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Author(s):

Konstantin N. Borozdin, William C. Priedhorsky, Mikhail G. Revnivtsev, Artem N. Emelyanov, Sergey P. Trudolyubov, Lev G. Titarchuk, and Alexey A. Vikhlinin

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Observations of some X-ray transients with RXTE

Konstantin N. Borozdin*, William C. Priedhorsky*, Mikhail G. Revnivtsev**, Artem N. Emelyanov**, Sergey P. Trudolyubov**, Lev G. Titarchuk†, and Alexey A. Vikhlinin††

*NIS-2, Los Alamos National Laboratory, Los Alamos, NM 87545
**Space Research Institute, 117810 Moscow, Russia
† Goddard Space Flight Center, Greenbelt, MD
†† Harvard-Smithsonian Center for Astrophysics

Abstract. We present results of observations of several X-ray transients with RXTE in 1996-1998, namely, GRS 1739-278, XTE J1748-288, GS 1354-64, 2S1803-245 and XTE J0421+560 (CI Cam). We studied light curves and spectra of their outbursts and compared them with observations of other X-ray transients. We discuss fits of high state spectra with BMC model, and similarities and differences between black holes and neutron stars in their low state. Special attention is paid to CI Cam as possible legate for new class of X-ray transients.

INTRODUCTION

Many X-ray binaries with low mass companions (typically K or M dwarf) are characterized by episodic irregular X-ray outbursts. The recurrence time for most of these systems is estimated to be 10-100 years. The typical duration of an outburst is several weeks, but some outbursts last just few days, while some other sources remain bright for years after an initial outburst. Because the time of the outburst cannot yet be predicted, data from X-ray all-sky monitors (ASM) are used to trigger multi-wavelength studies. In recent years most outbursts of X-ray transients were initially detected by ASM on-board Rossi X-ray Timing Explorer (RXTE) satellite [1]. Several examples of the outbursts observed with ASM/RXTE are shown in Fig. 1. LMXB transients are of special interest because most reliably identified black hole binaries belong to this class [2]. During an outburst, the flux from such source varies by orders of magnitude, typically accompanied by dramatic changes in spectral shape. These sources are natural laboratories for studying of mass accretion onto the compact object in very different regimes. Here we present some results obtained from RXTE observations of several X-ray outbursts.

UNUSUAL VERY HIGH STATE IN BLACK HOLE X-RAY TRANSIENTS

Many black hole X-ray transients demonstrate common evolution pattern during their outbursts with several typical states and transitions between them. We studied this pattern recently for XTE 1748–288 [3] and before - for KS 1730-312 and GRS 1739-278 [4–6]. Light curves of GRS 1739-278 and XTE 1748–288 (Fig. 1 - upper left and bottom right panels) were of FRED type [7]. XTE 1748–288 was observed by RXTE in *very high*, *high* and *low* spectral states, typical for black hole systems (Fig.2). During several observations corresponding to the peak X-ray flux, the spectrum of the source was in an unusual VHS, with a very bright hard component. Similar spectra were detected at the beginning of the outbursts of X-ray black hole Novae GS/GRS 1124–68 [8,9], KS/GRS 1730–312 [4,5] and GRS 1739–278 [6]. One may consider this spectrum to be representative of a new state or sub-state in black hole X-ray transients.

We studied the relationship of the spectral and temporal properties of XTE J1748–288 in its VHS [3]. The general correlation between the main parameters describing the power density spectrum of the source was observed. Most striking is the established close relation between the evolution of the spectral and timing parameters of the source. In particular, there is a clear trend of increasing the QPO centroid frequency with rise of the soft component flux. This type of correlation holds on the wide range of time scales from seconds to several days.

