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The Giant Radio Flare of Cygnus X-3: Predictions Come True

Sergei Trushkin, N. Nizhelskij, P. Tsybulev, G. Zhekanis **satr@sao.ru, SAO RAS, Nizhnij Arkhyz & Kazan Federal University, Russia**

In the long-term multi-frequency monitoring program of the microquasars with RATAN-600 we discovered the giant flare from X-ray binary Cyg X-3 on 13 September 2016. It happened after 2000 days of the 'quiescent state' of the source passed after the former giant flare (∼18 Jy) in March 2011. We have found that during this quiet period the hard X-ray flux (Swift/BAT, 15-50 keV) and radio flux (RATAN-600, 11 GHz) have been strongly anti-correlated. Both radio flares occurred after transitions of the microquasar to a 'hypersoft' X-ray state that occurred in February 2011 and in the end of August 2016. The giant flare was predicted by us in the first ATEL #9416. Indeed after decrease of the hard X-ray 15-50 keV flux and 4-11 GHz fluxes (a 'quenched state') a small flare (0.7 Jy at 4-11 GHz) developed on MJD 57632 and then on MJD 57644.5 almost simultaneously with X-rays radio flux rose from 0.01 to 15 Jy at 4.6 GHz during few days. The rise of the flaring flux is well fitted by a exponential law that could be a initial phase of the relativistic electrons generation by internal shock waves in the jets. Initially spectra were optically thick at frequencies lower 2 GHz and optically thin at frequencies higher 8 GHz with typical spectral index about -0.5.

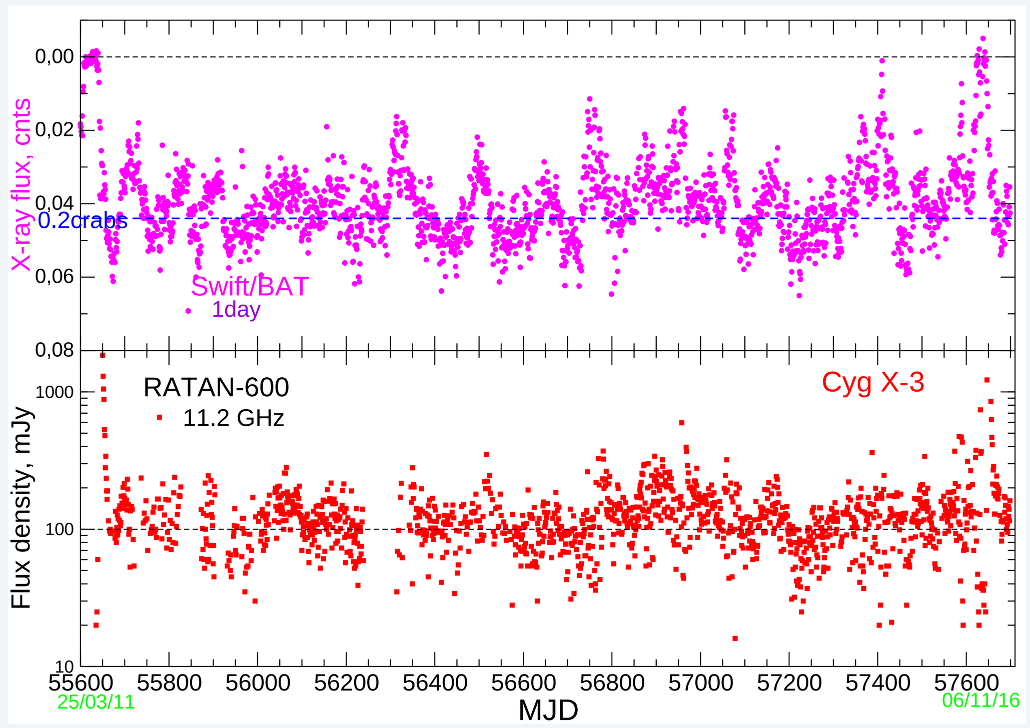

Fig.1: The light curves of Cyg X-3 at 11 GHz and at 15-50 keV during 2011-2016. For the best comparison the axis of X-ray fluxes is directed downwards.

