INTEGRAL observations of IGR J11215–5952: the first Supergiant Fast X–ray Transient displaying periodic outbursts

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Abstract. The hard X–ray source IGR J11215–5952, discovered with INTEGRAL during a brief outburst in 2005, has been proposed as a new member of the class of Supergiant Fast X-ray Transients. Analysing archival INTEGRAL observations of the source field, we have discovered two previously unnoticed outbursts (in July 2003 and in May 2004), spaced by intervals of ∼330 days, suggesting a possible orbital period. The 5–100 keV spectrum is well described by a cut-off power law, with a photon index of ∼0.5, and a cut-off energy ∼15–20 keV, typical of High Mass X–ray Binaries containing a neutron star. The luminosity is ∼3×10^{36} erg s^{-1} assuming 6.2 kpc, the distance of the likely optical counterpart, the blue supergiant HD 306414. A fourth outburst was discovered in 2006 with XTE/PCA, 329 days after the third one, confirming the periodic nature of the source outbursts. Follow-up observations with Swift/XRT refined the source position and confirmed the association with HD 306414. The 5–100 keV spectrum, the recurrent nature of the outbursts, the blue supergiant companion star HD 306414, support the hypothesis that IGR J11215–5952 is a Supergiant Fast X–ray Transient, and it is the first object of this class of High Mass X–ray Binaries displaying periodic outbursts.

Keywords: X–rays; Neutron Stars; X–ray Binaries

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INTRODUCTION

The INTEGRAL satellite has discovered more than one hundred hard X–ray (E>15 keV) sources since its launch in 2002 (see e.g. the 2nd IBIS catalog, [1]). A large fraction of these objects (about 30%) have been identified as High Mass X–ray Binaries (HMXRBs), either thanks to their association with blue supergiants or Be stars, or based on their X–ray properties typical of HMXRBs, like e.g. periodic pulsations or hard X–ray spectra (photon index around 0.5–1 in the 2–10 keV energy range).

Interestingly, INTEGRAL has discovered a growing number of members of two different classes of HMXRBs: highly absorbed persistent sources (with properties similar to Vela X–1), and transient sources displaying brief outbursts, with a duration of few hours, significantly shorter than the transient Be/XRBs outbursts (the Supergiant Fast X–ray Transients, SFXTs; e.g. [2], [3]).

IGR J11215–5952 is a transient hard X–ray source discovered with the INTEGRAL satellite in April 2005 [4] and tentatively associated with the supergiant star HD 306414 [5]. Here we report on the discovery of two previous unnoticed outbursts from this source through the analysis of archival INTEGRAL observations (for details see [6]).
OBSERVATIONS AND RESULTS

The ESA INTEGRAL gamma-ray observatory was launched in October 2002 and carries three co-aligned coded mask telescopes: the imager IBIS ([7]), which allows high angular resolution imaging over a large field of view (29° × 29°) in the energy range 15 keV–10 MeV, the spectrometer SPI ([8]; 20 keV–8 MeV) and the X-ray monitor JEM-X ([9]; 3–35 keV).

The sky region of IGR J11215–5952 was repeatedly observed by INTEGRAL. We analyzed all the public IBIS/ISGRI observations pointed within 15° of the source. This translates into 850 individual pointings performed between December 2002 and August 2004, yielding a total exposure time of about 1.8 Ms.

IGR J11215–5952 was detected in the 17–40 keV range in 17 pointings, which correspond to two outbursts occurring on 3–4 July 2003 and 26–27 May 2004. The first of these two outbursts was independently discovered also by Sguera et al. ([10]). The sparse sample allows us only to put lower limits on the outbursts durations, which are ∼9 hours and about two days for the 2003 and 2004 outbursts, respectively. Both outbursts did not exceed ∼7 days.

Our refined estimate for the source position has been obtained summing together the pointings from both outbursts: R.A. (J2000)= 11°21′50.8″, Dec. = −59°52′48.3″, with a statistical uncertainty of 1.2″. This position is consistent with that obtained during the April 2005 discovery outburst ([4]) and the refined uncertainty region still includes the proposed optical counterpart HD 306414 ([5], [11]).

