The outbursts era of the microQSO H1743-322

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Abstract

On March 2003 after about 25 years, H 1743-322 was observed again in outburst by the INTEGRAL satellite. After this bright outburst the source entered in a new phase showing several more outbursts within a few years. These outbursts had an unusual regularity insomuch as it is even possible to extrapolate two different recurrence periods. This peculiar behavior has been observed before only in the BH 4U1630-47 until 1998. Moreover some of these outbursts did not follow the state transition sequence expected for a BH X-ray binary. We review here the high energy evolution of H1743-322 as seen by INTEGRAL and RXTE with special attention to differences and similarities between the outbursts and the nature of the their recurrence. Moreover we present some results of a NIR campaign performed during the 2009 outbursts.

Key words: LMXRB, BHC, X-ray novae

1. Introduction

From the observational point of view, the emission properties of accreting black holes are often classified in terms of spectral and timing parameters. The spectra can be simply described as combination of a soft thermal component together with a hard component that can fall off more or less steeply with energy. The spectral evolution seems to be strictly connected with the variation of the timing properties: the state transitions follow a hysteresis behavior where the transition from low-hard to high-soft occurs with higher emission than the return to the low/hard state from the high/soft one. Each outburst has its own luminosity that varies from outburst to outburst and also their recurrence cannot generally be established but the sequence of the spectral and timing evolution follows the same scheme even if rare exceptions have been reported in literature (Capitanio et al. 2009, Brockshop et al. 2004 and references therein).

We briefly resume here the principal characteristics of the canonical states of a Transient Black Hole Binary (TBHB). The sketch in Figure 1 resumes the Hardness-Intensity diagram evolution of a typical TBHB in the different spectral states (for details see e. g. Fender, Belloni & Gallo, 2004 and Homan & Belloni 2005).

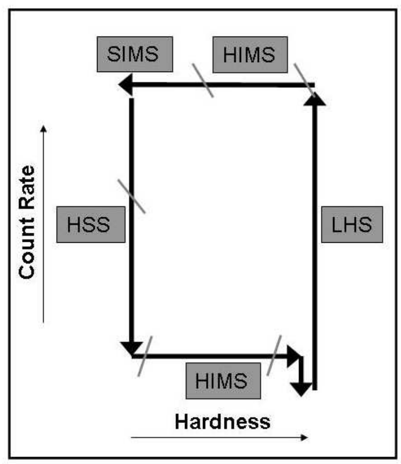

Fig. 1. Sketch of the canonical hardness-intensity diagram of a TBH in outburst.

1.1. Low Hard State (LHS)

The flux starts to increase with harder spectral shape, the energy spectrum is hard and strong band limited noise (30-40%) is observed in the power density spectrum. This state is probably associated to compact jet.

1.2. Hard Intermediate State (HIMS)

The energy spectrum becomes softer and a soft thermal disk component becomes detectable. The radio spectrum becomes steeper and the velocity of the jet outflow increases. The power density spectrum features have higher characteristic frequencies than LS and usually there is a rather strong 0.1-15 Hz type-C QPO.

1.3. Soft Intermediate State (SIMS)

Before the transition to the SIMS state, the jet velocity increases rapidly, giving origin to a fast relativistic jet and strong radio flares. Also significant changes appears in the power density spectrum features. This happened when the source approaches the "jet line in the HID. Past the line, there are non more radio detections. The source remains for a long time in this state drawing several loops in the HID. The spectrum is dominated by the disk component. No band-limited noise is observed but the power density spectrum shows complex and variable features.

1.4. High Soft State (HSS)

The energy spectrum is soft and strongly dominated by a thermal disk component, a weak power law hard component is present without any detectable cutoff up to 300 keV. The flux decreases with time and only weak power-law noise is observed. No core radio emission is detected. In this configuration the source is in a regime that is probably the closest one to Sakura Suniayev theory of the accretion disks.

1.5. Hard Intermediate State II

The flux stats to increase and the spectrum hardens again. The source enters again in HIMS state with the same characteristic of previous transition but with a weaker flux.

1.6. Low Hard State II

The source continues to harden and moves to the right side of the HID reaching the same value as when it started its outburst.

