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Memorie della

New INTEGRAL High Mass X-ray Binaries

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Abstract. The discoveries of new Galactic sources obtained by the INTEGRAL satellite in the first four years of observations are opening a new view in the High Mass X–ray Binaries field. Several new INTEGRAL sources are highly obscured X–ray binaries, others belong to a new recognized class of HMXB transients, the Supergiant Fast X–ray Transients, with short outbursts, apparently lasting only a few hours. Here we propose a new possible explanation of the short duration outbursts from these sources, and we show how the highly obscured sources discovered by INTEGRAL will take advantage from the future observations with the instruments on-board the Simbol-X satellite.

Key words. X–rays: binaries

1. Introduction

The Galactic plane monitoring performed by the INTEGRAL satellite has led to the discovery of several new Galactic sources (see e.g. the latest ISGRI catalogue, Bird et al. 2007, or Bodaghee et al. 2007 for a detailed description of the sources). About 30% of them have been later identified as new High Mass X–ray Binaries, thanks to the discovery of X–ray pulsations, or thanks to the hard X–ray spectrum resembling that of "classical" X–ray pulsars, or due to the optical identification with Be stars or blue supergiants. Moreover, the new sources are mainly located in the direction of the spiral arms of our Galaxy.

Some of the new High Mass X–ray Binaries are highly obscured sources, probably with persistent, although highly variable, X–ray emission, which escaped detection with previous missions. The first source of this kind is IGR J16318–4848, discovered in January 2003 (Courvoisier et al. 2003), which shows a huge absorption of 10^{24} cm^{-2} and intense iron emission lines (Ibarra et al. 2006).

Other IGR (*INTEGRAL* Gamma-Ray) sources are transients with short recurrent outbursts (typically shorter than those of the Be X–ray binaries), blue supergiant companion stars (as in the "classical X–ray pulsars", like Vela X–1) and their X–ray spectrum is similar to that of accreting X–ray pulsars. These supergiant transients have been recognized as a new class of sources, and named "Supergiant Fast X–ray Transients" (SFXTs; e.g. Negueruela et al. 2005a). The typical duration of the outbursts (as observed with INTEGRAL or RXTE) seems to be below a few hours. The peak luminosity of outbursts from SFXTs with known distance is about 10^{36} erg s^{-1} (see e.g. Sguera et al. 2005, Sguera et al. 2006).

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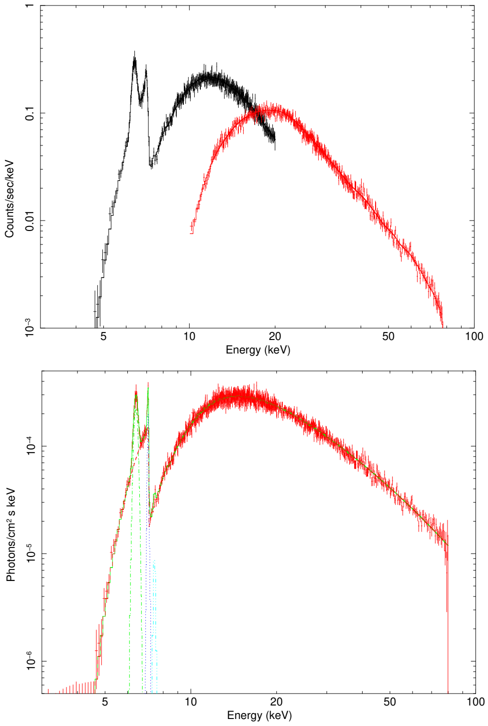

Fig. 1. Simulation of the spectrum of IGR J16318–4848 as would be observed by Simbol-X instruments, assuming a net exposure time of 50 ks and the parameters observed with XMM-Newton and INTEGRAL (from Ibarra et al. 2006, see text). In the upper panel the simulated count spectrum is reported, while in the lower panel the photon spectrum is shown.

