

# The giant flares of the microquasar Cygnus X-3: X-rays states and jets

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In the long-term multi-frequency monitoring program of the microquasars with RATAN-600 we discovered the giant flares from X-ray binary Cyg X-3 on 13 September 2016 and on 01 April 2017. First one happened after 2000 days of the 'quiescent state' of the source passed after the former giant flare ( $\sim 18$  Jy) in March 2011. We have found that during this quiet period the hard X-ray flux (15-50 keV) and radio flux (11 GHz) have been strongly anti-correlated. The radio flares occurred after a transition of the microquasar to a 'hypersoft' X-ray state that occurred in Feb 2011, Aug 2016 and March 2017. The all giant flares were predicted by us. Indeed after decrease of the hard X-ray 15-50 keV flux and 4-11 GHz fluxes (a 'quenched state') on MJD 57644.5 and 57844.5 almost simultaneously with X-rays radio flux rose from 0.01 to 16 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 indices  $-0.4$  —  $-0.7$ . The first results are given in arXiv:1612.00634. The extended paper is preparing.

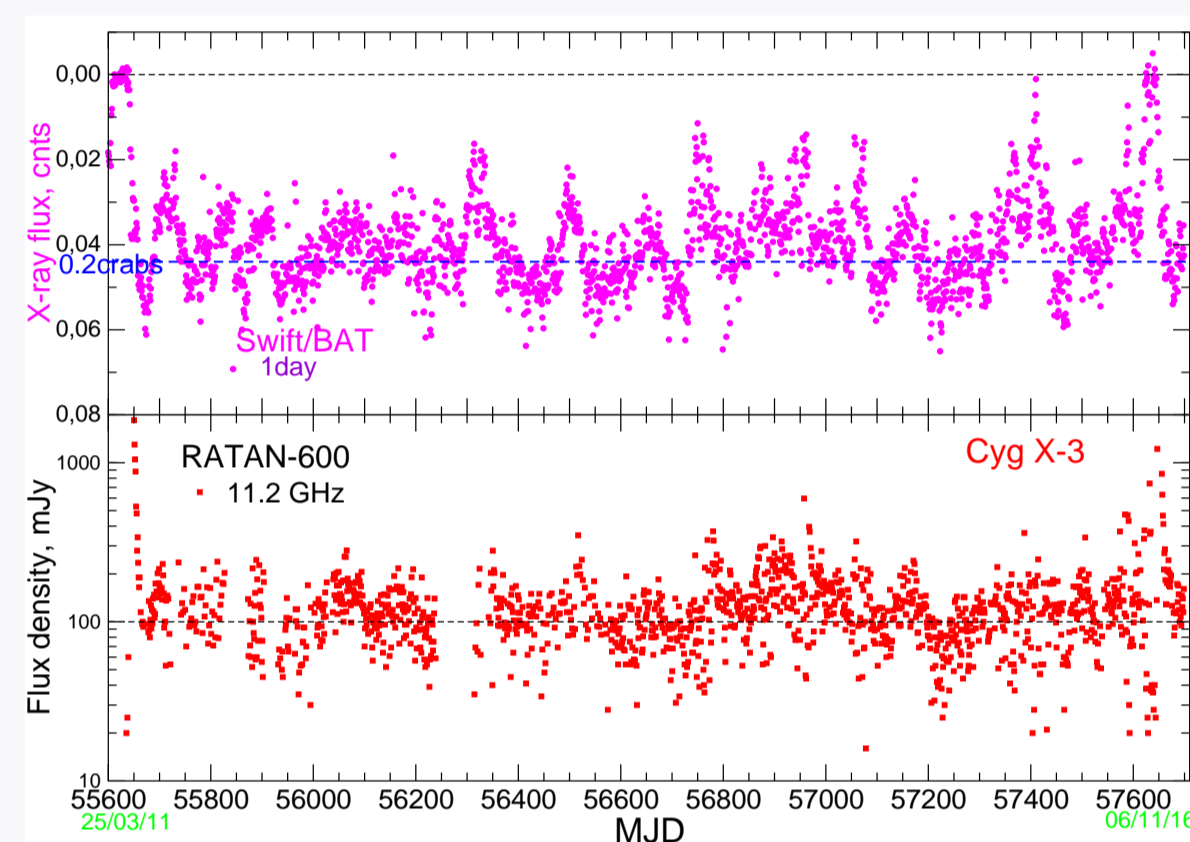


Fig.1: The light curves of Cyg X-3 at 11 GHz and at 15-50 keV during 2011-2016. For the best comparison the axis of X-ray fluxes is directed downwards.