2. The behavior of the H1743-322 outbursts from 2003 until 2010

On 2003 March 21 IBIS, the γ-ray monitor on board INTEGRAL satellite, (Ubertini et al. 2003) detected a relatively bright source named IGR J17464-3213 (Revnitsev et al. 2003). The source was associated with H 1743-322 a bright BHC observed by HEAO-1 in 1977 with an intensity of 700 mCrab in the 2-10 keV. H1743-322 is classified as microquasar: jets have been detected in both radio and soft X-ray band (Corbel et al. 2005). QPOs at typical frequency of BHC have been reported by Homan et al. 2003. After this outburst other seven fainter outbursts have been detected during the last years. these outbursts had typical behaviors as seen by the most of the TBH showing the canonical four spectral states (see Figure 1). H1743-322 is considered as an example of typical transient Black hole Binary in despite of nature of the system that has still not a sure dynamical confirmation. October 2008 outburst has been considered as an exception: the observations, performed during this outburst, indicate that the source had undergone in a transition from the LHS to the HIMS but suddenly the source reached again the quiescent state without any detectable transition to the HSS (Capitanio et al. 2009). We summarize in this section the high energy view (especially as seen by INTEGRAL and RXTE) of the outbursts occurred from 2003 until 2009 pointing out the peculiar characteristics of the spectral and timing behavior of this intriguing BHC.

2.1. The 2003 outburst

This outburst was observed by INTEGRAL after many years of quiescence. The outburst was very bright reaching about 1 Crab in the range 2-10 keV. It was also the brightest respect to the subsequent ones. Figure 2 shows the INTEGRAL spectra of four different states of this outburst.

The spectrum evolves following the canonical q-track diagram starting from a LHS until the HIMS and SIMS. Than, after a period in which the sources was in HSS (not covered by INTEGRAL observations), the sources start again a transition to hard states and then down to quiescence (for details see e.g. Capitanio et al. 2005, McClintock et al. 2009). This outburst was observed by most of the X-ray satellites operating during 2003 and by several ground facilities covering a wide energy range spanning from radio to γ-rays. Many results have been extracted from these data, for details see also e.g. Homan et al. 2005, Capitanio et al. 2005, Corbel et al. 2005, Miller et. al 2006, Kalemci et al. 2006, Mclintock et al. 2009 and reference therein.

2.2. The 2004 and 2005 outbursts

The 2004 outburst (Swank 2004) was poorly observed by the X-ray satellites. The INTEGRAL data covered only the final part of the outburst (Capitanio et al. 2006): the source, after the peak of the emission, seemed to harden again, but suddenly it came back to a softer state drawing a loop in the hardness-intensity diagram (this behavior is quite common during the softest states): Figure 3 shows the same loop as a function of single spectrum photon index vs 3-200 keV flux (Capitanio et al. 2006).

The best fit for the data of the softest state of the source is obtained with a disk black body plus a simple powerlaw without any detectable cutoff above 200 keV (Figure 4). Unfortunately the data coverage is not enough to permit any conclusion, but the lack of cutoff in the spectrum could be a signature of HSS.

The 2005 outburst was very short and faint, few data were collected and generally it has been poorly studied. (see e.g. Rupen et al. 2005 and Swank et al. 2005).

2.3. The two 2008 outbursts as seen by INTEGRAL, Swift and RXTE

H1743-322 undergone in outburst two times during 2008 (January and October).

Figure 5 shows the RXTE /PCA light curve of the two outbursts between 3-20 keV. The October light curve is