The X-ray transient source Cyg X-3 was discovered in by Giacconi,+ (1967). In 1972 in the first time the giant flares have been detected by B. Greqory and later 22 papers about these events were published in special issue of Nature. A such flaring behavior were detected a lot of time since 1972 (Waltman,+ 1996) indicating the recurrent activities of relativistic jets. Thus Cyg X-3 was recognized as a microquasar, the X-ray binary, consisted of a black hole (or a neutron star) and orbiting (P=4.8h) with a Wolf-Rayet star. The source is observable at X-rays, gamma-rays and IR waves. Cyg X-3 was detected in very high gamma-rays. (AGILE: Tavani,+ 2009, Fermi: Abdo,+ 2009)

The VLBI mapping shows a jet-like structure during flares (Miller-Jones,+ 2004). The microquasar have been daily monitored from February 2011 to October 2016 at four frequencies with the RATAN-600 radio telescope.

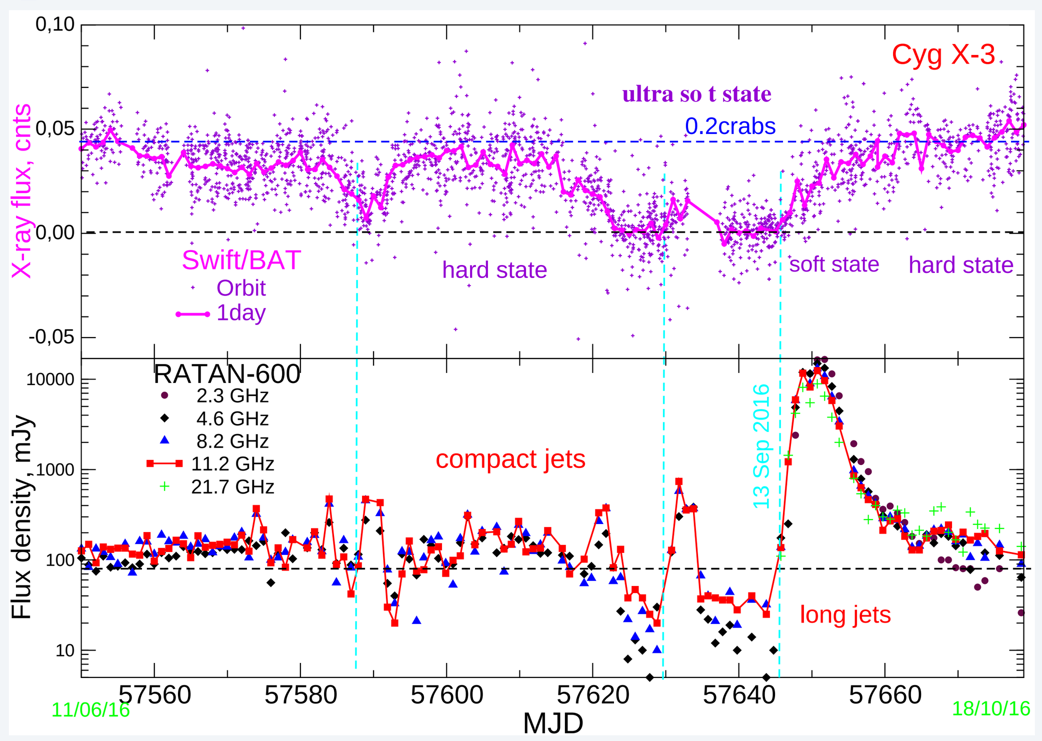

Fig.2: Light curves before or during the flare at X-ray 15-50 KeV (top) and the multi-frequency data of the RATAN measurements.

Almost 2000 days of the 'quiescent state' of the Cyg X-3 have passed after the former giant flare (~ 18 Jy) in the end of March 2011. We have detected it with RATAN-600 at 2.3-30 GHz. We have found that during this quiet period the hard X-ray flux (Swift/BAT, 15-50 keV) and radio flux (RATAN-600, 11 GHz) were strongly and anti-correlated ($\rho = -0.85$) (Fig.1). The nature of this regression could be related with properties of the compact radio jets, forming during such 'quiescent' state and strongly depending on an accretion rate on to a black hole.

