THE X-RAY NOVA H1743-322: THE LATE 2008 OUTBURST, AND COMPARISONS WITH PREVIOUS ONES

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We study the X-ray properties of the Black-Hole Candidate H1743−322. This source has undergone 5 outbursts of various amplitudes during the past 5 years. We analyse the 3-200 keV spectra from simultaneous INTEGRAL and RXTE observations, and follow its spectral evolution during its late 2008 outburst. We also used the timing capabilities of *RXTE* to look for QPOs in the lightcurves of this source. Using these data, we focus on the possible links in the evolution of the accretion disc and the corona of H1743−322. First, we detect an important evolution of the QPO frequency over the outburst. Under the common hypothesis that the frequency of QPOs are determined by the accretion disc, this indicates an evolution in the radius of the inner accretion disc. Then, we see a strong correlation between the QPO frequency and the photon index. Since the photon index depends directly on the characteristics of the corona, this indicates a strong link between the behaviours of the accretion disc and of the corona.

1 Introduction

Low-Mass X-ray Binaries (LMXB) are binary systems consisting of a compact object orbiting a non-degenerate low-mass star. These systems spend most of their time in a faint quiescent state, when they are barely detectable. They may undergo sudden and bright few-month-long X-ray outbursts with typical recurrence periods of many years [1]. The picture commonly accepted to explain the emission of such objects involves the emission of an optically thick and geometrically thin accretion disc, mostly emitting at typical energies of $\sim$1 keV. A second medium is detected as a power law spectrum in the $\sim$10 keV-1 MeV range. This medium of unknown geometry is called a "corona", and is probably composed of hot electrons where soft X-ray photons originating in the disc undergo inverse Comptonization. In addition, a relativistic jet, usually detectable in the radio range, might be present.

Depending on the relative strengths of these media, we can distinguish several spectral states [2,3]. The two main ones are the High Soft State (HSS), dominated by emission from the accretion disc, and the Low/Hard State (LHS), dominated by non-thermal emission. Further states have been identified as "Intermediate", depending on the details of the spectral and temporal characteristics. These features are coupled to radio changes, a compact jet being usually observed in the LHS while it is quenched in the HSS [4].

The X-ray transient H1743−322 was discovered during a bright outburst that occurred in 1977 with the *Ariel V* and *HEAO I* satellites [5]. In 2003, another bright outburst was detected with *INTEGRAL*, and has been deeply studied at all wavelengths[6,7,8]. It was shown in particular that H1743−322 had a behaviour consistent with most black-hole X-ray transients, and was, thus, classified as a Black-Hole Candidate. This 2003 outburst was followed by weaker episodes in 2004, 2005, in early 2008 [9] and in late 2008 [10].

Herein, we first present the results of the X–ray coverage of the source in late 2008, focusing on the evolution of the accretion disc. Then, we compare the variability of the source to the well-studied 2003 outburst, and try to link the evolution of the accretion disk to that of the coronal medium.

2 Available data and quick reduction description

Between 2008 September 23 [11,12] and 2008 November 19, INTEGRAL and RXTE observations of H1743−322 occurred almost every second day, while at softer X-rays, Swift (XRT) and XMM/Newton respectively provided 3 and 1 observations. All these data were reduced in a standard way. The *INTEGRAL* data were reduced using the `Off-line Scientific Analysis (OSA)` v7.0 software package, *RXTE* and *Swift*/XRT observations were reduced with the `HEASOFT` v6.5 software package, while *XMM/Newton* ones were reduced with the Science Analysis Software, `xmmsas`, v7.1 [10]. We use these data to follow the source in late 2008 from ∼1 keV to ∼200keV.

We also used the timing capabilities of *RXTE* in our analysis, and analysed light curves covering the five outbursts since 2003. We extracted high time resolution light curves from the PCA EVENT data with ∼500 μs resolution. We then produced power-density spectra (PDS) in the frequency range 0.0156–1024 Hz.

3 The late 2008 outburst

During the last outburst of H1743−322 to date, the source underwent two short spectral transitions. It began its outburst in a pure Low Hard State, then transited into a Hard Intermediate State (HIMS), and eventually went back into LHS [10]. This means that for a few days, the coronal flux decreased significantly, but the source did not reached Soft States dominated by emission from the accretion disc. In other words, and following the standard scheme, the accretion rate stayed well below the Eddington limit during the entire outburst. This makes the late 2008 outburst the fourth Hard outburst since 2003.

Using *RXTE*, we looked for Low Frequency Quasi Periodic Oscillations (LFQPOs) in the lightcurves of H1743−322. LFQPOs are present in many microquasars, mainly during states dominated by coronal or jet emission [13]. Although the precise origin of these oscillations is still unknown, QPOs are thought to be generated in the inner parts of the accretion disc. This idea stems from the fact that their frequencies are similar to the keplerian frequencies of the disc, and their evolution is correlated to the disc behaviour [14,15]. The theoretical attempts to model QPOs rely mainly on hot spots, or instabilities propagating inside the disc.

