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960-day Radio Monitoring of X–Ray Binary LSI+61^{o}303 with RATAN-600 telescope

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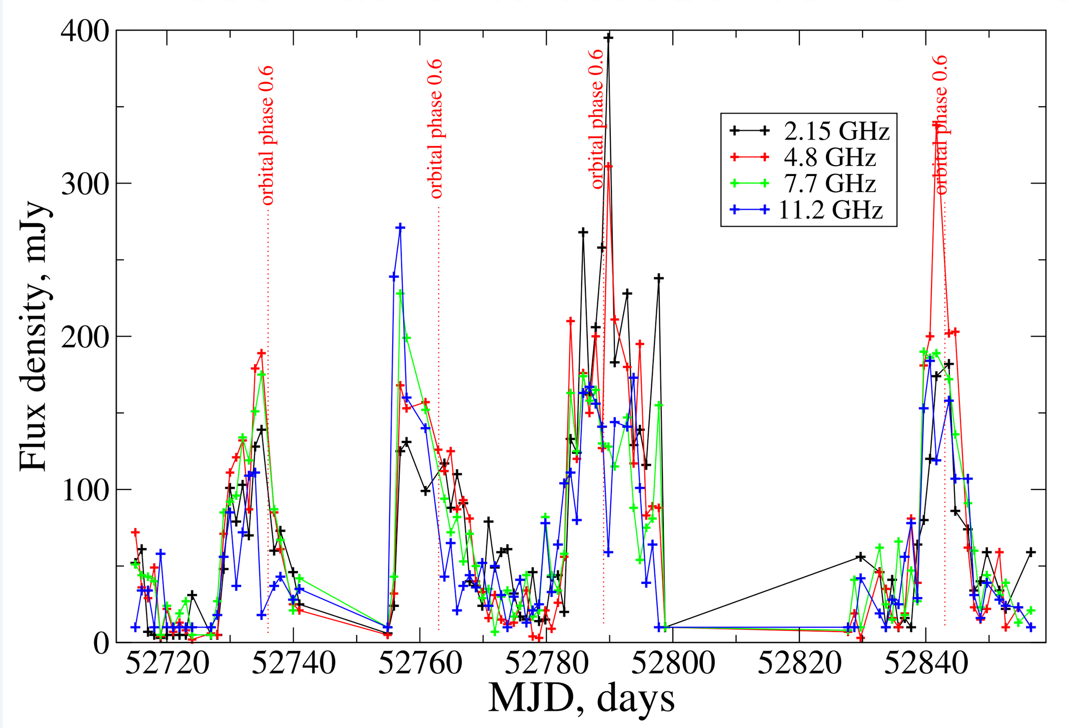
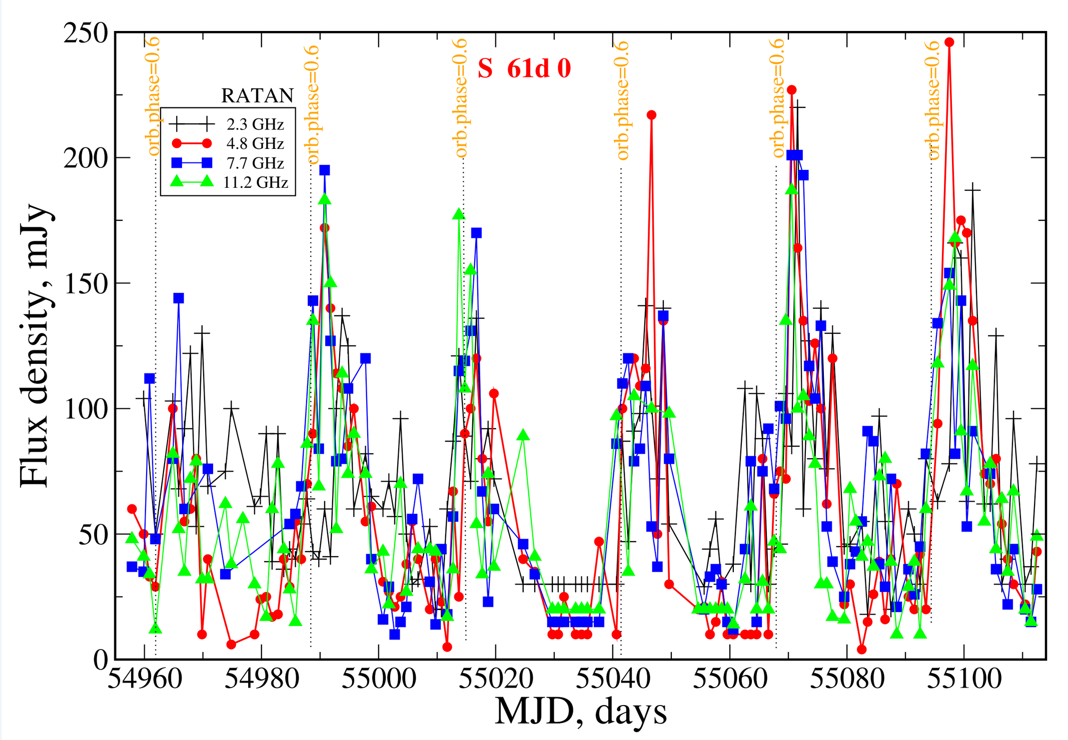
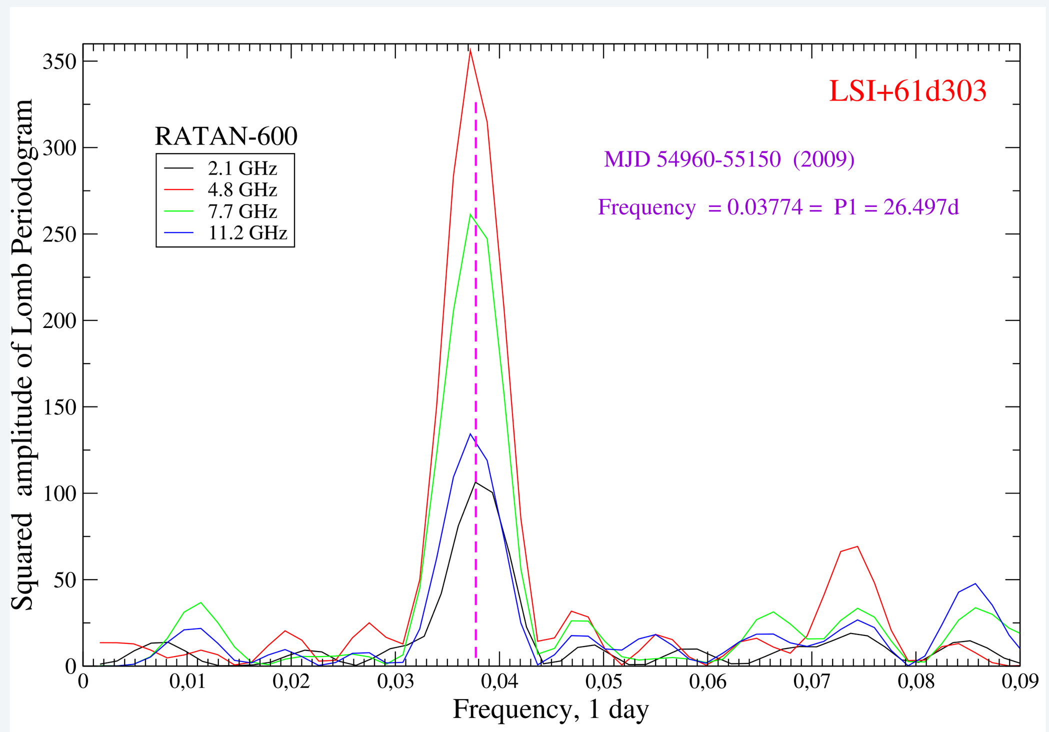
In 2003, 2009 and 2013–2016 we have monitored of the X-ray and VHE γ-ray binary, probably microquasar, LSI+61^{o}303 with the RATAN-600 radio telescope. The multi-frequency light curves were measured during last 36 orbital periods (P_1 = 26.5d). LSI+61^{o}303 is single periodically flaring source from radio waves to VHE γ-ray band. We detected radio flares with maximal flux 150–350 mJy, while between flares the fluxes of the source fell down to 10–20 mJy. The measurements were made near the phases θ_2 = 0.6–0.7 (2003), θ_2 = 0.95–0.05 (2009) and θ_2 = 0.95–0.52 (2013-2016) of the super-orbital period P_2 = 1667 days, which modulated peaks of the radio flares according to the ephemerids of Gregory (2002) based on the GBI data. Mean orbital light curves from the GBI data, received in 1990th for the same super-orbital phases showed that flares in 2003 Feb-May and in 1994 Feb-June (GBI data) started at the same orbital phases (θ_1 = 0.35), while the maxima of the flares were at orbital phases near 0.45 in 1994 and 0.55 in 2003. In 2009 the starting and the maxima moments of the flares were drifted to the orbital phases 0.6 and 0.7 respectively, meanwhile these phases were rather 0.5 and 0.6 in the GBI data of 1996.

