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An INTEGRAL timing and spectral history of 1A 1118-615

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The INTEGRAL/IBIS/ISGRI instrument has detected this Be X-ray Binary system (BeXRB) very rarely during its 10 years of operations. However, all variability time scales of the source are covered by these observations: the pulse period of the spinning neutron star, orbital modulated outbursts, and one Type II outburst possibly related to a violent mass ejection episode from the optical counterpart. The orbital period of ∼24 days is apparent in the ISGRI data. Pulse period changes are analyzed as well, together with the aperiodic variability of the source at short and long time scales.

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1. Introduction

1A 1118-615 is a Be X-Ray Binary System (BeXRB), i.e., it is composed by a Be star and a neutron star orbiting around each other. A Be star is a O/B main sequence star which exhibits Balmer lines in emission and IR excess, both are thought to be due to the presence of a circunstellar disk around its equator. X-Ray emission is due to the accretion of disk/wind matter from the Be star onto the neutron star companion. See [9] for a review.

1A 1118-615 has been detected during three periods of high activity in 1974 ([7]), 1992 ([2]), and 2009 ([4]). In all cases the source has shown a highly structured variability accompanying a giant outburst ([10]).

We report on observations of INTEGRAL/ISGRI of 1A 1118-615. The observations cover the period around the 2009 outburst as detected by INTEGRAL/ISGRI.

2. Short term and Long term behaviour

INTEGRAL/ISGRI instrument has detected 1A 1118-615 very rarely during its 10 years of operations. Figure 1 depicts the detections of the source, the upper limits when the significance of the detection was low, and the epochs at which the source was in the field of view of INTEGRAL/ISGRI but it was not detected. It is noticeable that, except for a couple of detections in June 2004 and February 2006, and before the period of activity during 2009, the source has been below the detectability threshold of INTEGRAL/ISGRI since the launch of the spacecraft (October, 2002).

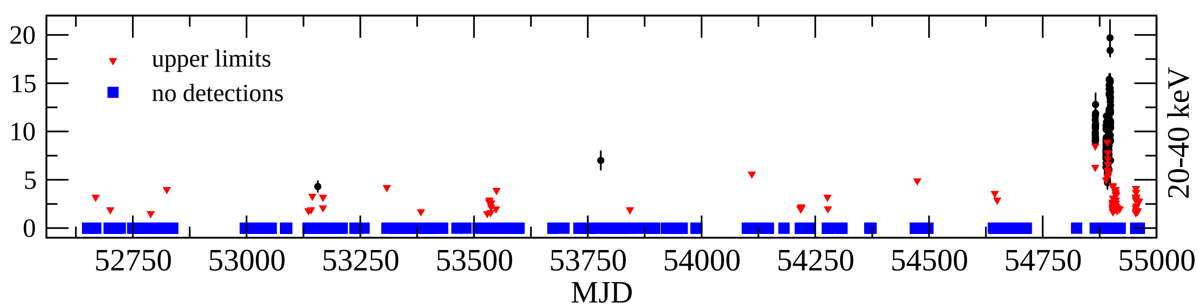

Figure 1: Long term light curve of 1A 1118-615, including the epochs when the source was in the field of view of INTEGRAL/ISGRI but was not detected (indicated with a square blue symbol).

Figure 2 shows a more detailed view of the light curves and pulse period evolution of 1A 1118-615 for the 2009 epoch of activity.

We can differentiate two types of outburst during this epoch. The fainter ones, with a peak about 12 count s^{-1} (MJD ∼54866, ∼54890, and ∼54893) and a brighter one (peaking around MJD∼54897 and reaching almost 20 count s^{-1}). We can notice that the first two faint outbursts are separated ∼24 days, which is the orbital period of the system. However, observations of INTEGRAL/ISGRI were done exactly with this timing, therefor we can not conclude that the orbital period of the system is detected in INTEGRAL/ISGRI data.

