INTEGRAL OBSERVATIONS OF X-RAY PULSARS X 1845-024 AND XTE J1858+034

R.F. Doroshenko[1], **V.A. Doroshenko**[1], **K.A. Postnov**[1], **A.M. Cherepashchuk**[1], **and S.S Tsygankov**[2]

[1]*Sternberg Astronomical Institute, Universitetsky pr. 13, 119992, Moscow, Russia*
[2]*Space Research Institute, Russian Academy of Sciences, Profsoyuznaya 84/32, 117810, Moscow, Russia*

ABSTRACT

We analyze IBIS/ISGRI observations of poorly studied transient X-ray pulsars X 1845-024 and XTE 1858+034 carried out in 2003 and 2004. Light curves and spectra of the sources are constructed in the energy range 18-70 keV. For each source outbursts were detected with a flux of 13 mCrab for X 1845-024 and 111 mCrab for XTE 1858+034. The significant hard X-ray flux during the XTE 1858+034 outburst enabled measurements of the spin period of the neutron star at 220.4 s.

Key words: X-ray pulsars.

1. INTRODUCTION

X J1845-024. The transient hard X-ray pulsar X J1845-024 with a pulse period $P \simeq 95$ s was discovered by Ginga in 1988 [1]. In 1996, BATSE detected outbursts from the source with a duration ~ 13 days and maximum flux ~ 75 mCrab which demonstrated ~ 241-day periodicity [2] interpreted as the binary orbital period. Further analysis by Soffitta et al. [3] suggested that the pulsar resides in a Be/NS X-Ray binary with an eccentricity of $e \simeq 0.88$.

XTE J1858+034. This hard X-Ray source was discovered in February 1998 in the ASM RXTE data[4]. Periodic 221-s pulsations were detected in the follow-up observations with RXTE PCA [5]. In further RXTE PCA observations, the source coordinates were determined more precisely [6] and low frequency QPO (0.11 Hz) were discovered [7]. In April 2004, an outburst from the source with maximum flux ~ 15 mCrab was observed both by RXTE and INTEGRAL [8], allowing a more precise determination of the source position and spin period. Searches for an optical counterpart in the INTEGRAL/RXTE error box revealed the presence of one faint source ($B \simeq 19.6$, $V \simeq 18$, $R \simeq 17$) with H_α emission [9].

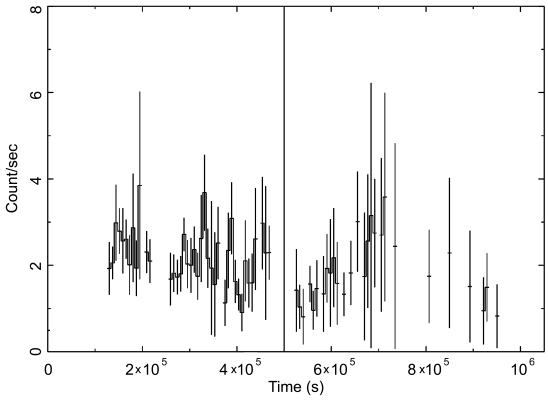

Figure 1. The 18 - 70 keV light curve of X 1845-024 in May 2003 during the outburst. Start time is MJD =12761.00.

2. OBSERVATIONS

INTEGRAL [10] surveyed the Sagittarius Arm tangent field from May 2003 to October 2004 (see Table 1) with a total exposure time of about 2000 ks. First results of the analysis of this field are published in [8, 11]. Both X-ray pulsars X 1845-024 and XTE 1858+034 fall within the fully coded FOV of the IBIS telescope [12]. In our analysis of hard X-ray emission from these sources we used both OSA 5.1 software and original programs developed for INTEGRAL data processing by the IKI group as described in [13].

2.1. X 1845-024

The light curve in the 18-70 keV energy range is presented in Fig. 1 (the May 2003 outburst) and in Fig. 2. The vertical lines correspond to the expected neutron star passages of the orbital periastron. It is seen that the May 2003 outburst occurred close to the periastron passage, while no clear outburst was detected during 2004 observations.

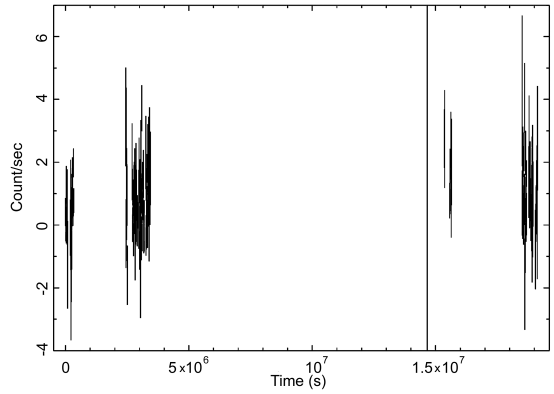

Figure 2. The 18 - 70 keV light curve of X 1845-024 in 2004. Start time is MJD = 13088.67.