The X-ray transient source LSI+61^{o}303 (GT0236+61) was discovered in 1978 by Gregory and Taylor in the Galactic Plane (GT-)survey at 5 GHz. This single periodically flaring in radio band, very high-energy (VHE) γ–ray binary, and probably microquasar was monitored during February–May 2003, and May-October 2009 and four frequencies with the RATAN-600 radio telescope (SAO RAS).

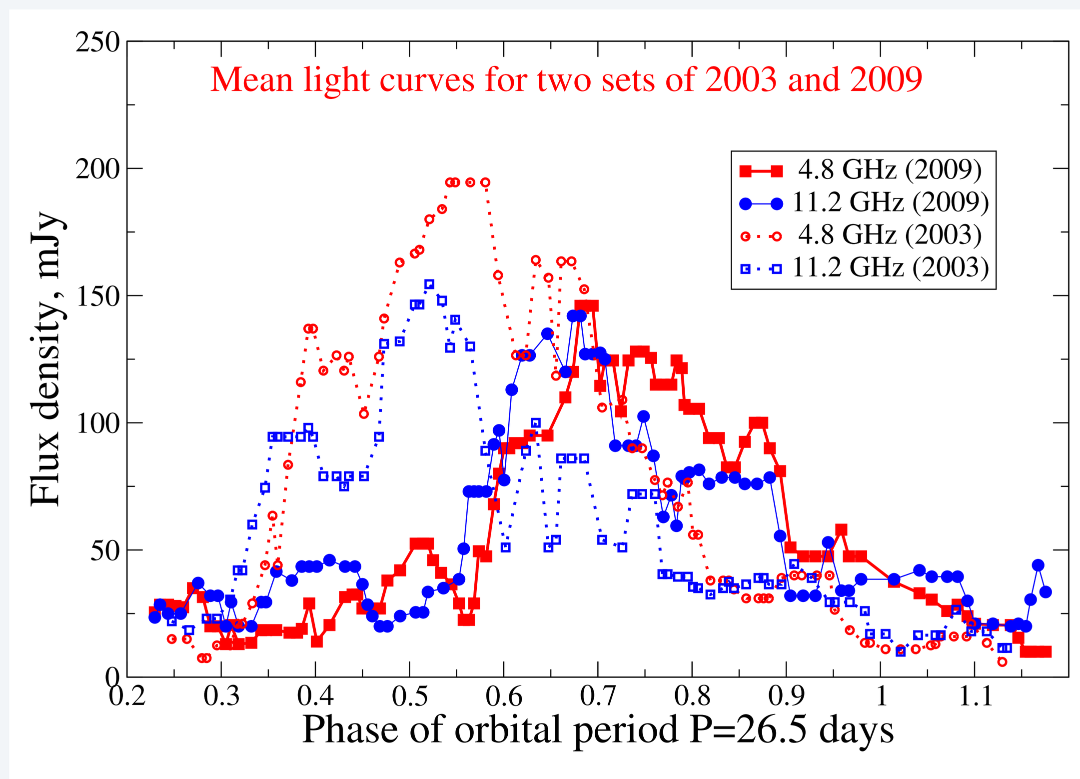




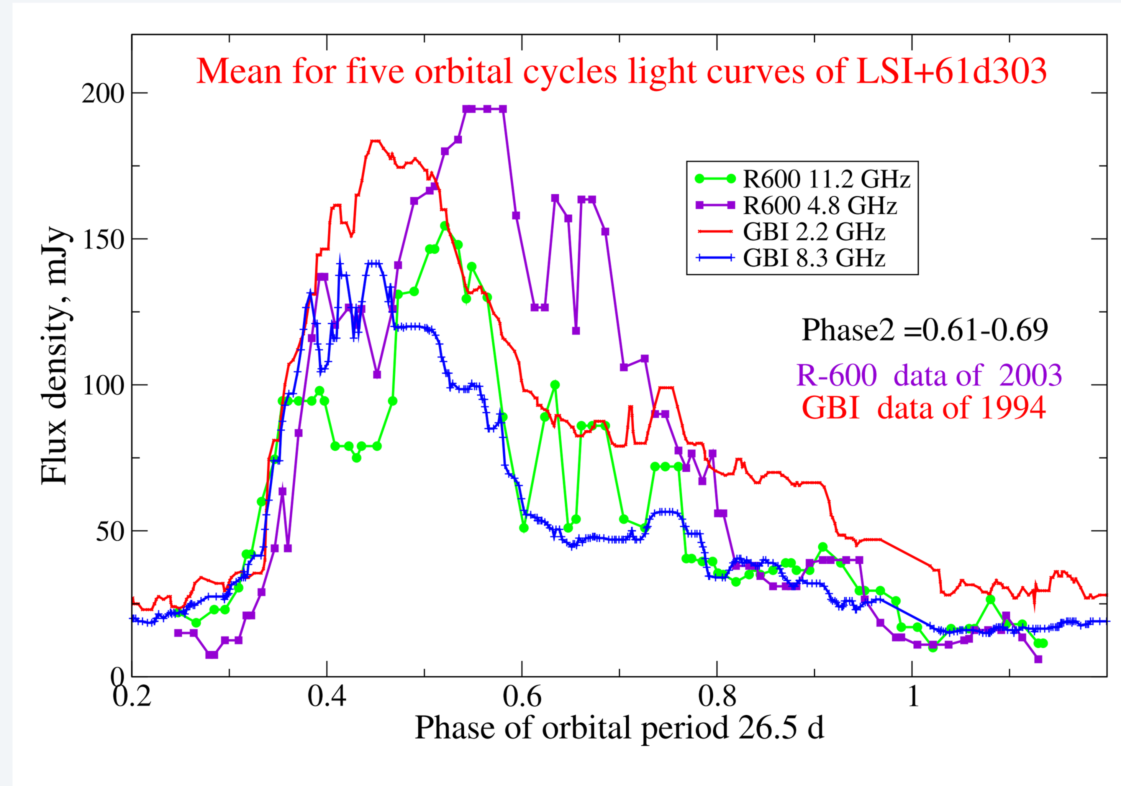
In the radio band the periodically varied relativistic accretion forms the jets – collimated outflows in this Galactic X-ray binary with big eccentricity (e = 0.54), possibly consisted of neutron star or black hole and rapidly rotating massive Be (B0Ve) star.