2. The case of IGR J16318–4848

IGR J16318–4848 is the prototype of the highly obscured sources discovered with INTEGRAL. In Fig. 1 the source spectrum, simulated with Simbol-X with a net exposure time of 50 ks, is reported. The simulated spectrum assumes the following parameters: a column density of 2×10^{24} cm^{-2}, a power-law spectrum with a photon index of 1.6 and a cut-off at 60 keV, plus three Gaussian lines at the energies 6.4 keV, 7.099 keV and 7.45 keV (from Ibarra et al. 2006).

Simbol-X will clearly represent a significant advantage with respect to other satellites, especially in observing over a broadband range, up to 80 keV (fundamental in such highly absorbed sources) and in detecting column density variability on short timescales (crucial in order to understand the structure of the local absorbing matter in highly variable sources).

3. IGR J11215-5952 and a new explanation for the Supergiant Fast X–ray Transient phoenomenon

IGR J11215-5952 is a SFXT discovered with INTEGRAL in 2005 during an outburst lasting a few thousand seconds (Lubinski et al. 2005). The source was later optically identified with a B-type supergiant (Negueruela et al. 2005b, Masetti et al. 2006). The analysis of archival INTEGRAL data led to the discovery of a period of ~330 days in the outburst recurrence (although a half of this periodicity could not be excluded due to the poor coverage with INTEGRAL observations, Sidoli et al. 2006). The suggested recurrence time was later confirmed with RXTE/PCA observations in 2006 (Smith et al. 2006a). This periodicity makes IGR J11215-5952 a unique SFXT, and can be linked naturally to the possible orbital period of the binary system. The source is also an X–ray pulsar, displaying a pulsation period of ~187 s, discovered from RXTE observations (Smith et al. 2006b, Swank et al. 2007).

A monitoring campaign of the 2007 outburst, expected on February 9th 2007, was performed by Swift/XRT (Romano et al. 2007) and led to the interesting result that the accretion phase in SFXTs lasts longer than previously thought based on less sensitive instruments. Only the brightest phase of the outbust lasts few hours (and less than one day). Thus, INTEGRAL instruments caught only the brightest phase of the outbursts from SFXTs. A large X–ray variability in the IGR J11215-5952 flux has also been observed, with short flares.

These X–ray observations, covering the whole outburst from IGR J11215-5952, can be interestingly used to build a model for the X–ray emission from SFXTs. Negueruela et al. (2005a) proposed that SFXTs are HMXBs in wide eccentric binaries, in order to explain the

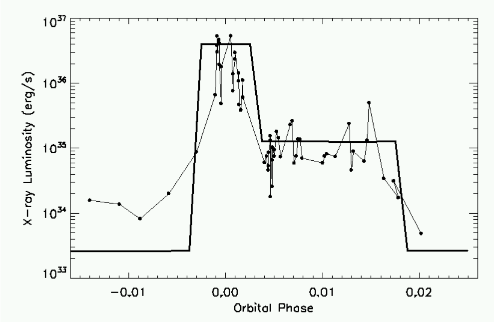

Fig. 2. Result of the suggested wind model to explain the SFXTs outburst (solid line), compared with the IGR J11215-5952 lightcurve, as observed by Swift/XRT in February 2007 (small dots). See text for details.

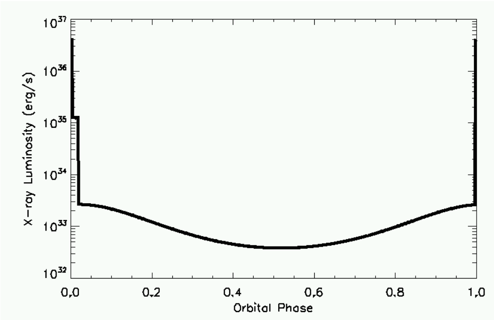

Fig. 3. Variations along the neutron star orbit of the X–ray luminosity, as calculated from the disk wind model proposed here for IGR J11215-5952 (assuming an eccentricity e=0.4; see text for details)

low quiescent luminosity ($\sim10^{32}$ erg s^{-1}) observed in a few sources of this class.