The spectrum of the source (18-70 keV) during the May 2003 outburst is shown in Fig. 3. The best fit to the spectrum is given by a single power law with a photon index $\alpha \simeq 2.6$ (Table 2), which is close to the BATSE fit with $\alpha \simeq 2.6$ [2]. No high energy cut is observed.

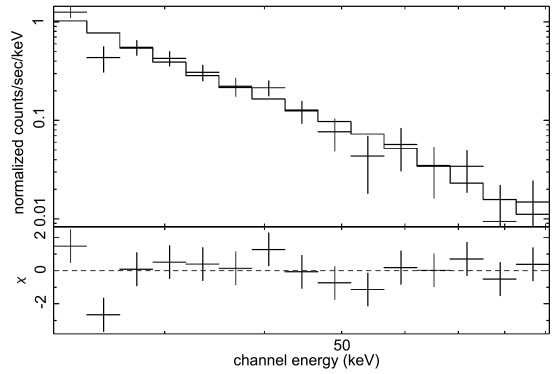

Figure 3. Hard X-ray spectrum of X 1845-024, obtained during the outburst. The shape resembles plain power-law.

2.2. XTE J1858+034

The 18-70 keV light curve of XTE J1858+034 during 2004 observations is shown in Fig. 4. A strong outburst with maximum flux 111 mCrab was detected in April 25 – May 3 2004. An insert in fig. 4 shows an outburst in greater details. Lightcurves from IBIS (18-70 keV) and JEM-X (4-18 keV) and their ratio are shown. There is no significant hardness evolution during the outburst. The broadband spectrum of the outburst is presented in Fig. 5. Best fit is given by the power law model with exponential cutoff and low-energy hydrogen absorption. Either model components are required to describe the spectra. Modeled spectra parameters are listed in the table 2. Similar spectral parameters of the outburst were independently obtained in [11]. No significant details (i.e. iron line at 6.5 keV previously reported by [7]) were found.

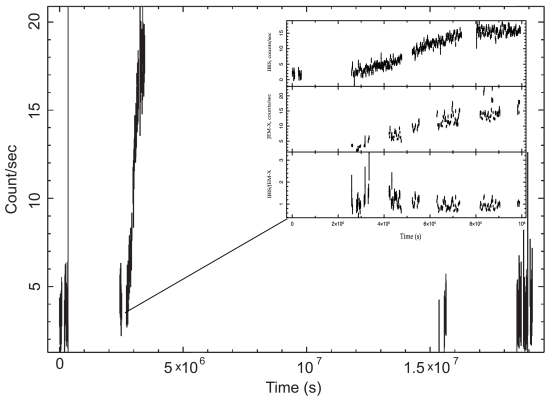

Figure 4. The 18 - 70 keV light curve of XTE J1858+034 in 2004. Start time is MJD = 13088.67.

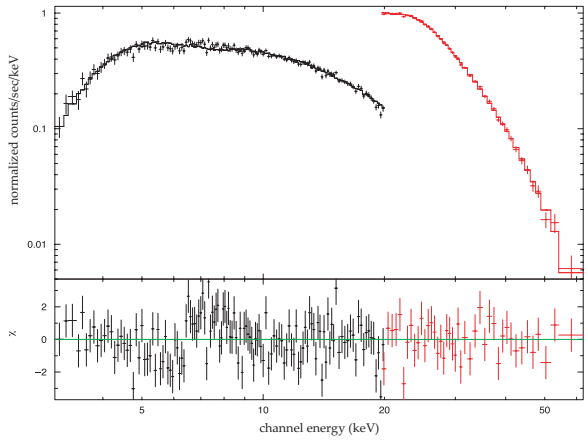

Figure 5. Broadband X-ray spectrum of XTE J1858+034, obtained during the outburst. Hydrogen absorbed power-law with exponential cut off model was used.

The significant X-ray flux during the outburst allowed us to measure the spin period of the neutron star in XTE J1858+034 to be 220.4 ± 0.3 s using the epoch folding method (Fig. 6). A series of Monte-Carlo simulations was performed to find the error of the period estimation. Period value is the same within errors with value given by [5] (221 ± 0.5 s). The X-ray pulse profile demonstrates a sine-like shape and is presented in Fig. 7.

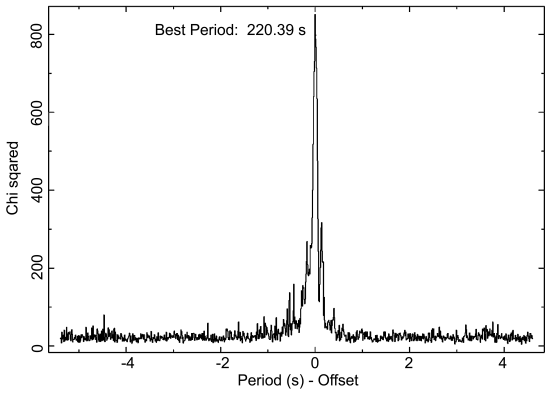

Figure 6. The periodogram of XTE J1858+034 during the outburst obtained by the epoch folding method.