We extracted the IBIS/ISGRI spectra at the peak of the two different outbursts. The low energy JEM-X spectrum was available only for the first outburst (Figure 1). The 5–100 keV spectrum of July 2003 is well described by a cutoff power-law ($\chi^2=47.5$ for 50 degrees of freedom, dof), with a photon index of $0.5^{+0.4}_{-0.6}$ and a cutoff energy of $15^{+5}_{-4}$ keV. The derived fluxes are $6.2\times10^{-10}$ erg cm$^{-2}$ s$^{-1}$ (5–100 keV) and $2.8\times10^{-10}$ erg cm$^{-2}$ s$^{-1}$ (20–60 keV).
FIGURE 2. Corbet diagram of accreting X-ray pulsars with known orbital and spin periods. The typical loci for wind-fed, disk-fed pulsars and transient Be/XRB are also marked. Few newly discovered INTEGRAL sources (IGRs) with known orbital and spin periods are also marked with large triangles. The arrows mark the IGR sources with only one period measured (orbital or spin period). The large square marks the position of IGR J11215–5952, if the pulse period of $\sim 195$ s will be confirmed.

During the peak of the second outburst (May 2004) only the IBIS/ISGRI spectrum (20–100 keV) was available, and could be well fitted with a single power-law ($\chi^2=12.9$ for 8 dof) with a photon index of $2.6^{+1.8}_{-0.6}$. The 20–100 keV flux is $2.5 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$ and the 20–60 keV flux is $2.1 \times 10^{-10}$ erg cm$^{-2}$ s$^{-1}$. Note that the cutoff power-law best-fit to the first outburst is a good fit to the spectrum of the second outburst as well.

**DISCUSSION AND CONCLUSIONS**

Analysing all the public INTEGRAL data, we have discovered two unnoticed outbursts from the source IGR J11215–5952. Our refined position was still consistent with the proposed optical counterpart HD 306414. Masetti et al. ([11]) found evidence for an H$\alpha$ emission line, and confirmed the spectral classification as a B1 Ia-type star, with an estimated distance of d$\sim 6.2$ kpc. At this distance, the peak fluxes of the two outbursts correspond to a luminosity of $3 \times 10^{36}$ erg s$^{-1}$ (5–100 keV). This luminosity, as well as the spectral shape derived with INTEGRAL, are typical of High Mass X-ray Binaries containing a neutron star.
The three outbursts from IGR J11215−5952 observed with INTEGRAL are spaced by ∼330 days, possibly indicative of an orbital period. This suggested periodicity has been confirmed by the detection of the fourth outburst from IGR J11215−5952 with RossiXTE/PCA on March 16-17, 2006, after 329 days from the third outburst. This observation confirms our suggested periodicity, and makes IGR J11215−5952 the first SFXT with periodic outbursts. The X–ray emission seen with RXTE/PCA, shows a strong variability and a hard spectrum, well fit by a power-law with a photon index of 1.7 ±0.2 in the range 2.5−15 keV, absorbed by a column density of 11×10^{22} cm^{-2}, higher than the interstellar value.

Following the report of renewed activity in IGR J11215−5952, a Swift/XRT ToO observation of the source field was obtained, leading to a refined source position: R.A.(J2000): 11° 21′ 46.9″, Dec(J2000): −59° 51′ 42″ with an estimated error radius of 5″. This is consistent with the INTEGRAL position, and still includes the supposed optical counterpart, confirming the physical association with the blue supergiant star.

The transient nature of the source, the spectral properties and the association with a blue supergiant, confirm that IGR J11215−5952 is a member of the growing class of Supergiant Fast X–ray Transients (SFXTs).

This is a new class of X–ray binaries with a supergiant companion, similar to the persistent accreting pulsars, but displaying bright X–ray emission only during short X–ray outbursts. This transient nature is quite surprising since neutron stars accreting from the winds of supergiant companions were, until recently, seen as relatively steady sources. The four outbursts observed to date from IGR J11215−5952 are equally spaced by about 330 days, possibly indicative of the orbital period of the binary system. This periodicity is worth noting, since in no other source belonging to the class of SFXTs a periodic behavior has been observed. Such a long period is more typical of Be/X–ray binaries than of Supergiant HMXRBs, which typically have orbital periods shorter than ∼20 days. Smith et al. reported a possible pulse period of ∼195 s from IGR J11215−5952 detected during the RXTE/PCA observations. If this is confirmed, IGR J11215−5952 would be located in the typical region of Be/X–ray binary pulsars in the so-called Corbet diagram of pulse period versus orbital period for HMXRBs (see Figure 2).

The long orbital period found in IGR J11215−5952 is consistent with the scenario proposed by Negueruela et al. for the SFXTs: they suggested that SFXTs have wider orbits than “normal” supergiant persistent HMXRBs (Vela X−1−like systems) and that the compact source accretes from a less dense environment, in order to explain the very low emission level during quiescence in SFXTs (∼10^{32}−10^{33} erg s^{-1}). The short outbursts and the long orbital period indicate that the binary system is wide and with a high eccentricity.

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