On the other hand, the application of Bondi-Hoyle accretion to wind-fed X–ray binaries in eccentric orbits leads to the conclusion that the outburst from IGR J11215-5952 is too short (the brightest part lasting less than one day) to be explained with accretion onto the neutron star from a spherically simmetric homogeneous wind from the B1-type supergiant in an eccentric orbit, even in presence of extremely high eccentricities.

This indicates that the blue supergiant wind is not spherically symmetric. We suggest the presence of a second, denser wind component in the form of an equatorial disk, inclinded with respect to the orbital plane, which would intersect the neutron star path only in a small portion of its orbit. When the neutron star crosses this disk, the denser and slower wind accretes more efficiently and the brightest part of the short outburst is produced. The presence of equatorial disk components in the winds of supergiants has been studied by other authors (e.g. Ud-doula et al. 2006).

A rough estimate for the thickness *h* of the densest part of this disk can be obtained from the duration of the brightest part of the outburst and the neutron star velocity, 100–200 km s^{-1}: $h\sim(0.8–1.7)\times10^{12}$ cm. Assuming a density for the equatorial disk around 10^{-15}–10^{-14} g cm^{-3} (see also Ud-doula et al. 2006), it is possible to model the IGR J11215-5952 outburst lightcurve (Fig. 2) with the following parameters (in the framework of Bondi-Hoyle accretion from the companion wind): an orbit with a period of 329 days and an assumed eccentricity of e=0.4 (this only in order to reach low luminosities outside outburst, as observed in other SFXTs); a supergiant mass of 39 $M_\odot$ and radius of 42 $R_\odot$, with a "polar wind" simmetrically spherical component with a terminal velocity of 1800 km s^{-1} and a mass loss of 4×10^{-6} $M_\odot$ yrs^{-1}; an equatorial disk with a 100 times higher mass loss than in the polar regions and a terminal velocity of 900 km s^{-1} is able to reproduce the lightcurve shape during the brightest emission, while the fainter X–ray emission can be obtained assuming a 0.3 times less dense wind with respect to the equatorial disk (Figs. 2 and 3).

The geometry proposed here is sketched in Fig. 4, where four cases are considered: in case "a" the outburts are periodic and regularly spaced, and a certain eccentricity is required in order to allow a low quiescent luminosity (as observed in a few SFXTs). Case "b" represents a circular orbit with an inclined equatorial disk from the companion (in this case two equally spaced outbursts per orbits are expected). Case "c" can be a possibility for all the other SFXTs where a periodicity in the outburst recurrence has not been found yet. In case "d" the equatorial disk lies on the orbital plane (this is not the case for SFXTs, but maybe the case for per-

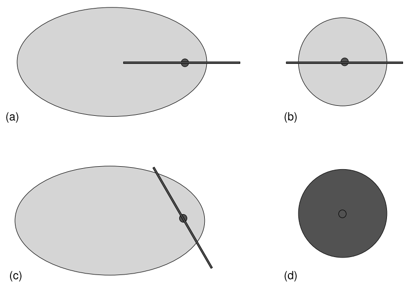

Fig. 4. The proposed geometry for different kinds of systems with supergiant companions. The ellipses (or circles, light color) mark the orbital plane. The equatorial wind (in the form of a disk) from the supergiant is inclined with respect to the orbital plane, with the dark line, centered on the supergiant star, indicating the intersection of the equatorial wind with the orbital plane (see text for the explanation of the 4 cases.

sistent HMXBs, like Vela X-1) and the neutron star moves always inside the disk wind.

In conclusion, we have proposed here a new possible explanation for the short X–ray outbursts from SFXTs. Our model involves the presence of an equatorial wind (in the form of a disk) outflowing from the supergiant companion, inclined with respect to the orbital plane. The outburst is produced when the neutron star crosses the disk along its orbit. In order to test this still highly speculative model, new observations are needed. INTEGRAL has opened a new window in the observations of highly obscured HMXBs and of Supergiant Fast X–ray Transients. Both classes of new INTEGRAL sources will surely greatly benefit from the Simbol-X satellite, thanks to its large energy band and its capability of performing very long uninterrupted observations on the same target.

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