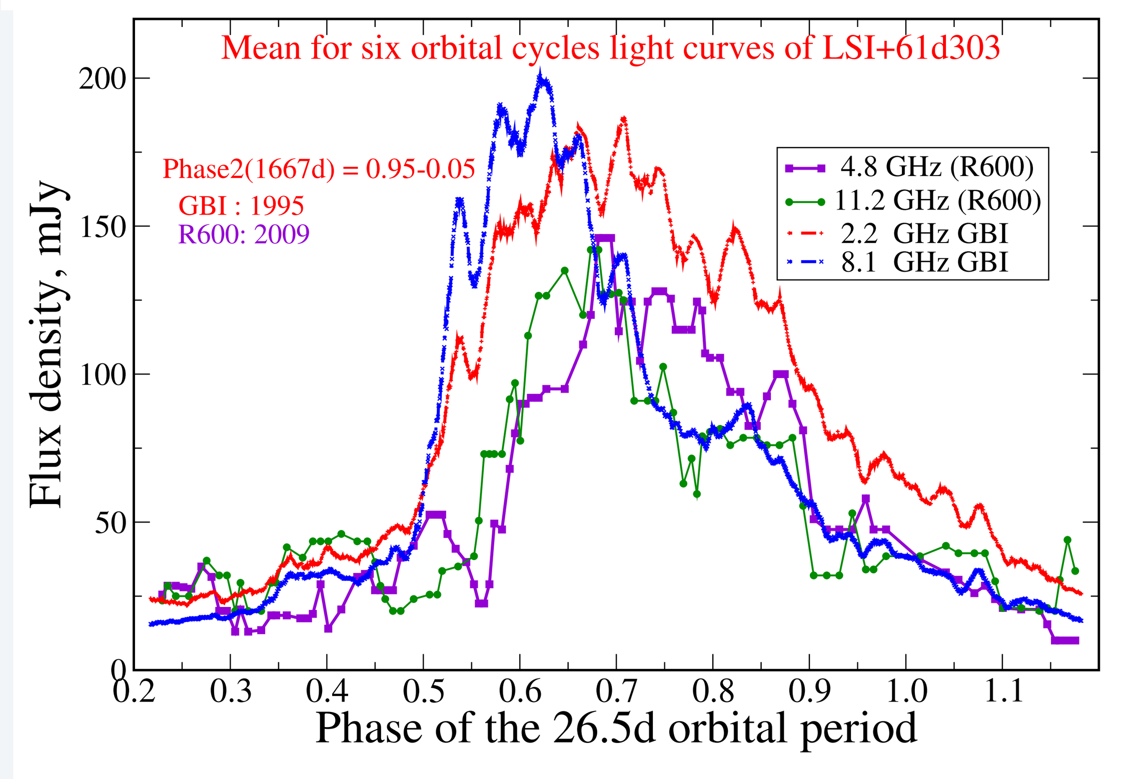


Near the each orbital phase $\theta_1 = 0.6$) we detected six flares from 150 to 250 mJy in 2009 at four frequencies 2.1, 4.8, 7.7, and 11.2 GHz. Thus the multi-frequency light curves were measured during six orbital periods. The Lomb periodogram analysis gives single periodicity with orbital period $P_1 = 26.5$ days. In both earlier sets maxima fluxes at 2.1 GHz were later than at the higher frequencies, that is a reason of the positive ($S_\nu \propto \nu^\alpha$) spectral indices between 2 and 11 GHz in the beginning of a flare. These measurements were made near the phases $\theta_2 = 0.6-0.7$ (2003) and $\theta_2 = 0.0$ (2009) of the super-orbital period $P_2 = 1667$ days according to the ephemerids of Gregory (2002). In both sets maxima fluxes at 2.1 GHz were later than at the higher frequencies, that is a reason of the positive spectral indices between 2 and 11 GHz in the beginning of a flare. We compared the mean orbital light curves with the GBI data, received in 90ths years for the same super-orbital phases. The flares in 2003 Feb-May and in 1994 Feb-June (GBI data) began at the same orbital phases ($\theta_1 = 0.35$), while the maxima of the flares were at orbital phases near 0.45 in 1994 and 0.55 in 2003.