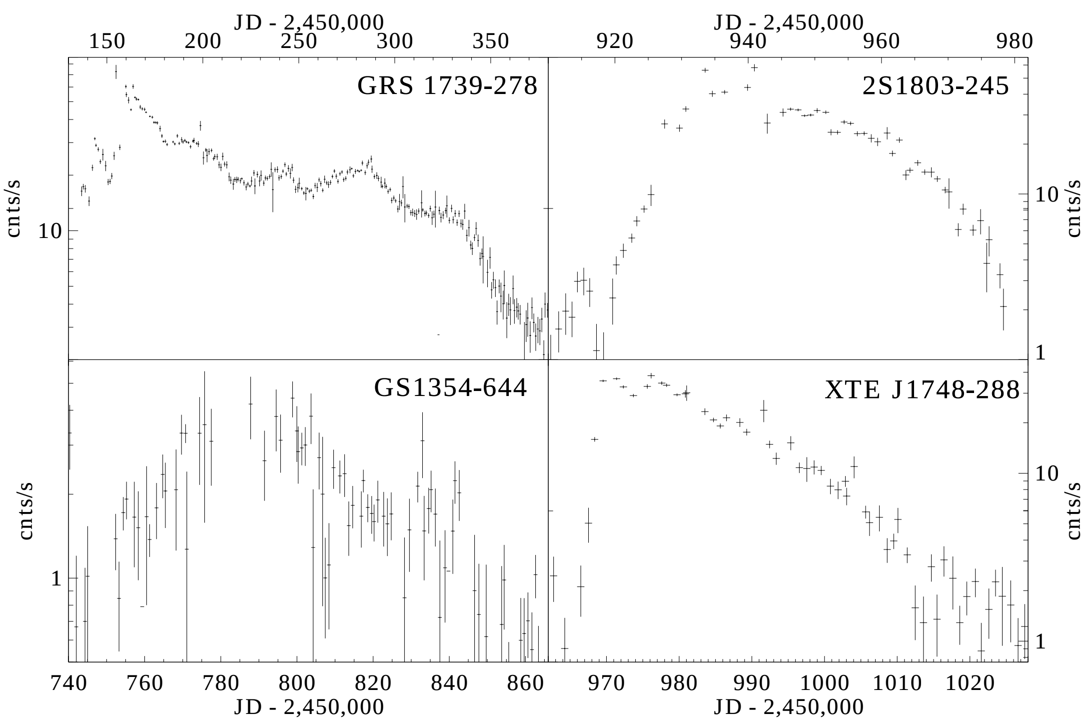

FIGURE 1. Some outbursts of X-ray Novae detected with ASM/RXTE.