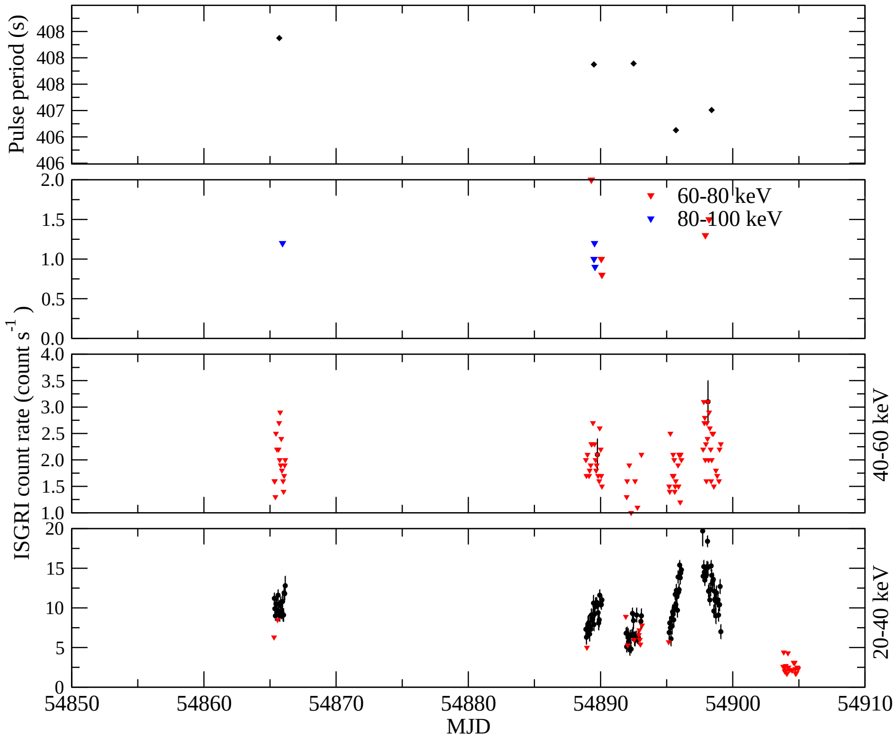

Figure 2: Light curve and spin period evolution of 1A 1118-615 during the 2009 epoch of activity. In the bottom panel, the 20-40 keV ISGRI light curve is shown, with red downwards triangles indicating upper limits. In the middle panels, only upper limits are shown. In the top panel, the evolution of the pulse period of 1A 1118-615 is drawn.

3. Pulse period evolution

In Figure 3 we have depicted the cleaned power-spectra of the 20-40 keV from INTEGRAL/ISGRI light curves extracted from revolutions 770 (MJD ∼54866), 778 (MJD ∼54889), 779 (MJD ∼54892), 780 (MJD ∼54895), and 781 (MJD ∼54898). The pusle period measurements are shown in the upper panel of Figure 2. The first three measurements represent the continuation of a normal spin-up tendency of the source. The spin-up rate can be estimated to be -0.017 yr^{-1}. This tendency is broken when entering the brightest outburst. A large spin-up followed by a spin-down tendency are suggested by the data.

In order to investigate the aperiodic variability of 1A 1118-615, we have compared the power-spectra of the light curves from revolutions 770 and 778 (fainter outbursts, left panel of Figure 4) and revolutions 780 and 781 (rise and decay of the brighter outburst respectively, right panel of Figure 4). The only clear feature in all of them is the significant peak at the spin period frequency. Furthermore, the spectral indexes of the power-spectra are the same in all cases, both during faint and bright outburst, i.e., there are no changes in the slope of the power-spectra.

4. Spectral properties

Depicted in the Figure 5, we can find the averaged spectra from revolutions 770 and 778 (upper