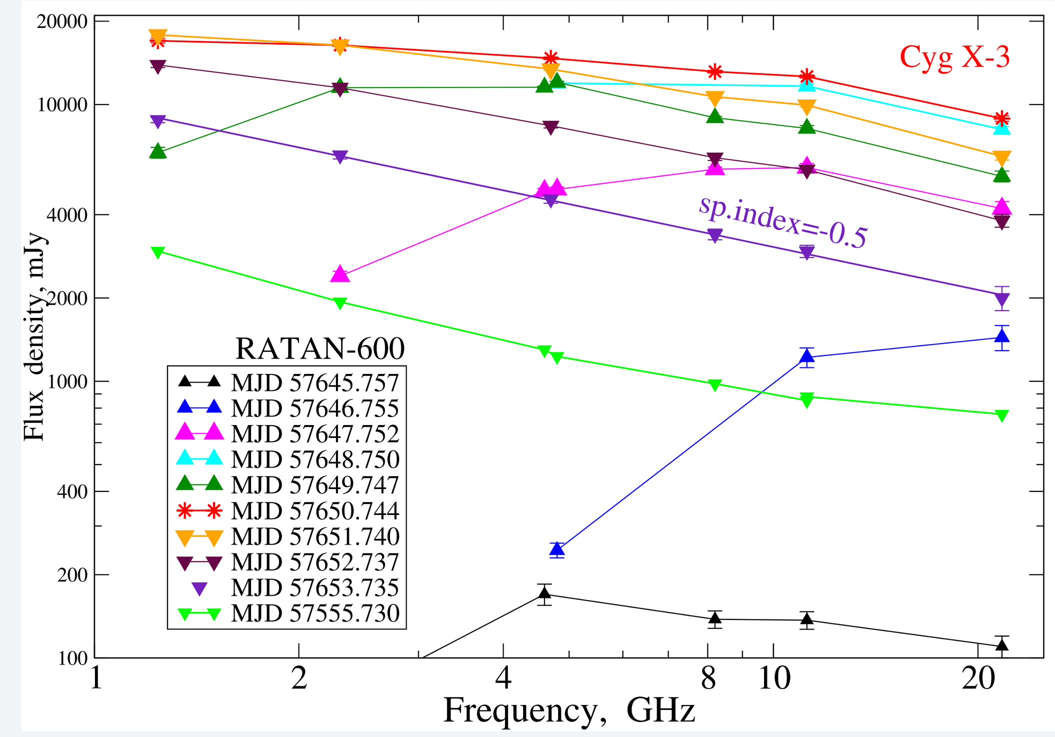

Fig.3: The radio spectra during first ten days of flare. There is clear transition from the optically thick mode to the optically thin one after MJD 57650.

McCollough+ (1999) analyzed the giant flare of 1999 and found that the radio fluxes have anti-correlated with the hard (BATSE) X-ray fluxes and correlated during the flare. The active period of the Cyg X-3 in 2006-2009 showed similar dependencies between soft (RXTE ASM), hard (Swift/BAT) X-rays and radio emission or even with GeV gamma-ray emission. The accretion disk-jet coupling in X-ray binaries has been discussed during last 10-15 years especially in the frame of the hardness-intensity diagram (HID) studies. Based on the first-time developed HID of the microquasar Cyg X-3 have detected the 'jet-line' of the powerful ejections only after so-called a 'hyper-soft' state, when hard X-ray fluxes fallen down to detection level, meanwhile soft X-ray emission stays on high level. Trushkin+ (2006) have successfully applied computer routine to model radio flaring activity (in July 2006) of Cyg X-3, based on the model created by Marti,+ (1993) and found main parameters: magnetic field (~ 0.05Gs), thermal electron densities (3×10^5)cm^{-3} and the bulk speed of jets (~ 0.5c). The spectral evolution of the giant flare is described by a single (during 3-4 days) ejection of the relativistic electrons, that moved with high velocity away from the binary and expanded as a conical structure. During first days of the ejection jets is probably optically thick due to synchrotron self-absorption or by thermal electrons mixed with relativistic ones. It is interesting that just in the beginning of the new flare in September 2016 the MAXI sort X-ray (2-20 keV) fluxes decreased from 0.35 crabs to 0.1 crabs thus Cyg X-3 returned in hard state.

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