Fig. 1, left, shows the evolution of the QPO parameters over the late 2008 outburst. In the first part of the outburst, in all observations before MJD 54760, a strong QPO with its first harmonic is present. Then, during the HIMS, the QPO frequency increases dramatically, before slowly decreasing during the second LHS. This evolution in the QPO frequency is of particular interest. Indeed, if we suppose that the QPO frequency is somehow related to the Keplerian rotation frequency, then the increase in frequency can be interpreted as a movement of the inner part of the disc. Indeed, if the inner part of the disc moves in, the rotation frequency increases, and thus so does the QPO frequency. After the transition to the HIMS, when the QPO frequency increases dramatically, this would indicate that the disk had moved further inwards. Unfortunately, H1743−322 was not bright enough to enable the inner radius of the accretion disc to be determined precisely using spectral models.

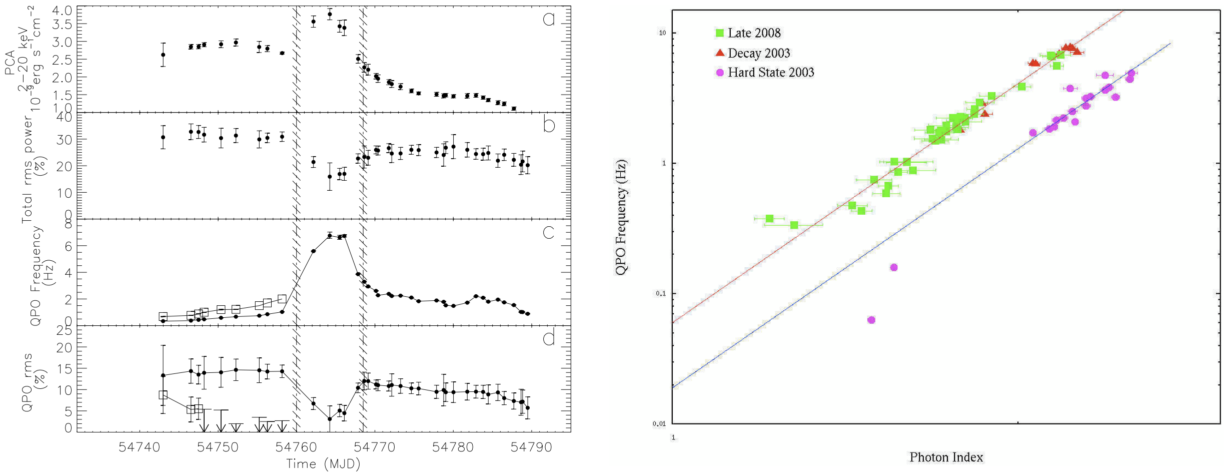

Figure 1: **Left:** Spectral and timing characteristics of H1743−322 over its late 2008 outburst. From top to bottom, **a)** lightcurve in the 2–20 keV bend, **b)** total rms power, **c)** frequencies of the two detected QPOs and **d)** rms power of these QPOs. The filled zone marks the spectral transition from the Hard State (HS) to the Hard Intermediate State (HIMS). Error bars are at the 90% confidence level. **Right:** QPO frequency as a function of the X-ray photon index, during Hard States of H1743−322. The two parallel lines are fits to the rising phase of the 2003 outburst, and to the combined decay phase of 2003 and late 2008 outburst. Between the two tracks, the QPO frequency is multiplied by 3.

4 QPO frequency / Photon index correlation

In recent years, a correlation between the QPO frequency and the photon index has also been detected in several Black-Hole Candidates [16]. The photon index is, in microquasars, characteristic of the Comptonized component that forms the corona. If now the QPO frequency is set by some disc property, then this correlation provides a strong link between the inner parts of the disc and the corona.

In the case of H1743−322, we plotted the frequency of QPOs during Hard States, versus the photon index of the Comptonized component (Fig. 1, right). QPOs were detected during the 2003 and late 2008 outbursts only. During the first Hard State of the 2003 outburst, that corresponds to the rising phase, these two parameters are linked by a power-law correlation (purple points on Fig. 1, right). Then, during the decay phase of this outburst, and during the late 2008 Hard outburst, the source follows a second track, with the same slope. Both tracks are parallel, and the intercept is multiplied by 3 between them.

The correlation between QPO frequency and photon index reveals the parallel evolution of the disc and coronal medium in H1743−322, and confirms similar results on other microquasars. However, contrary to previous observations, we detect two distinct tracks. Note that these tracks arise from observations separated by several months, but correspond to very similar spectral characteristics. This is an unexpected result, and we can only make assumptions to explain it.

An explanation for the presence of these two distinct tracks may reside in the physics of QPOs. Indeed, QPOs are known to sometimes appear together with harmonic frequencies. H1743−322 itself showed pairs of low frequency QPOs in 2003 [13] and late 2008 [10], composed of a fundamental oscillation and its first harmonic. In this respect, the two distinct tracks may come from the same oscillation that amplifies two different harmonics, depending on the initial conditions.

Theoretical models, such as the Accretion-Ejection Instability [17] (AEI), do explain QPOs. In this model, a spiral shock could result from the non-linear evolution of the AEI, just as the gas forms shocks in the arms of spiral galaxies. In some cases, several arms can develop, which explain the presence of several harmonics. The name of this instability relates to the fact that, if the disk is covered by a low-density corona, a sizable fraction of the accretion energy extracted from the disk can end up in Alfvén waves emitted by the instability in the corona, where they might energize a jet [18]. However, this model do not predict that the fundamental mode of a QPO could be quenched, while its second harmonic becomes dominant. Thus, this observation, if confirmed in the case of other microquasars, can prove to be a strong constraint on disc models.

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