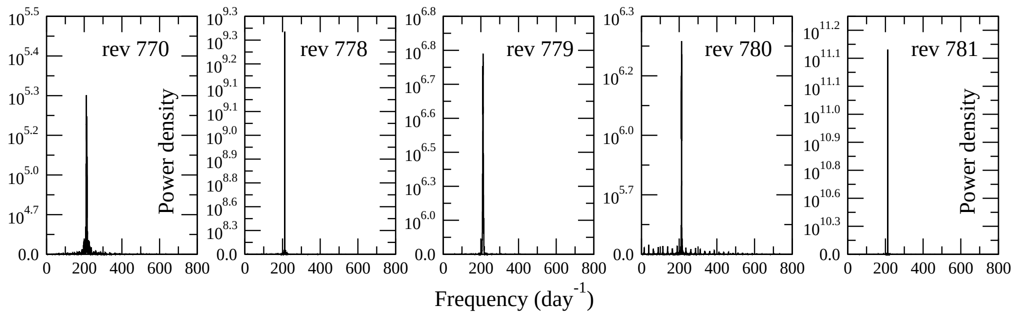

Figure 3: Cleaned power-spectra of light curves of 1A 1118-615 from revolutions 770, 778, 779, 780, and 781. The peaks correspond to the pulse period measurements shown in the upper panel of Figure 2.

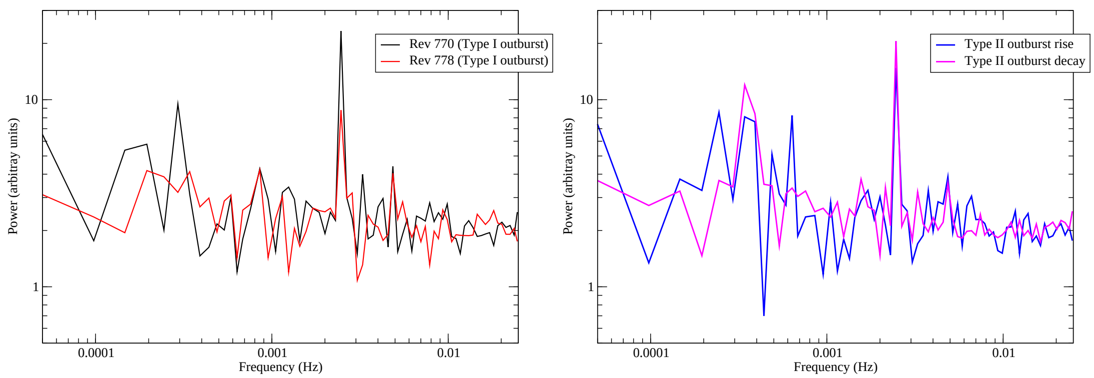

Figure 4: Comparison of the power-spectra of the light curves of revolutions 770 and 778 (left panel) and 780 and 781 (right panel).

panel), and 780 and 781 (lower panel). To obtain a good fit a powerlaw plus a cut-off had to be used as fitting model. The overall flux of revolution 770 is higher than that of revolution 778 and the spectrum looks softer. In the lower panel, the softer spectrum corresponds to revolution 780, which shows an overall flux higher than that of revolution 781.

We have also studied the evolution of the spectral photon index (Γ) of the 20-100 keV energy range. The evolution of Γ mimics the behavior of the light curve, rising towards softer photon indexes when the count rate increases.

We have indentified RXTE/ASM observations of the 2009 activity period of 1A 1118-615 which are contemporaneous with those of INTEGRAL/ISGRI. With these two sets of data we have calculated the hardness ratios defined as $(F_{20-40} - F_{2-12})/(F_{20-40} + F_{2-12})$, where F_{20-40} and F_{2-12} are fluxes in Crab units for the 20-40 keV (INTEGRAL/ISGRI) and 2-12 keV (RXTE/ASM) energy ranges. A clear correlation of the hardness ratio to the flux in the 2-12 keV energy band is found. There is a tendency towards softer spectra when the flux increases.

5. Discusion and conclusions

We have reviewed the long term behaviour of 1A 1118-615 as detected by INTEGRAL/ISGRI