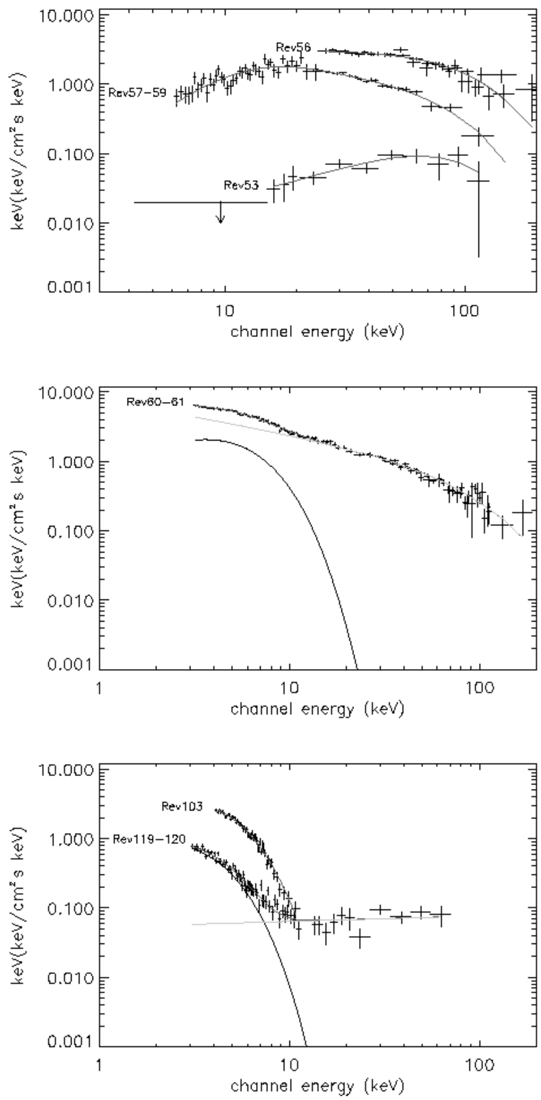

Fig. 2. 2003 H1743-322 Outburst: INTEGRAL IBIS, JEM-X and SPI common spectra in different states of the source outburst (from Capitanio et al. 2005): the numbers on the top of each spectrum indicate the revolution number of the corresponding INTEGRAL observation. Rev. 53, 56 and 57-59: LHS. Rev. 60-61 HIMS/SIMS. Rev. 103: HSS. ReV. 119-120: HIMS

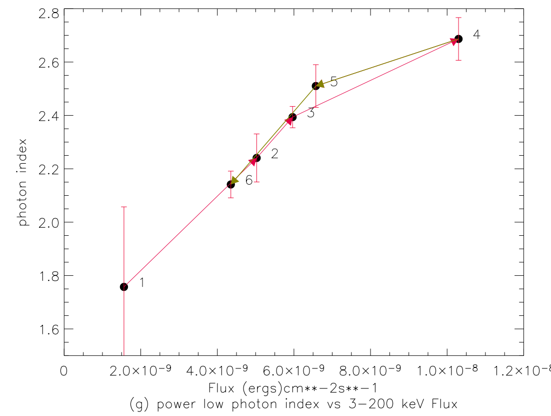

Fig. 3. 2004 outburst: photon index vs flux of the different INTEGRAL/IBIS spectra

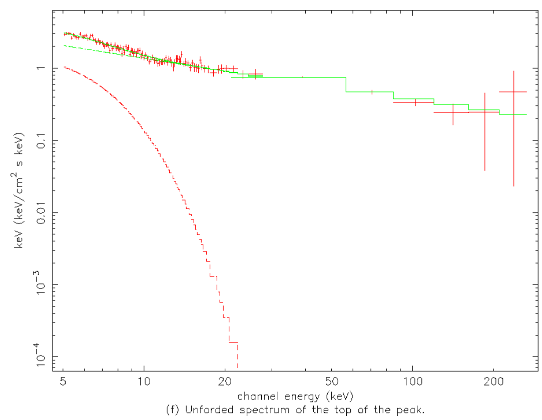

Fig. 4. 2004 outburst: softest spectrum of the INTEGRAL/IBIS data. The spectrum corresponds to the point 4 in Figure 3)

plotted in red while the January one is in blue (The different symbols of the blue curve corresponds to the same symbols in Figure 6). The January outburst was poorly observed, only RXTE collected some data of the final part of the outburst. Instead the October outburst was densely observed by Swift, RXTE and INTEGRAL. The January outburst, even if observed by RXTE only in the final part, seemed to follow the canonical q-track in the hardness-intensity diagram (Chen et al. 2010, Motta et al. 2010). While the October 2009 outburst was quite short and fainter in the 2-10 keV energy range. Figure 5 shows Swift/BAT, INTEGRAL/IBIS and RXTE/PCA light curves of the October 2008 outburst: the source flux above 10 keV remains quite important during all the outbursts, even if there is an sharp increase of the soft flux in the PCA light curve, the hard light curve does not decrease. However in the Hardness-Intensity diagram the PCA flux increasing corresponds to a moderate softening. Looking also to the ASM and BAT light curves of Figure 8 it is clear that the hard part of the outburst is dominant respect to the soft one. The timing analysis (Capitanio et al. 2009) confirms that the softening reach only the HIMS. Thus this outburst did not complete the canonical "q-track" diagram.

