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Flashes in Be/X-ray Binary A0535+26

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Abstract. A luminosity of the transient optical flashes of HMXB A0535+26 amounted to 1.4×10^{38} erg s^{-1}, the same order of magnitudes as a power of giant X-ray outbursts of the system. The flashes are very similar to ultrafast bright (on the timescale of 1 msec) flashes which have been detected in LMXBs in the MANIA experiment. Apparently the flashes arise as a result of non-thermal processes which excited in both type of binaries. The program of searches of the high energy optical transients among HMXBs is proposed.

A0535+26 (HDE 245770, V725 Tau) belongs to the subgroup of HMXB (high mass X-ray binaries) containing Be giant and neutron star (Liu et al. 2000). It is one of the most remarkable and well-studied objects of the North Hemisphere in the entire spectrum - from Gamma ray to infrared and radio region (see, for example, Lyuty & Zaitseva 2000; Clark et al. 1999; Giovannelli & Graziati 1992).

We started the dual-channel photometry of V725 Tau with the Mt.Dushak-Erekdag 0.8 m telescope of Odessa Astronomical Observatory (Dorokhov et al. 1995) in October - November 1995 within the framework of the Russian Ministry of Science Program "Monitoring of Unique Astrophysical Objects". On the night 28/29 Oct. 1995 we detected the very bright optical flashes of A0535+26. During the integration time (10 sec.) the star became up to 5 times brighter, then the brightness fell down to the quiescent level, and then next pulses followed. There were occurred about 300 flashes during 1.7 hours, afterwards the star turned into the quiescent state. The figures and detail description of the phenomenon have been presented in IBVS (Dorokhov & Dorokhova 1996).

For comparing of the flashes' energy with the energy of X-ray outbursts we estimated a mean luminosity of the star for the used Johnson's B filter as $\sim 3 \times 10^{37}$ erg/sec, taking into account that the star of 9 mag is at a distance of 2.6 kpc. The luminosity of the star at the outburst's maximum run up to $\sim 1.44 \times 10^{38}$ erg/sec by factor 4.79 brighter than in a quiescent state.

The value is comparable with the estimation of the Feb-March 1994 'giant' X-ray outburst of A0535+26 amounted to $L_x \approx 1 - 1.5 \times 10^{38}$ erg/sec (Borkus et al. 1998). Thus the object's luminosity in the maximal 'blue' optical flash was the same order of magnitudes like a luminosity at the maximum of a 'giant' in X-ray outburst (Dorokhova & Dorokhov 2000). At the same time the energy output of a 'giant' in X- ray outburst was higher by the 2 - 3 order of magnitudes than one of the optical transients taking into account that $L_{opt}/L_x \approx 10^3$ in a quiescent state.

Table 1. The list of Be/X-ray binaries for observations

object	Opt.Ctp.	α(2000)	δ(2000)	V mag	Sp.type
A0535+26	V725 Tau	05 38 55	+26 18 57	8.9-9.6	O9.7IIIe
4U 0352+309	X Per	03 55 23	+31 02 45	6.0-6.6	B0III-Ve
J0146.9+6121	V831 Cas	01 47 00	+61 21 24	11.33	B1Ve
4U 0728-25	V441 Pup	07 28 54	-26 06 28	11.6	O8-9Ve
4U 0115+63	V635 Cas	01 18 32	+63 44 24	14.5-16.3	B0.2Ve

We searched and requested the information concerning:

1) other optical observations in interval TJD 50019.45 - 50019.55 of the flashes' appearance. Although in that time the star was actively observed at the Tien-Shan and Crimean Observatories it was not observed just at this interval.

2) the X-ray behavior of A0535+26 on that time. However none of well-known cosmic laboratories: Mir-Kvant (Borkus et al. 1998), CGRO (Wilson 2000) and ASCA (Nagase 1999) - have not detected the source in Oct - Nov 1995.

In spite of almost 30 years of systematic photoelectric observations the similar phenomena were not described in the previous history of the star. Possibly, observers related such pulses to instrumental errors. We revealed only a very brief report by Urasin and Shaimukhametov (1987) about the short-time optical flashes with amplitudes 2-3^m and duration 0.2 - 0.3 sec. Their individual flashes are very similar to the flashes observed by us taking into account that their time resolutions were 0.1 sec. and 0.05 sec (respectively by the factor of 100 and 200 higher than our resolution). The luminosity of their flashes is $\sim 10^{39}$ erg/sec.