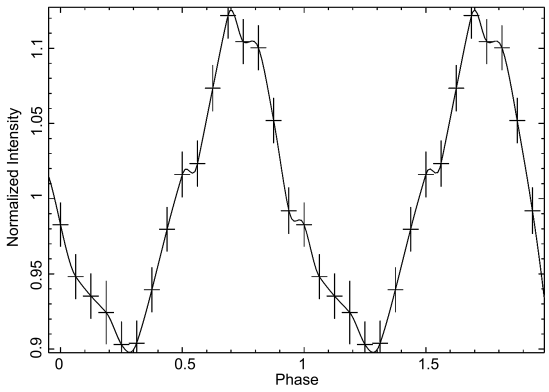

Figure 7. The 18 - 70 keV pulse profile of XTE J1858+034 during the outburst.

3. CONCLUSION

Our analysis of hard X-ray emission observed by INTEGRAL/IBIS from X 1845-024 and XTE J1858+034 in the Sagittarius arm tangent field shows that their spectral properties are common with other X-ray pulsars seen by INTEGRAL (cf. [11]). The pulse period of XTE J1858+034 is measured with higher accuracy compared to previous studies (220.4 s). We conclude that regular INTEGRAL monitoring of these transients, and especially observations of bright outbursts, is necessary to enable more detailed analysis of the evolution of their spectral properties and pulsation period.

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Table 1. INTEGRAL observations of X 1845-024 and XTE J1858+034

INTEGRAL Orbits	JD	Dates	X 1845-024 mean flux (18 - 70 keV)[1](mCrab)	XTE J1858+034 mean flux (18 - 70 keV)[1](mCrab)
0067	2452762.5 - 2452763.5	3.05.03 - 4.05.03	13.19±1.62	-
0068	2452763.9 - 2452766.5	4.05.03 - 7.05.03	11.75 ±1.12	-
0069	2452766.9 - 2452769.5	7.05.03 - 10.05.03	9.12 ±1.69	-
0070	2452770.8 - 2452772.1	11.05.03 - 13.05.03	7.81 ±3,88	-
0176	2453088.6 - 2453089.6	24.03.04 - 25.03.04	1.75 ±1.56	19.81 ±1.69
0177	2453091.0 - 2453092.6	27.03.04 - 28.03.04	4.69 ±1.36	23.12 ±1.38
0186	2453117.9 - 2453118.6	22.04.04 - 22.04.04	5.44 ±1.94	25.62 ±1.81
0187	2453120.9 - 2453122.5	25.04.04 - 27.04.04	3.38 ±0.94	36.69 ±0.75
0188	2453123.0 - 2453125.5	28.04.04 - 30.04.04	4.56 ±1.00	86.31 ±0.69
0189	2453126.5 - 2453128.5	1.05.04 - 3.05.04	5.00 ± 1.12	111.69 ±0.75
0236	2453266.5 - 2453269.5	18.09.04 - 21.09.04	17.12 ±8.19	15.94 ±4.38
0237	2453269.5 - 2453269.7	21.09.04 - 21.09.04	6.44 ±2.44	18.56 ±4.00
0248	2453302.9 - 2453304.9	24.10.04 - 27.10.04	4.69 ±1.19	23.75 ±3.62
0249	2453306.0 - 2453307.9	28.10.04 - 29.10.04	4.06 ± 1.38	21.69 ±1.19
0250	2453309.1 - 2453311.5	30.10.04 - 31.10.04	3.06 ±1.81	21.12 ±1.38

[1] 1mCrab $\approx 3 \cdot 10^{-11}$erg/(s·sm^2). Data of the revolutions 0176-0250 was not used in the analysis of the X 1845-024 due to low signal to noise ratio of the source

Table 2. Spectral parameters of X 1845-024 and XTE J1858+034 during the outbursts.

model	Photon index (α)	χ^2	${\chi_{dof}}^2$	K	N_H	E_{cut}	E_{fold}
$X\ 1845-024$: A(E) = $KE^{-\alpha}$	2.57± 0.21	14.15	1.09	0.31±0.22	-	-	-
$XTE\ J1858+034$: A(E) = $KE^{-\alpha}$ $e^{-(E-E_{cut})/E_{fold}}$ $\times e^{-N_H \cdot \sigma(E)}$	1.26± 0.08	181.75	1.05	0.09± 0.01	(9.0± 1.3)·10^{22}	26.7± 0.7	6.6± 0.3