Radio Properties of FR0 Radio Galaxies: RATAN-600 Observations

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Abstract. Compact radio sources FR0 are the dominant population among radio-loud AGNs in the local Universe. The nature of FR0s is still unclear and needs a research. This paper presents the observational results of 33 FR0 radio galaxies in the first half of 2020. The radio luminosity of the FR0s lies within $10^{38.8 \div 40.6}$ erg/s with the average value of $10^{39.7}$ erg/s. RATAN-600 data confirm the deficit of extended radio emission: the average core-dominance parameter is $\log R \approx -0.10$ which exceeds typical values for FRI radio galaxies significantly. Spectra are peaked for 44 % objects with three quasi-simultaneous points at least. Three most probable GPS sources were found using additional CATS data. On the whole, FR0s have the flat spectra with a complex structure. It means that the FR0 radio galaxies have opacity in the radio domain and several components contribute to the resulting spectrum.

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1 Sample and Observations

The sample includes 33 objects from FR0CAT (Baldi et al. 2018) with the flux density $S_{NVSS} > 30$ mJy at 1.4 GHz. The objects have declination $-08^\circ \div +47^\circ$, RA $= 00 \div 17$ h and redshift $z < 0.05$. The observations were carried out with the Northern sector of the RATAN-600 in the transit (meridian) mode in February, April and May 2020. Quasi-simultaneous spectra were obtained twice for some sources. We defined the spectrum as quasi-simultaneous if it was obtained as a result of averaging transit scans of the source over 7-10 days. The data were processed using standard methods for the RATAN-600. Most sources (70 %) were detected at three or more frequencies, four objects were detected at five frequencies. Ten sources were detected at one or two frequencies (30 %). The

obtained spectra are completed with data from CATS, VLA, VLBI and are shown in Fig. 1.

2 Results

The radio luminosity at 4.7 GHz was calculated according to the expression: $\nu L_\nu = 4\pi(D_L)^2 \nu S_\nu (1+z)^{-\alpha-1}$, where ν is the frequency, S_ν - the flux density, z - redshift, α - spectral index and D_L is the luminosity distance. The relative contribution of the core emission is characterized by the parameter $R = S_{8.2}/S_{1.4}$ i. e. the ratio of the flux density at 8.2 GHz to the flux density at the NVSS survey frequency. The distributions of the radio luminosity and the core-dominance parameter are shown in Fig. 2. It's obvious that FR0 radio galaxies are characterized by: 1) a moderate power in the radio band; 2) a deficit of extended radio emission with respect to FRI radio galaxies for which $\log R \approx -1 \div -2$.

There were obtained quasi-simultaneous spectra at the frequency range of $2.25 - 22.3$ GHz with the RATAN-600. The spectral shapes for 23 objects which were detected at three frequencies at least are following: peaked – 10, steep – 7, inverted – 3 and upturn – 3 sources. This means that most of FR0s are opacity in the radio range. The spectra of FR0s are flat in all frequency bands because the average spectral index $\alpha < 0.5$. The average spectral index is almost zero at 4.7-8.2 GHz and there are $0.5 < |\alpha| < 1.0$ only for three objects. The spectrum steepening occurs at 8.2-11.2 GHz and there are $\alpha < -1.0$ for seven objects thus the greater scatter of the spectral indices is noted (Fig. 3). The number of measured spectral indices is small at $2.25 - 4.7$and $11.2 - 22.3$GHz therefore the conclusions can do only separate sources.

According to the RATAN-600 data, 16 objects have a convex spectrum (Fig. 1). We approximated the convex spectra with a log-parabola and determinated the Full Width at Half Maximum (FWHM) (O'Dea et al. 1991). Most of objects have the $FWHM$ = 1–2 decades of the frequency but the distribution has the tail with $FWHM > 2$ (Fig. 4). Mean and median values are equal 2.14 and 1.78 decade of frequency, respectively. Our estimates shows that FR0s have a smaller curvature of the spectrum versus to the classical GPS sources for which FWHM is equal 1.2. This fact have been noted by Capetti et al. (2019), however, authors used non simultaneous archival data in the range 0.15-5 GHz. Comparison these data with the RATAN-600 measurements hints about a possible steepening of the spectrum with increasing the frequency that had been noticed in VLA observations (Baldi et al. 2019). Analysis of all available data allows us to find out three sources which can be GPS: J0115+00, J0909+19 and J0943+36. Therefore, some objects (10-20 percent) can be young GPS radio sources with low powers among the FR0 population. However, the nature

