The Universe at Low Radio Frequencies
IAU Symposium, Vol. 199, 2002
A. Pramesh Rao, G. Swarup and Gopal-Krishna, eds.

Radio Variability of the Galactic X-ray Binaries with Relativistic Jets

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Abstract. Variable non-thermal radio emission from Galactic X-ray binaries is a trace of relativistic jets, created near accretion disks. The spectral characteristics of a lot of radio flares in the X-ray binaries with jets (RJXB) is discussed in this report. We carried out several long daily monitoring programs with the RATAN-600 radio telescope of the sources: SS433, Cyg X-3, LS I +61°303, GRS 1915+10 and some others.

Many flaring RJXB show, exponential and power laws of flare decay. Moreover, these different laws could be present in one or several flares and commonly flare decays are faster at a higher frequency. The decay law seems to change because of geometric form of the conical hollow jets. The synchrotron and inverse Compton losses could explain general frequency dependences in flare evolution.

X-rays Binaries with Jets

The Galactic plane bright X-ray sources are close binaries, in which a neutron star (NS) or black hole (BH) traps matter from a companion, forming a accretion disk. Amongst $\sim$ 250 X-ray binaries only $\sim$ 30 are detected as radio sources (S_ν > 1 mJy). Many (or all!) such bright sources resolved into the relativistic jets with detectable proper motion of bright blobs. This sample of 10-15 such X-ray binaries with jets (RJXB) is extremely interesting for understanding of the astrophysical relativistic jets phenomenon.

Just after the discovery the superluminal sources in 1994, ten Galactic radio-emitting close X-ray binaries were unified into a sample of RJXB showing relativistic jets. In the binaries the accretion disks are created by flowing of material from a normal star, filling its Roche lobe, to a compact one.

The RATAN-600 Radio Monitoring of RJXB

During 1995–99 we carried out a long term monitoring program for radio variability of RJXB sources: GRO J1655−40, LS I +61°303, GRS 1915+10, SS433, Cyg X-1, Cyg X-3, and CI Cam, in which the dynamical radio spectra in the 1–31 cm wavelength range were measured. We found consistent patterns in spectral variability of RJXB. Some of the light curves of the RATAN monitoring of the RJXB are in Bursov & Trushkin (1995), Trushkin (1998), Trushkin & Bursov (1999) and Trushkin (1999). The dynamically resolved black hole **GRO J1655−40** is a second (after GRS 1915+105) superluminal X-ray transient discovered by BATSE in July 1994, with 0.92c jets detected by VLBI and

https://doi.org/10.1017/S0074180900169451 Published online by Cambridge University Press

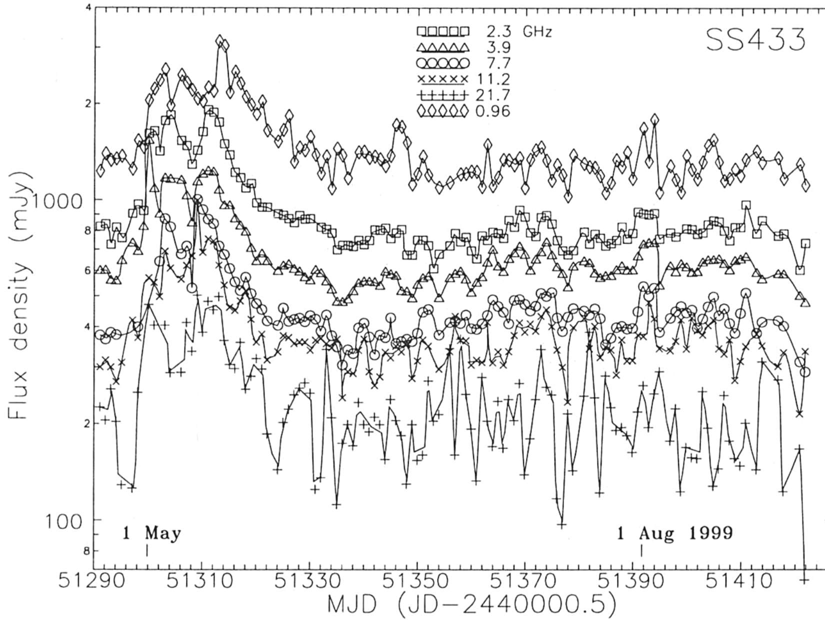

Figure 1. Light curves of SS433 at six frequencies in May-August 1999.

the VLA. We observed GRO J1655−40 only during the decay of most powerful flare in August 1994. The rates of flux decreasing are similar at different frequencies, but the power law spectra are steeper from 12th to 22th days from the flare beginning.