Until now all black hole transients have shown two types of behavior: after the initial LHS, most of the sources show a transition to the HIMS at a luminosity level which is always different and probably related to the previous history of the transient (Yu et al. 2007). If this transition takes place, the source always reaches the HSS. However, a few sources never leave the LHS at all as

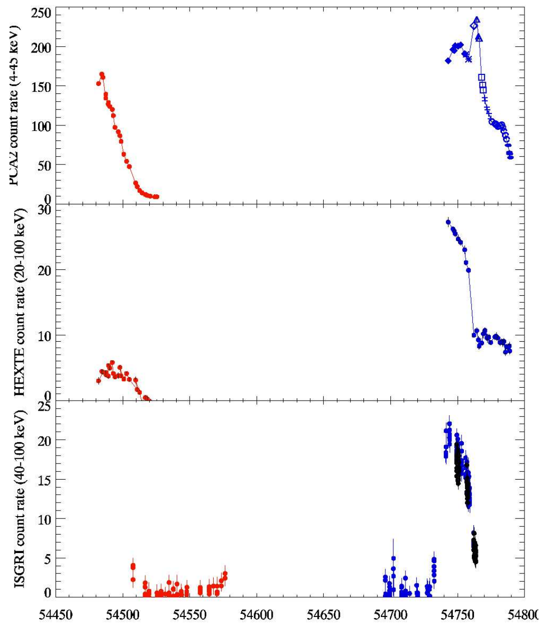

Fig. 5. Light curves in different energy ranges of the two 2008 outbursts: January light curve in red and October one in blue.Top panel: RXTE /PCA (4-45 keV), the different symbols of the blue curve corresponds to the same symbols in Figure 6. Middle panel: HEXTE (20-100 keV). Bottom panel: IBIS/ISGRI (40-100 keV)

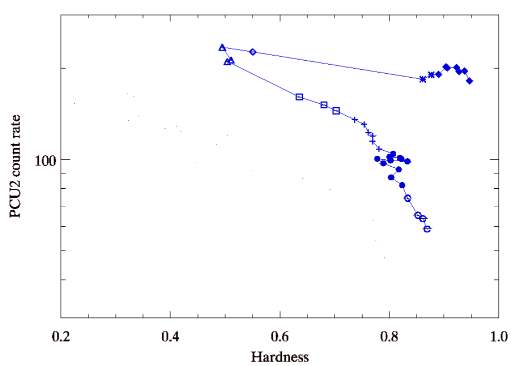

Fig. 6. RXTE /PCU2 hardness-intensity diagram (HID) of the October 2008 outburst of H1743-322. The different symbols of the blue curve are associated with the light curve in Figure 5

reported, for example by Brocksopp et al. (2004). The only two exceptions are represented by both the 2001 outburst of SAX J1711.638 (Wijnands & Miller 2002) and this outburst of H1743-322 (Capitanio et al. 2009).

3. Near-IR observations in the Ks band during the 2009 outburst

We have obtained near-infrared images in Ks -band on June-06-2009, near the last part of the outburst of May, and on August-29-2009 during a quiescent phase. The images were taken with the Persson's Auxiliary Nasmyth Infrared Camera (PANIC) attached to the Magellan Baade 6.5m telescope at Las Campanas Observatory. The images were calibrated using standard stars in use at Las Campanas Observatory.

Figure 7 show two Ks images of H1743-322 taken near the outburst end (right panel) and in a quiescent phase (left panel). The Ks flux decrease by a factor 5,6 during the two stages. In addition the Ks -band magnitude (Ks= 17.05) observed at the end of the outburst is in agreement with the value observed by McClintock et al.(2009) during the quiscent phase in May 2006.

4. The Outbursts Recurrence

The eight outbursts of H1743-322, that have been detected from 2003 until 2010, recurred regularly with a quasi periodic behavior. A similar behavior has been observed before also in another BHC, 4U1630-47. This source undergone in quasi-periodical outbursts in a period that covers about 23 years: from 1969 until 1992 (Parmar et al. 1995).

The recurrence period of H1743-322 decreased drastically between the first 3 outbursts and the last four, insomuch that it is possible to find two different recurrence periods: P1 = 377 $\pm$19; P2 = 221 $\pm$5 (P1 is approximately twice P2). The two recurrent periods are divided by a long period of quiescence (about 2P1). However an increasing of the flux in both ASM and BAT light curve was marginally detected in the period MJD=54100-54200. This detection is compatible with P2 but unfortunately the analysis of the few INTEGRAL/IBIS data available during this period do not confirm the detection. Figure 8 shows the light curves of three different X-ray and soft γ-ray monitors: RXTE/ASM, Swift/BAT and INTEGRAL/IBIS, where the two groups of outbursts with different recurrence period are also marked in different way.