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 times (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 ( $P=4.8$ h) 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 struc-

ture 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.

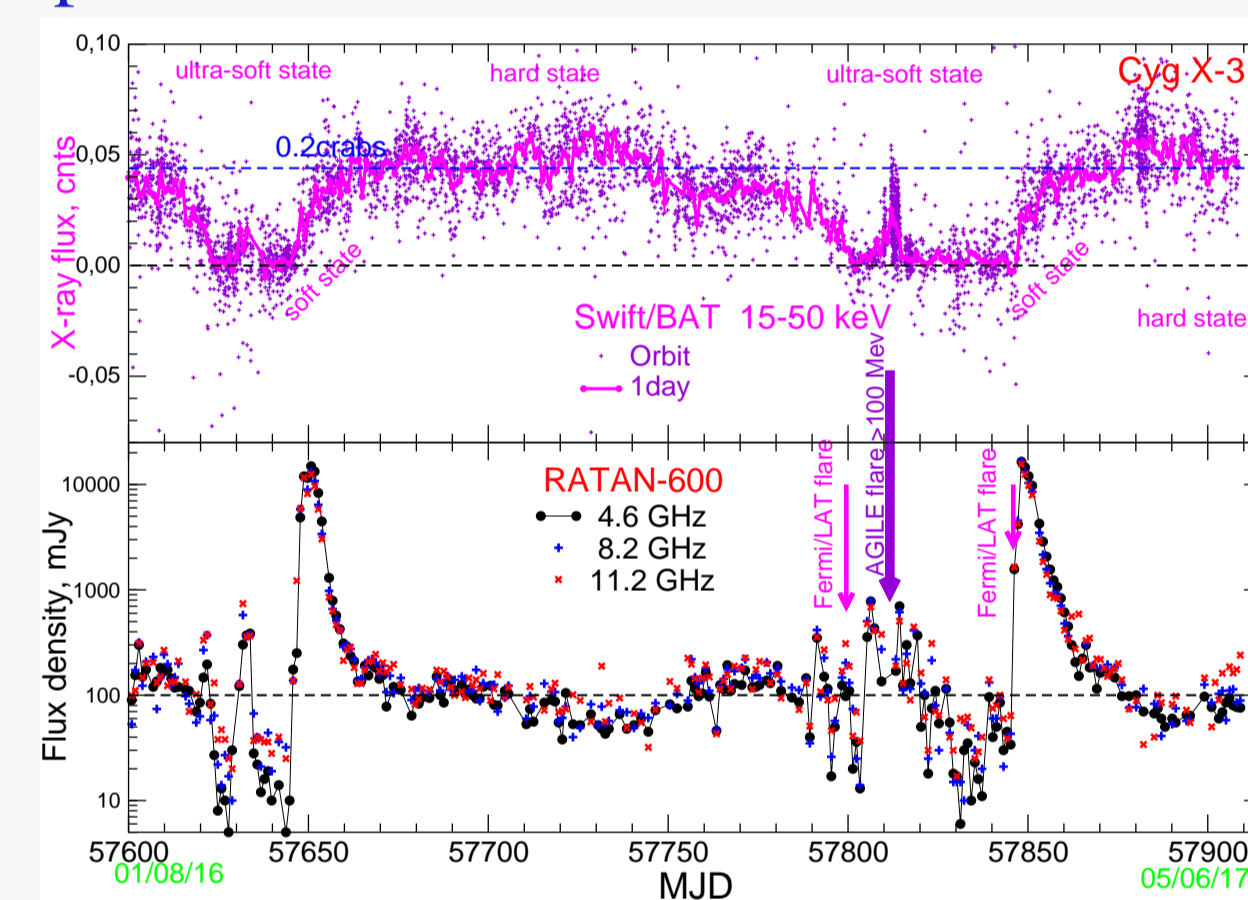


Fig.2: Light curves before or during the flare at X-ray 15-50 keV (top) and the RATAN multi-frequency data included both giant flares.