The Be star/X-ray source **LSI 61° 303** was discovered as the variable source GT0236+61. Two the orbital periods (26.5 days) were monitored at five frequencies. Generally the light curves have well correlation, while the latter maxima of flares come at the lower frequencies.

Trushkin (1998) discussed in details the flaring events in **Cyg X-3**. Analysis of the light curves in X-ray and radio range (McCollough et al., 1998, Trushkin, 1999) confirmed the high correlation of the hard X-ray flux (20–100 keV) and flaring radio flux, and the anticorrelation with soft X-ray emission (2–12 keV) during powerful flaring activity ($S_\nu > 3$ Jy).

The X-ray binary and luminous star **SS 433** is a persistent bright radio source. Its active periods are characterized by powerful flares with the flux increasing two-ten times during 1-2 days (e.g. Bursov & Trushkin, 1995). SS433 was resolved into radio blobs on scales from 0.005″ to 3″, the radio structure location followed a kinematic model, constructed from "moving" emission lines, originated in two opposite directing precessing jets.

In Figure 1 radio light curves of the SS433 flares detected in May 1999. There is evidence of the orbital period modulation in the light curves during quiet 100-days period (June-August). We detected the prominent 6.5, 13.2, and 26-days harmonics in Fourier spectra at all radio frequencies.

Conclusions

Sources Cyg X-3, Cir X-1, CI Cam (XTE 0421+560), 1E1740.7−2942, GRS 1758−258, GX339−4, LSI+61°303 and SS433, are radio jet X-ray binaries. Probably jets play a key role in formation of powerful non-thermal radio emission. The correlation of hard X-ray and radio emission seems to be a common feature of RJXB.

All RJXB are strongly variable X-ray and IR sources. VLBI observations of RJXB show multi-component structure on a scale $0.001 - 5''$. High velocities, $0.1 - 0.92c$, are detected from the proper motion of blobs in resolved sources, often showing a apparent superluminal expansion. The relativistic electrons and magnetic fields constitute a large portion of the total power of flare. The synchrotron spectra $S_\nu = S_\circ \nu^\alpha$ of RJXB are variable with flares. Also high linear polarization was detected in RJXB. The basic model of the synchrotron emission evolution is an adiabatic expansion of the blobs moving away from binaries. A conical geometry of jets and considerations of the radiative losses, synchrotron radiation and inverse Compton scattering are a modification the basic model to satisfy the spectral and temporal dependences during the flare evolution.

Monitoring of radio variability shows that the decay of flaring flux after the maximum follows: a power law $S_\nu = S_\circ\, t^{-2p}$, as the Shklovski-van der Laan model predicts and a exponential law $S_\nu = S_\circ\, e^{-t/\tau}$ the cause of which is a geometric structure of jets. Here often (but not always) $\tau \sim \nu^\beta$, where β ranged from −0.8 to −0.4, thus a flare decays faster at the higher frequency. Maybe there are two different types of flare in RJXB with or without delays and different laws of decay: "flare of core" and "brightening zone" in SS433.

Recently the radio observations of the 1999 September flaring event (12 Crab) in the very fast X-ray transient XTE J1819−254 were carried out (Hjellming et al., 2000). Finite jet segment models argued a relativistic jet with velocity of 0.88c. At a probably distance of 0.5 kpc, XTE J1819-254 is the closest relativistic jet source yet observed.

Acknowledgments. Authors are thankful to RFBR for supporting the project of monitoring X-ray binaries, grant N98-02-17577.

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