5. Conclusions

The IR campaigns performed until now (see also McClintok et al. 2009) did not follow the behavior of the source during an entire outburst, thus it is not possible to extrapolate any conclusions about the IR/X-ray correlation as for example reported by Homan et al. 2005b for GX 339-4. Anyway the extremely faint IR emission during quiescent state supports the hypothesis of a faint companion star, thus a LMXB system.

Even if H1743-322 is considered a typical transient BHC, its characteristics make this source as peculiar case. The second 2008 outburst, for example, took place at low luminosity (L=0.1 L_{Edd}) and did not show any soft-state transitions. This can be probably connected to a premature decrease of the mass accretion rate emphasizing one of the important key questions about the

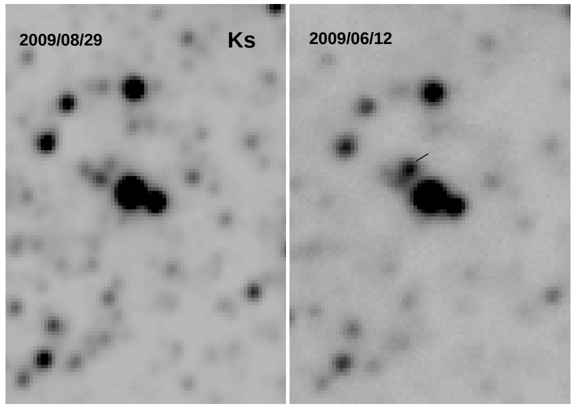

Fig. 7. Ks-band images of H1743-322 observed during the quiescent phase the source (left panel) and in the last part of the outburst (right panel). The source is marked with a line on the right panel. North is up and east is left.

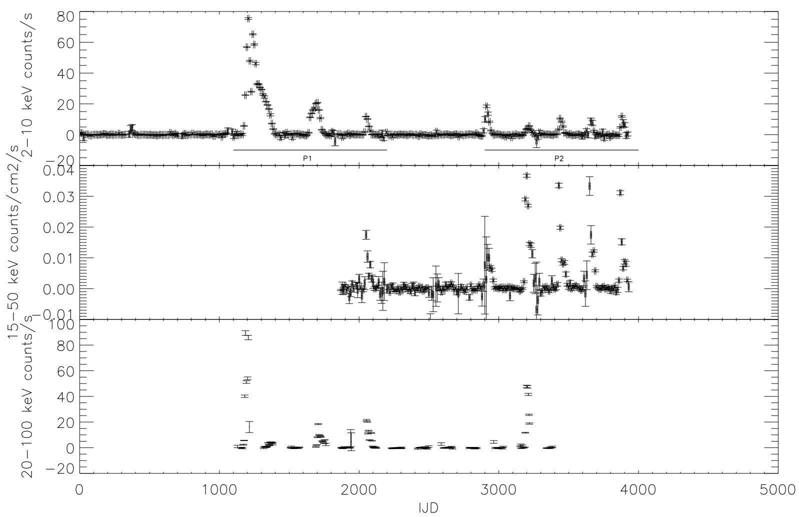

Fig. 8. Light curves of H1743-322 from 2003 until 2010 detected with three different X-ray Monitors. Top Panel: 2-10 keV RXTE/ASM light curve. Middle Panel: Swift/BAT 15-50 keV light curve. Bottom Panel: INTEGRAL/IBIS 20-100 keV light curve

outburst evolution: the nature of the physical parameter that determines the transitions.

Another peculiarity of this BHC is the quasi-periodical outbursts. It is possible that this behavior is due to the companion star characteristics (the nature of the H1743-322 companion star is still not well established), however the fact that the first period is about twice the second and even the long period of quiescence between the third and the fourth outburst 2005-2007 is about a multiple of P1, could be a connection with the orbital period of the system. Especially for P2 the phase is maintained strictly all over the last four cycles. It is worth to know that in the last four outburst, there is a correlation between the time delay between an outburst and the subsequent one and their intensity peak in the BAT and IBIS light curves (see middle and bottom panels of Figure 8). This behavior is in agreement with the empirical rule reported by Yu et al. 2007. In fact the waiting time between the last four outbursts is strictly the same (with only 5 day of error) and thus the luminosity peaks of the LHS is mostly of the same order of magnitude in the four outbursts. In this proceeding we pointed out the peculiarity of H1743-322 and in this framework we consider interesting the recent results reported by Coriat et al. 2010 on X-ray/radio correlation should be at least mentioned.

The authors acknowledge the financial support from the agreement ASI-INAF via contracts I/033/10/0 and I/009/10/0.

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