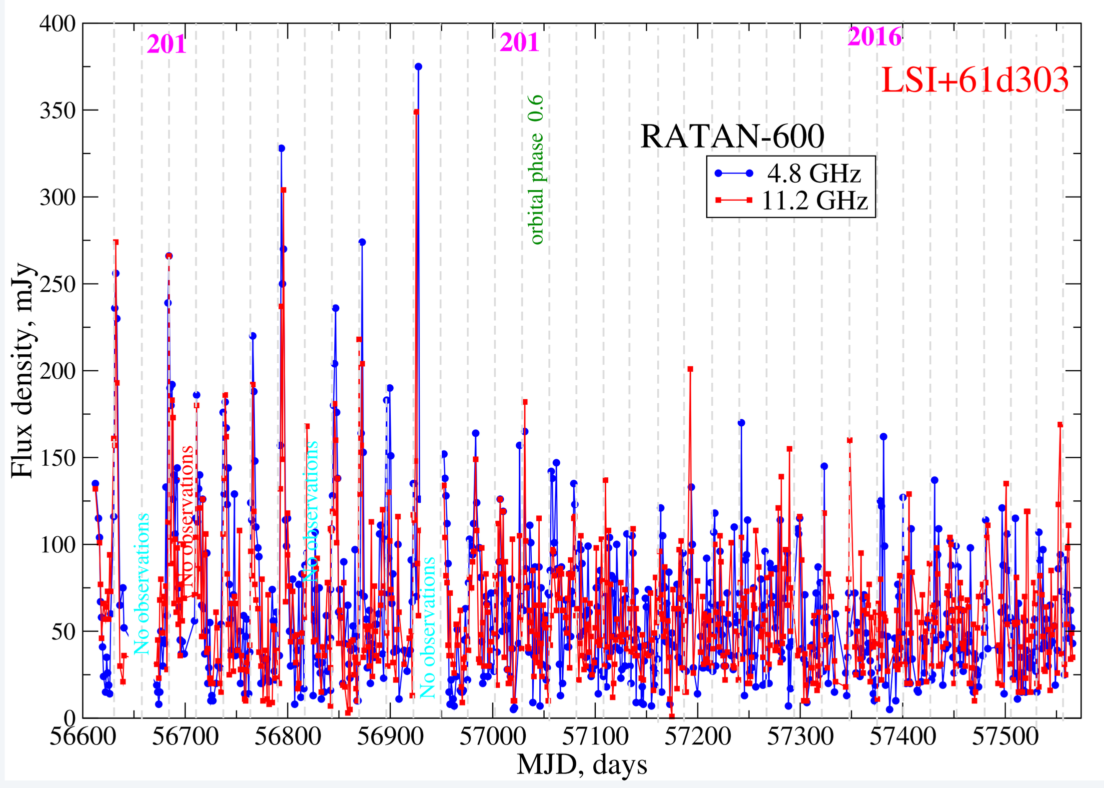


In 2009 the beginnings of the flares and maxima of the flares were drifted to the phases θ_1 0.6 and 0.7 respectively, meanwhile these phases were rather 0.5 and 0.6 in the GBI data of 1996. Thus we confirmed the drifts of the maxima in dependence on a super-orbital period phase. We found that at least during last years the maximum flaring fluxes happened at 3 days later than being predicted by the Gregory's ephemerids. That could be related with instability (or uncertainty) of the super-orbital 4.6-year period. We discuss the possible reasons of the modulation of the synchrotron radiation properties by the super-orbital 4.6-year period. Gregory (2002) have found that the phases of maxima and their values in the Green Bank Interferometer data at 2.3 and 8.5 GHz have been modulated by 4.6 years (1667d) period.

