literature. The source was active for only ∼3.5 h, being characterized by a short flare (∼1.5 h duration). The 17–300 keV spectrum of the total outburst activity was best fitted by a hard power law ($\Gamma = 0.55 \pm 0.18$) plus a black body model ($kT = 1.0^{+0.2}_{-0.3}$ keV). There is no indication in the spectrum of any break up to 300 keV. Spectral analysis at ScW level revealed spectral evolution of the source during the outburst, its spectrum being much harder ($\Gamma \sim -0.36$) at the end than at the beginning ($\Gamma \sim 1$).

No X-ray, gamma-ray and radio sources are located inside the ISGRI error circle (radius ∼1.′5) in any of the available catalogs in the HEASARC database. As for the optical and infrared band, the ISGRI error circle is naturally too large for a fruitful identification using catalogs such as USNO–B1.0 or 2MASS. A much more refined source position is strongly needed to this aim. It is worth pointing out that Negueruela & Schurch (2006) used existing photometric catalogues to search for early type stars within the error circles of unidentified X-ray source believed to be HMXBs. Their method was very efficient at finding reddened OB stars, resulting in the detection of the counterpart to several unidentified X-ray sources. However, no suitable candidates were found in the field of IGR J11321−5311 (Negueruela & Schurch 2006).

Though the observational data on IGR J11321−5311 are few, all the findings reported here may give indications on its nature. The temporal and the spectral behaviour of the source are reminiscent of outburst characteristics from two different class of hard X-ray emitters: magnetars and black hole transients.

Indeed, IGR J11321−5311 could be a new member of the Anomalous X-ray Pulsars (AXPs) group. A review by Kaspi (2006) outlines the recent observational progress on temporal and spectral behaviour of the seven, possibly nine AXPs so far detected. They have pulsation periods ranging from 6 to 12 s, large period derivatives ($\sim 10^{-13}$–$10^{-10}$ ss$^{-1}$), very strong magnetic fields ($0.6$–$7.1 \times 10^{14}$ G) and some of them are located inside Supernova Remnants. Their relatively high X-ray luminosity ($\sim 10^{34}$–$10^{36}$ erg s$^{-1}$) cannot be accounted for by rotational energy losses, moreover no convincing evidence for a companion star has been found for any of them. Many observational properties support the idea that AXPs are magnetars, isolated neutron stars powered by the decay of their huge magnetic fields. Spectra in the traditional X-ray band (0.5–10 keV) are well described by two components; a blackbody ($kT \sim 0.3$–$0.6$ keV) due to internal heating caused by the intense magnetic field decay plus a relatively steep power law ($2 < \Gamma < 4$) resulting from resonant scattering of the thermal seed photons off magnetospheric currents in the twisted magnetoshere. The softness of the spectra predicts non detections above 10 keV, however recent INTEGRAL observations have showed that AXPs are very hard X-ray emitters with spectra extending well above 100 keV and characterized by no break up to 300 keV (Kuiper et al. 2006). Their pulsed spectra are exceptionally hard with a photon index in the range from −1 to 1, while the photon index of the total spectra (sum of pulsed and unpulsed components) are in the range from 1 to 1.4 (Kuiper et al. 2006). Until recently AXPs were believed to be steady X-ray emitters, however one of the recent interesting discoveries is the range and diversity of their X-ray variability properties. AXPs show long term flux variations and short term variability such as outbursting behaviour. A short outburst has been fortuitously detected from 1E 2259+589 (Kaspi et al. 2003; Woods et al. 2004), it lasted a few hours and it was accompanied by a dramatic hardening of the spectrum. XTE J1810−197 (Woods et al. 2005) and CXOU J164710.2−455216 (Israel et al. 2007) are other examples of recently discovered transient and bursting AXPs. The flaring behaviour, the spectral characteristics with no break up to 300 keV and hardening of the spectrum, the peak and quiescent luminosities of IGR J11321−5311 (∼$10^{37}$ erg $s^{-1}$ and upper limit of ∼$10^{34}$ erg $s^{-1}$ respectively), all favour the hypothes of an AXP. Being typically $|b| < 1°$ for the AXPs sample, the IGR J11321−5311 location off the Galactic plane ($b = 7.°85$) could be suggestive of a close by AXP. However if we assume a closer distance, i.e. 3 kpc, the upper limit on the quiescent luminosity would drop to $10^{33}$ erg $s^{-1}$, which is lower when compared with the average values for the known AXPs.

An alternative to the AXP scenario is a black hole (BH) transient nature. Here we briefly indicate a few BHs showing short and peculiar outbursts: SAX J1819.3−2525, XTE J0421+560 and Cyg X−1. The X-ray transient SAX J1819.3−2525 (see in't Zand et al. 2000; and Revnivtsev et al. 2002, for a review) showed a series of very bright and short X-ray flares occurred within less than 1.5–2 days. The brightest one reached a level of ∼12 Crab (2–10 keV) and then the source totally disappeared within 0.3 day. Spectra accumulated during the peak are reminiscent of a black hole when in the low state with $\Gamma < 2$, cut-off at energy 100–200 keV. XTE J0421+560/CI Cam was discovered in 1998 by RXTE (Smith et al. 1998), it brightened very quickly up to 2 Crab a few hours after the discovery and decayed exponentially with a very short e-folding time (0.6 day). The 20–100 keV BATSE data on the decline are consistent with a power law with a photon index of −3.9 while there is marginal evidence of a harder spectrum during the rise and/or peak (Belloni et al. 1999). In the case of Cyg X-1, seven episodes of strong hard X-ray emission occurred within 9 years (Golenetskii et al. 2003). These outbursts have duration up to ∼8 h and reached peak fluxes of $3 \times 10^{-7}$ erg $cm^{-2}$ $s^{-1}$ (15–300 keV). All the spectral characteristics of the above black hole outburst examples do not show the peculiarity of IGR J11321–5311, i.e. flat spectral index and lack of any spectral break up to 300 keV. Moreover, the duration of the outburst detected by INTEGRAL from IGR J11321−5311 (∼3.5 h) is very short when compared to typical transient activity of accreting black hole binaries, which is of the order of months.

The location of IGR J11321−5311 off the Galactic plane ($b = 7.°85$) could suggest also an AGN nature. However, BL Lacs and Blazars are known to display flares with timescales of days or weeks, significantly longer than the flare detected from IGR J11321−5311 (∼5500 s). A possible very short hard X-ray flare (∼2000 s duration) was reported only in one case, the Blazar NRAO 530 (Foschini et al. 2006). Moreover, Blazar or BL Lac are known to be strong radio sources, but no radio source is reported inside the ISGRI error circle of IGR J11321−5311 using all the radio catalogues available in the HEASARC database. However it is worth pointing out that the region of the sky containing IGR J11321−5311 has not yet been covered by deep radio surveys (e.g. NVSS).

Further detections of IGR J11321−5311 by INTEGRAL or other X-ray missions, as well as multiwavelength observations, could be very useful to shed more light on this enigmatic hard X-ray transient source.

*Acknowledgements.* We thank the anonymous referee for useful comments which helped us to improve the paper. This research has been supported by University of Southampton School of Physics and Astronomy. AB,LB,AM,PU acknowledge founding support via contract ASI/INAF I/023/05/0.

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