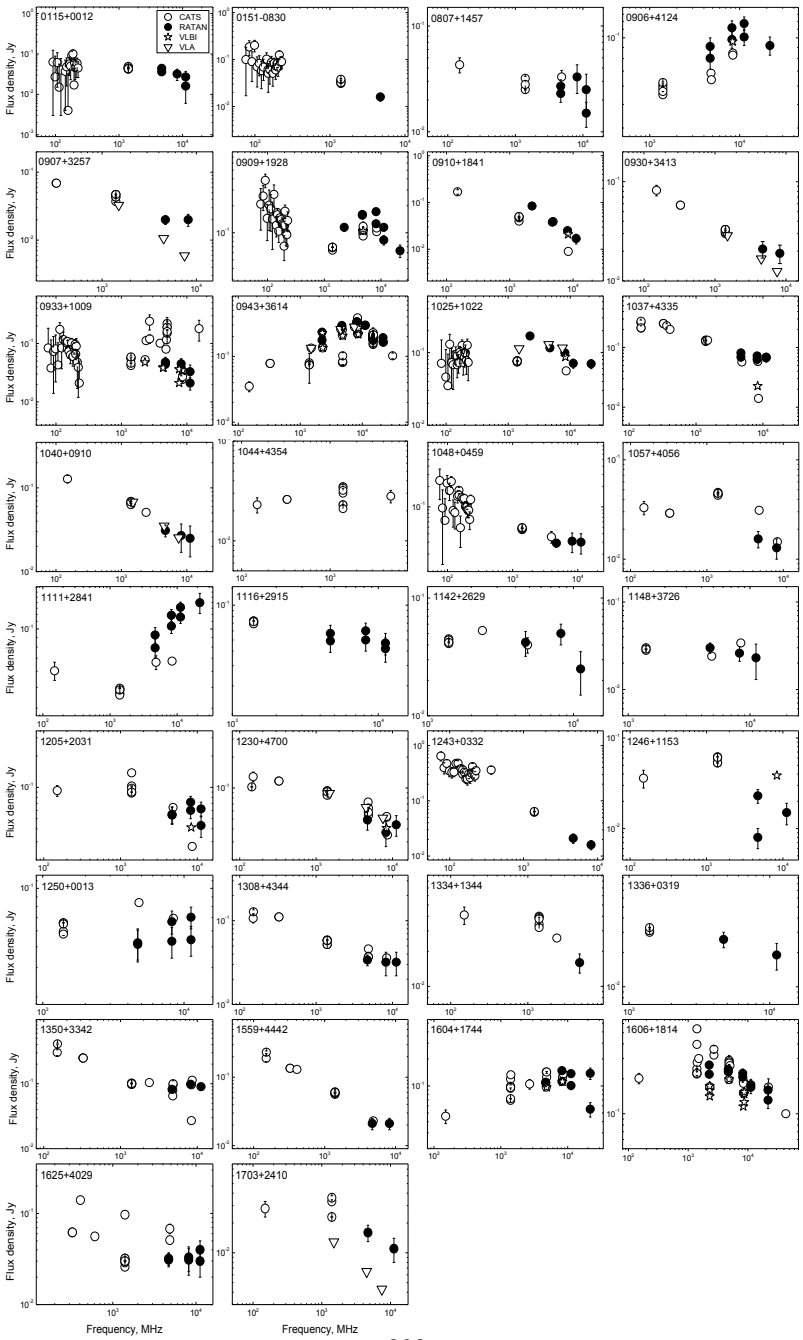

Fig. 1. Continuum radio spectra for FR0 radio galaxies.

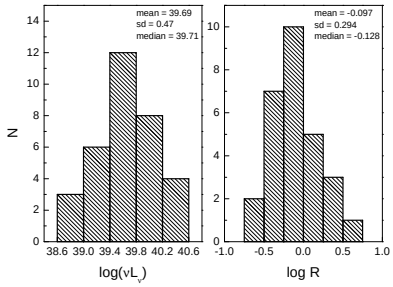

Fig. 2. The radio luminosity distribution and core-dominance parameter.

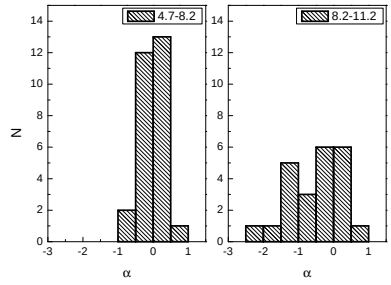

Fig. 3. The spectral indices distribution in different frequency ranges.

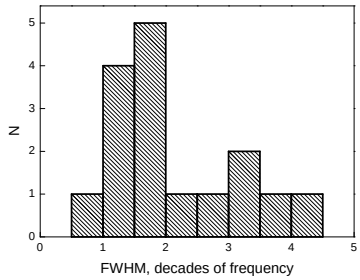

Fig. 4. The FWHM distribution.

of FR0s and their relationship with other classes of compact radio sources is still unclear and needs further investigations. We note that the analysis of the archival VLBI data made it possible to detect jet structures at the parsec scales (Cheng & An 2018).

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