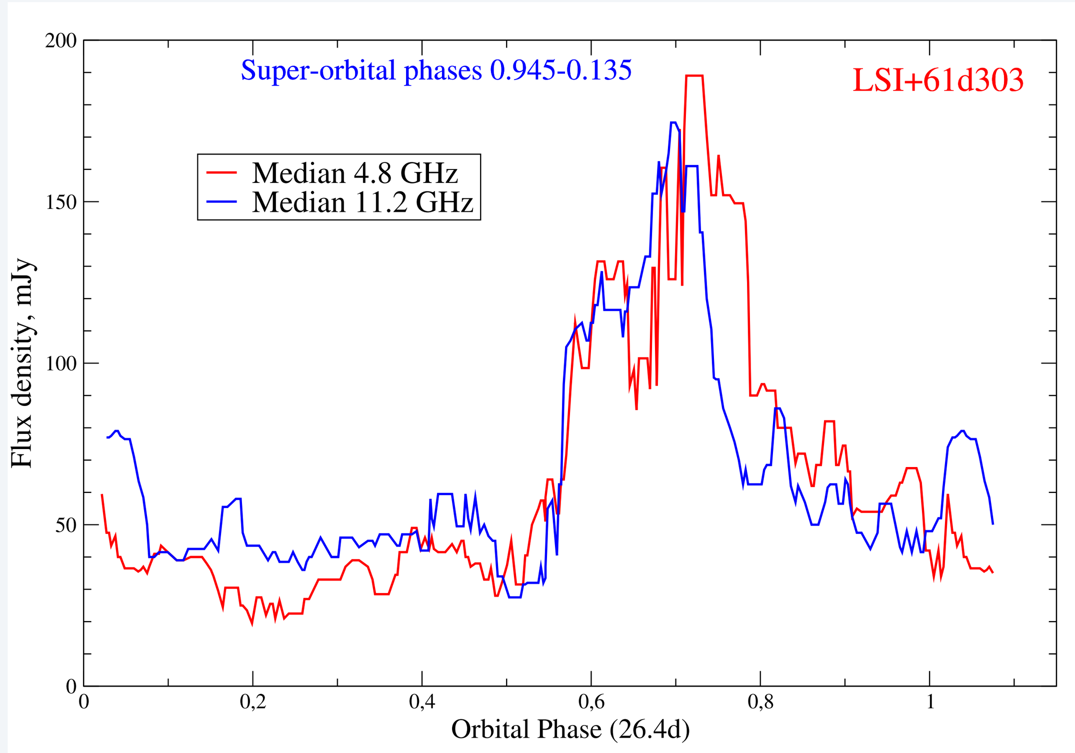


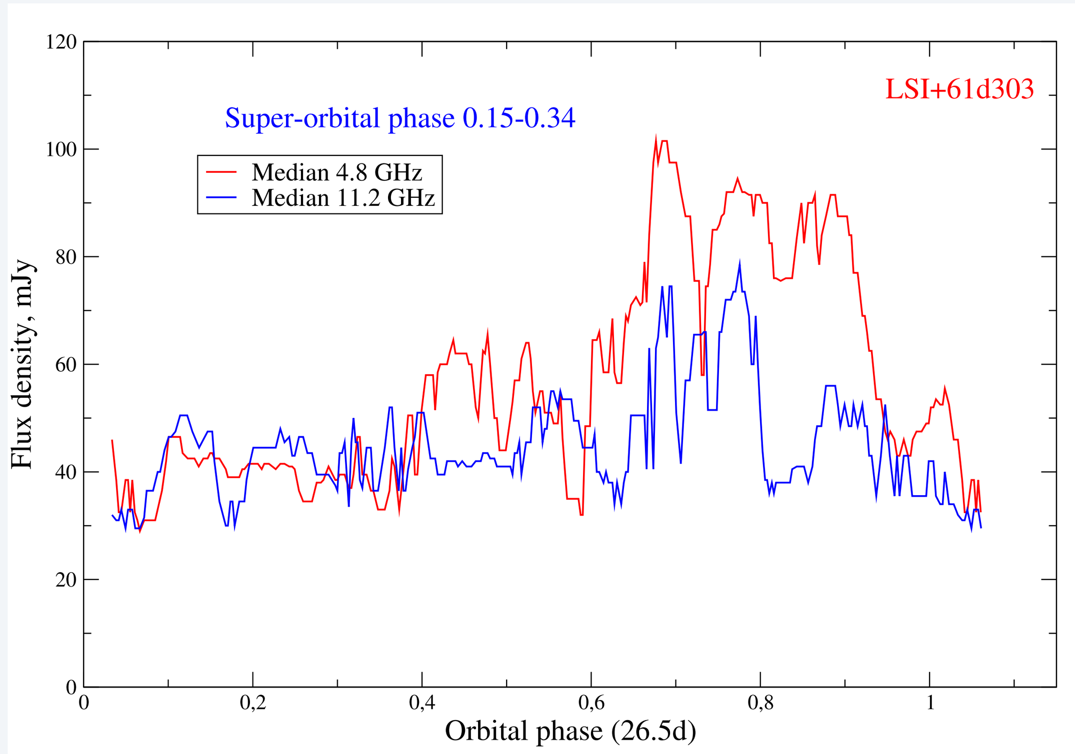


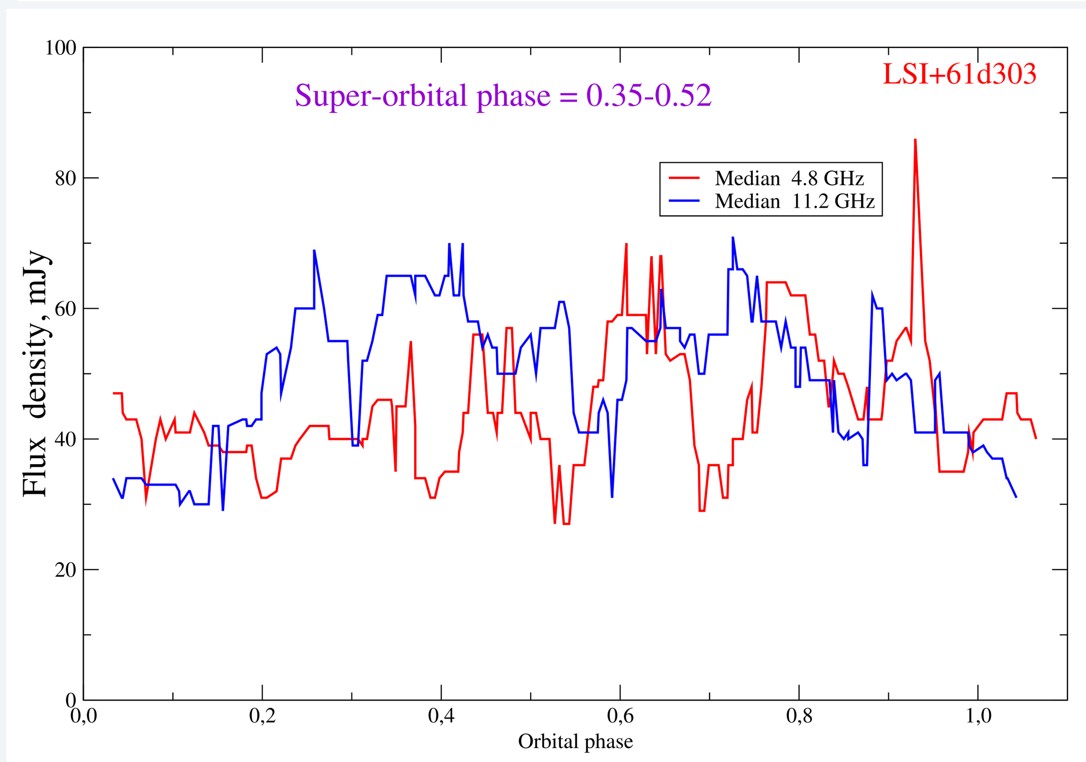
The data of 2003 and 2009 confirm the drift of the radio flares maxima but the mean orbital light curves do not follow the ephemerids based on the former GBI data. Thus new RATAN-600 data detected the new feature: the super-orbital period could be variable.



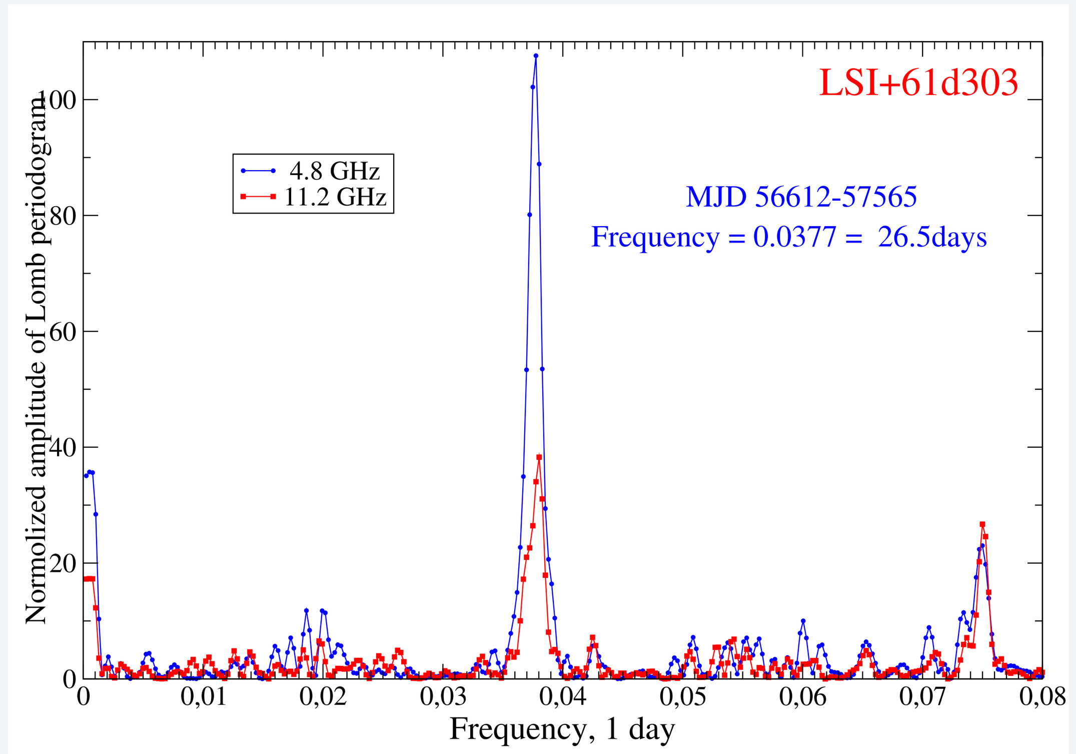
The long-term almost daily two-frequency monitoring of the radio fluxes from LSI+61d303 continue from Nov 2013 up to now and will be finished in 2018 in order to follow the total 1667-day super-orbital period. We have already measured 36 orbital periods from the super-orbital phases θ_2 from 0.95 to 0.52. We have detected clear change in the behavior of the flaring activity: in the first half of the light curves the maxima were the notably brighter than in the second part of the set. We obtained that during phase interval of θ_2 = 0.95–0.15 the mean flares had the maxima fluxes 200 mJy at both frequencies 4.8 and 11.2 GHz, being at orbital phase θ_1 = 0.6–0.7, but during phase interval of θ_2 = 0.15-0.35 the mean flares had maxima flares near 100 and 60 mJy at 4.8 and 11 GHz respectively, happened at θ_1 = 0.7–0.8. As usual the flares at the beginning phases of P2 have the the flatter spectra of maximal fluxes (spectral index ~0) than during the phases of θ_2 >0.3. The clear two-peaks have seen on mean orbital light curves during the all phases of θ_2. Probably it means that there are two locations of the second component star on the orbit where the generation of the relativistic electrons is maximal or there are two orbital moments of the jets formation (see Marti & Paredes, 1996). The nature of the super-orbital modulation of the radio flares became unknown, while the the models of the interaction of the precessing jets and disk-like wind around a Be-star were considered (see Zalmanov & Marti 2000).