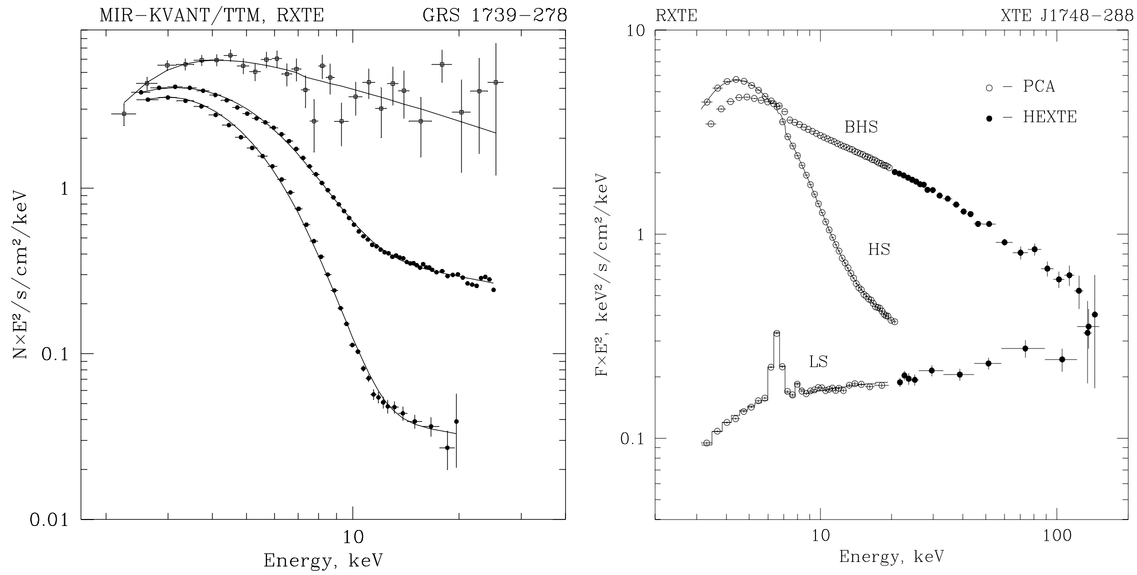

FIGURE 2. Typical broad-band energy spectra of GRS 1739–278 [6] and XTE J1748–288 [3] during the different stages of their outbursts: BHS – bright hard state (VHS), HS – high state and LS – low state. Upper spectrum on left panel taken with Mir-Kvant, two lower - with RXTE. Hollow and filled circles on right panel represent the data of PCA and HEXTE instruments respectively.

HIGH STATE

In *high* state black hole (BH) and neutron star (NS) binaries exhibit qualitatively different spectra. Neutron star binaries spectra have a soft thermal component characterized by color temperatures $\simeq 1 - 2$ keV, which is interpreted as radiation emanating from the neutron star surface and/or boundary layer. In the BH case we observe a thermal component from accretion disk and an additional hard power law component dominating at energies higher than 10–20 keV. One of the possible explanations for the origin of this hard emission is offered by *Bulk Motion Comptonization* model [10,11]. In this model hard X-ray emission is generated by up-scattering of soft X-ray photons on relativistic electrons rushing into black hole. This model is explaining the difference in spectra of BH and NS binaries in *high* and *very high* state. The application of BMC model to spectra of several black hole transients observed by the RXTE showed that the model is able to fit the spectra [12].

LOW STATE

Low state spectra for BH and NS binaries are very similar. We observed *low* state with RXTE from BH transients XTE J1748–288, GS 1354–64 [3,17], and from NS transient 2S1803–245 [13]. The overall power-law-with-high-energy-cutoff spectral shape may be approximated in each case by Comptonization models based on up-scattering of soft photons on energetic electrons in a hot plasma cloud.

The rapid time variability of the X-ray flux was in general very similar to the low/hard state of other Galactic black hole systems, such as Cyg X-1, Nova Persei 1992, and GX 339-4 [14–16]. We found that amplitude of rms variability for 2S1803–245 increased with energy. Our analysis of RXTE archival data for several sources, confirmed that an anti-correlation of fractional variability with energy is typical for Galactic black holes in their low spectral state, but a positive correlation is typical for neutron star systems in their low state [17]. This difference can be very useful for segregating neutron star binaries from black hole systems in their *low* state, which is otherwise difficult with X-ray data only.

UNUSUAL X-RAY TRANSIENT XTE J0421+560

The X-ray transient XTE J0421+560 was discovered on Mar. 31, 1998 with ASM/RXTE. The light curve of the source in 1.3-12 keV was characterized by extremely fast rise [18] with subsequent, also unusually fast decay of the flux. The observations by ASCA, BeppoSAX, and RXTE satellites showed an unusual spectrum with the strong emission line around 6.7 keV [19–21]. The optical counterpart of the X-ray source was identified as relatively close to the Sun ($\sim$1 kpc) symbiotic star CI Cam [22]. Following the detection of X-ray emission many researches suggested that compact object of the system is neutron star or black hole. The outburst however was distinctly different from any other X-ray transients. First of all it was much shorter than typical and the source returned to quiescence in few days instead of weeks or months. X-ray spectrum of the source can be described as the emission of two-temperature optically thin plasma, with prominent iron emission line around 6.5–6.7 keV and weaker, but detectable line around 8 keV [21]. Strong absorption was observed with RXTE in first two days of the outburst, but became undetectable later. The effective temperature and the center of iron line evolved with time significantly. Altogether the evolution of the X-ray spectrum can be interpreted as an emission of non-equilibrium plasma, which started inside larger cold cloud and later expanded. Radio observations started during the outburst and continued during at least half of a year after it showed the evidence of expanding quasi-spherical shell [23]. All these data confirmed that it was the first X-ray transient of such kind. The outburst somewhat resembles down scaled supernova explosion. Hopefully future observations will reveal more objects of this class and allow to understand their nature.

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