Since we had low time resolution one might assume that every flash of our observations was a series of very fast but merged and smoothed pulses. That is the power of the composing unsmoothed pulses should achiev much higher level. The profiles of the pulses were not resolved even with the 0.05 sec resolution, evidently, the processes were more fast. The nonthermal nature of both phenomena is obvious because the bottom level between the flashes was stable and equal to the brightness of the object in a quiescent state.

In this connection it should remain the results of the MANIA (Multichannel Analysis of Nanosecond Intensity Alterations) complex (see Beskin et al. 2000 and references there) in searching with a time resolution of 10^{-7} sec for ultrafast optical variability among some LMXBs (low mass X-ray binaries). Beskin et al. (1994), Bartolini et al. (1994) detected stochastic flashes on a timescale from 10-20 ms to 200 s. Brightness of the MXB 1735-44, for example, increased approximately in 15 - 30 times during the most strong of these flashes with very steep forward fronts (characteristic rising time being $\sim$ 50 - 60 msec), displaying a fine structure on timescales of $\sim$ 5 - 6 msec. Brightness temperatures rose to 10^{10° K thus it may be explained only by non-thermal processes. LMXBs were chosen for MANIA experiment because the normal component is faint enough and does not screen the optical radiation of accreting plasma. However the observed flashes of A0535+26 have been shown that these non-thermal processes might be much more powerful in the high mass Be/X-ray binary.

Possibly the specific conditions have been created in the system and 2 important factors can promote for this:

1) the pulsar A0535+26 has the largest magnetic field for this class of objects, 2×10^{13} G (Lipunov & Popov 2000).

2) the observations in X-ray region testify to the different regimes of accretion in this system and the changing of an accretion rate more than by factor of 20 (Borkus et al. 1998).

We have assumed that the flashes arise in the disk-fed around the neutron star in the system A0535+26 (Dorokhova & Dorokhov 2001). It may be proved theoretically in the magneto-flaring accretion scenario (Galeev et al. 1979). The optical radiation is generated by dissipation of magnetic fields of accretion structure. It could excite the non-thermal optical flashes on timescales of 10^{-6} – 10^{-4} sec with extremely high brightness temperature (Shvartsman et al. 1989).

Table 2. Basic parameters of the objects.

object	$P_s(s)$	$P_{orb}(d)$	Dist.	$QscL_x$	$MaxL_x$	B(G)
A0535+26	103	111	2.6	2×10^{35}	2×10^{37}	2×10^{13}
4U 0352+309	835	250.3	0.7	2×10^{34}	10^{35}	
J0146.9+612	1404.2	large	2.3	4×10^{34}	5×10^{35}	
4U 0728-25	103.2	35	6	3×10^{35}	10^{36}	
4U 0115+63	3.61	24.3	6	10^{36}	10^{38}	1.1×10^{12}

We continued the searches of such transient flashes of A0535+26. Unfortunately we had a very short observational time at the Mt.Dushak-Erekdag telescope because of financial difficulties in Ukraine. We proposed to some other observers and the persons of MANIA team to observe the object with a high time resolution. It should extend a scope of the searches and add other HMXBs since, possibly, V725 Tau has no conditions for the appearance of optical transients at present. According to Lyuty & Zaitseva (2000) the active phase of Be star had finished to 1998, and Be-giant became normal B star without dense envelope. It is still a question when the necessary conditions will arise once more.

Im table 1 we propose for the North Hemisphere observatories the list of objects which are interesting for searching of transient optical flashes: column 1 - the name of the pulsar; 2 - optical counterpart according to GCVS (Kholopov et al. 1985); 3, 4 - right ascension and declination, 5 - range of V magnitudes' variations, 6 - Spectral type.

In table 2 the basic parameters for each object are given: spin-period of the pulsar; orbital period; distance; X-ray luminosity in quiescent state and the approximate luminosity during the giant outbursts; magnetic field. The data were extracted mainly from the Catalogue of high-mass X-ray binaries (Liu et al. 2000), the paper of Negueruela (1998) and the electronic catalogue of Sergei Popov (http://xray.sai.msu.ru/ polar/html/publications/cat/x-ray_n2.www).

To present time we could find only a couple of the magnetic field's estimations for these sources, although this characteristic is very important. Really

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every object of this class is unique, and it is very difficult to find the similar objects. It seems V441 Pup (LS 437, 4U 0728-25) is more similar to V725 Tau.

In conclusion we would like to cite from the initial talk of this Symposium: "Unexpected discovery can be important and even revolutionary" (Hurley 2002).

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