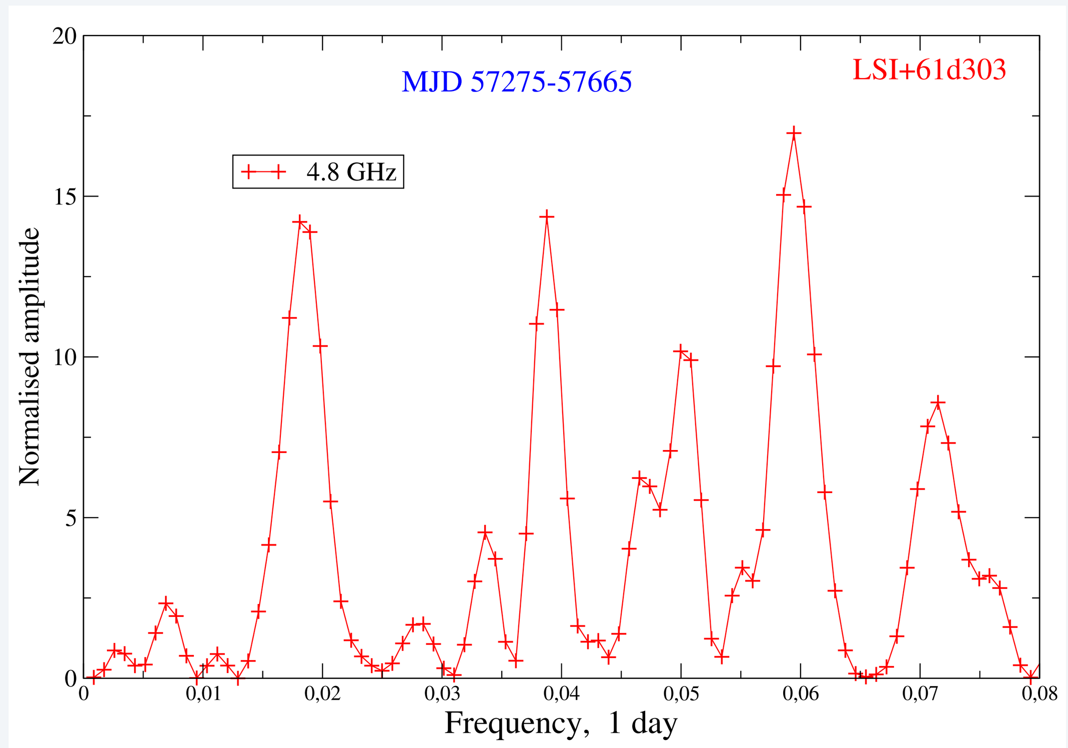






The median orbital light curves during different super-orbital phases varied from clear single maximum (θ_2 = 0.95–0.15), to clear double maxima (θ_2 = 0.15–0.35) and to faint double maxima (θ_2 = 0.35–0.52). The median orbital light curves in 2009 and 2014 in θ_2 = 0.95–0.1 are very similar, thus the properties of LSI+61^{o}303 repeated in the close super-orbital phases. Thus we confirm the early results based on the GBI data by Waltman et al. (1995) and Gregory (2002). By the way we found from the Lomb periodograms that the early GBI data have indeed show the only orbital periodicity 26.5 days at least during MJD 51000–51655.





The Lomb periodogram analysis for total 36 orbits shows that the orbital harmonics $\nu_1 = 0.0377$ day^{-1}, that again gives P_1=26.5 days and we have not detected any additional close frequencies. During the super-orbital phases θ_2 = 0.35–0.52 the orbital harmonics (ν_1) decreased and we can see the the harmonics $\frac{1}{2}\nu_1$ = 0.019 and $\frac{3}{2}\nu_1$ = 0.06 day^{-1}.

The nature of the relativistic object is unknown. The alternatives are a black hole or neutron star, rotating around the Be-star on the strongly elongated orbit. The searches for the pulsar radiation have been negative at different frequencies. We can not select the origin of the compact star from the radio data, meanwhile the formation of the jets from the center of the accretion disk seem to be preferable. The radio properties of LSI+61^{o}303 are compatible with other microquasars. These properties remind the irregular flaring behavior of Cyg X-3, SS433 and GRS1915+105. Thus models with precessing relativistic jets seem to be more preferable.

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