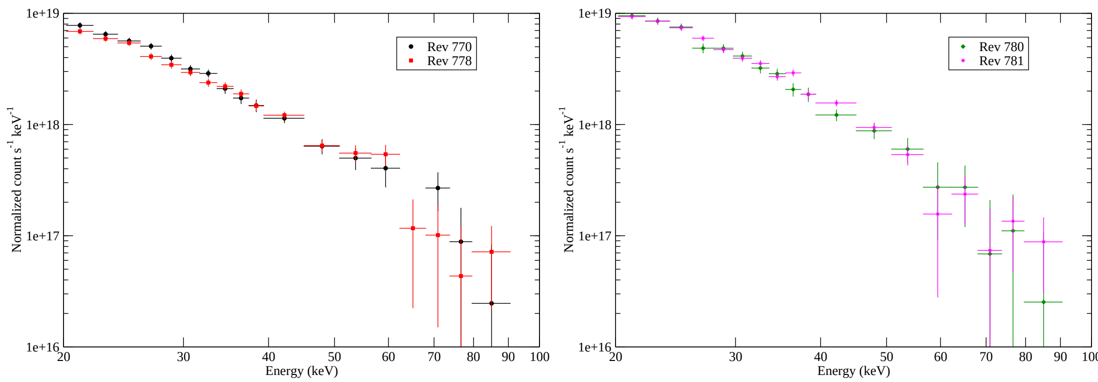

Figure 5: Averaged spectra of 1A 1118-615 at revolutions 770, 778, 780, and 781

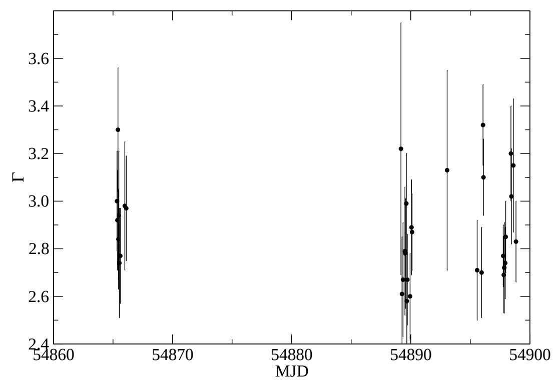

Figure 6: Evolution of Γ (20-200 keV spectral range).

data. The source is below the sensitivity of the instrument most of the time, but apparently still active, as indicated by two peculiar measurements in June 2004 and February 2006.

During the 2009 outburst the source becomes very active showing faint and bright outbursts with indications of different accreting regimes taking place in them. While the general spin-up tendency is maintained while faint outbursts take place, great spin-u and down changes occur while in the bright outburst. However, in general, the source becomes softer when flux increases, both in faint and bright outbursts.

No signs of aperiodic variability are seen in the power spectra of 1A 1118-615 from INTEGRAL/ISGRI data. In particular we can not find the QPO detected by [3], [8], and [6].

It is accepted that Be X-Ray binaries undergo two types of outburst. Type I outburst, modulated with the orbital period of the system, associated to periastron passages of the neutron star, and lasting for days. And Type II outburst, brighter than Type I ones and unpredictible, associated to disruptions of the circunstellar disk of the Be star, and lasting for weeks-months (see [9]). However, 1A 1118-615 shows a kind of intermediate behavior, showing an epoch of increased activity (with a duration of $\sim$2 motnhs, similar to Type II outbursts) but with a series of Type I ourbursts (apparently modulated with the source orbital period, see Figure 2) followed by a bright outburts which lasts a few days. A source showing a similar beahavior is SAX J2103.5+4545 (see

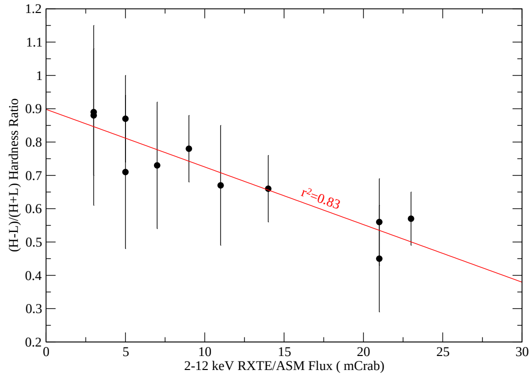

Figure 7: Hardness ratio versus RXTE/ASM flux, comparing contemporaneous RXTE/ASM and INTEGRAL/ISGRI data.

[1]) , which shows epochs of increased activity, with orbital modulation, and epochs of quiescence (or decreased activity below our detectavility thresholds). These two sources, which are among the ones with shorter orbital periods (see [5]), represent excellent laboratories to test our current konwdledge of BeX systems.

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