Almost 2000 days of the 'quiescent state' of the Cyg X-3 have passed after the former giant flare ( $\sim 18$  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 depending on an accretion

rate on to a black hole.

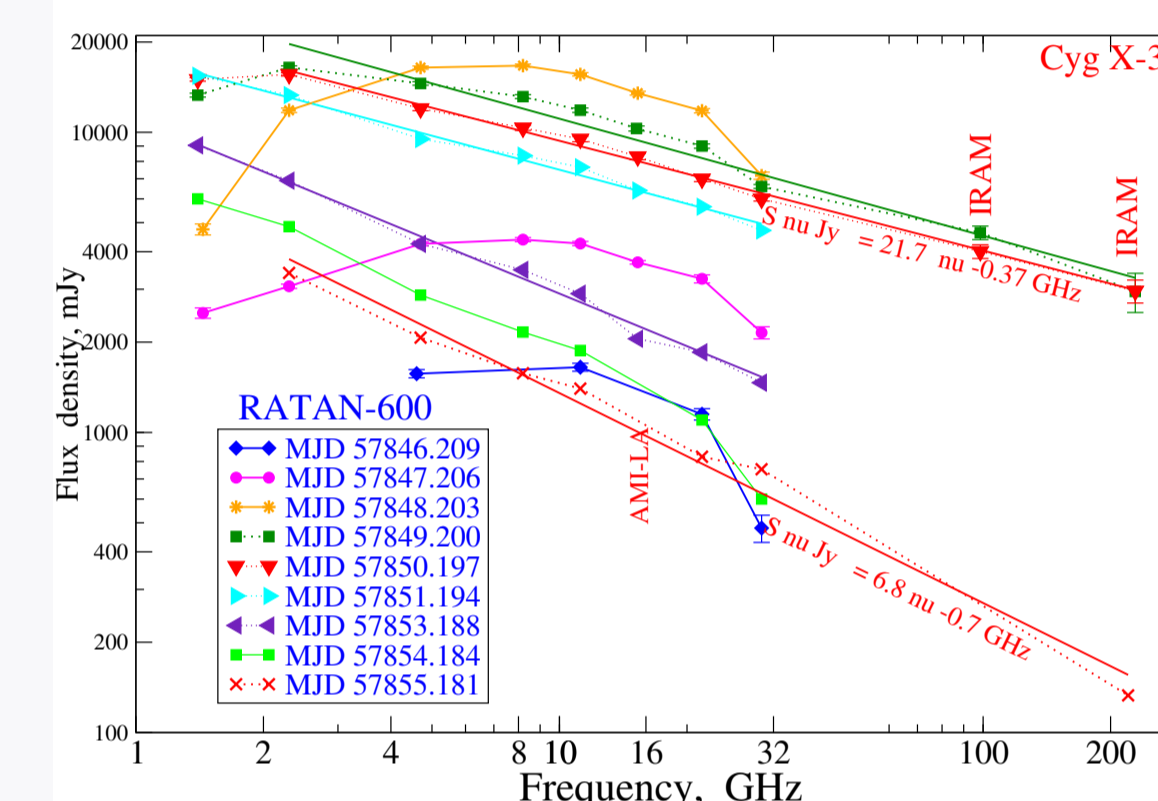


Fig.3: The radio spectra during first days of flare on Apr 2017. Optically thick mode was detected. Three close flux points at 90 and 230 GHz (IRAM and SMA) are direct extensions of the 4-30 GHz spectra.

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 ( $\sim 0.05$ Gs), thermal electron densities ( $3 \times 10^5$ ) $\text{cm}^{-3}$  and the bulk speed of jets ( $\sim 0.5c$ ). 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.

Observations with the RATAN-600 are carried out under the financial support of the Ministry of Education and Science of the Russian Federation (Contract No14.518.11.7054, code 2012-1.8-16-518-005) and the Program of the Common Physics and Astronomy of RAS.