Relation between continuum radio spectra and parsec-scale properties of extragalactic radio sources

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Summary

The goals of this study are:

- **To determine the fraction of the objects with bright relativistic jets within the whole population of extragalactic radio sources**
- **To investigate relations between source compactness and its broad-band radio spectrum**

The main results:

- **Almost 100% of flat spectrum sources and all peaked spectrum sources have shown relativistic parsec-scale jets.**
- **Among steep spectrum sources, about 1/5 have shown the evidence of compact structure.**

Sample and Observations

We study a complete sample including 502 extragalactic radio sources that meet the following selection criteria:

- Flux density ≥ 0.2 Jy at 1.4 GHz (NVSS catalogue)
- $+75^\circ \leq \mathrm{Dec} < +90^\circ$, $0^\mathrm{h} \leq \mathrm{RA} < 24^\mathrm{h}$

We used the following observational data for the analysis:

1. Very Long Baseline Array (VLBA) Northern Polar Cap Survey: 8 minute scan for each source; S and X bands (2.3 and 8.6 GHz).
2. Total flux broad-band simultaneous radio spectra from RATAN-600 (Mingaliev et al., 2007). Six frequencies: 1.1, 2.3, 4.8, 7.7, 11.2, and 21.7 GHz.

Simultaneous Single-Dish Spectra

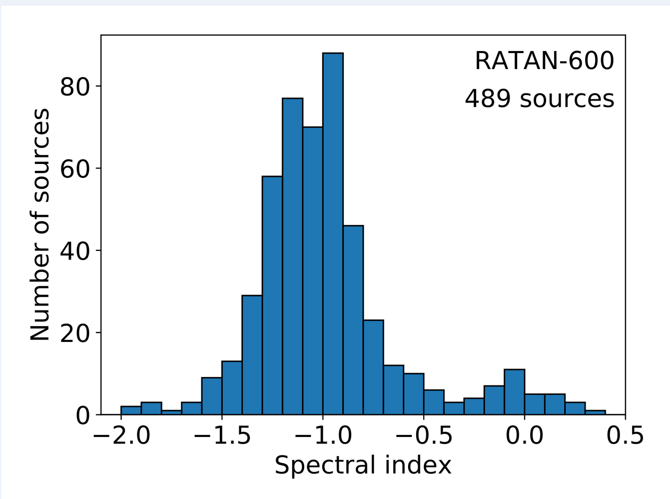

Figure 1: Spectral index distribution within the complete sample.

Spectral index. We calculate the spectral index $\alpha_{2/8}$ in the range from 2 to 8 GHz by fitting the power-law $S \sim \nu^{+\alpha}$ to the RATAN-600 fluxes at the frequencies 2.3, 4.8, and 7.7 GHz.

Shape of spectra. Spectra can be divided into three classes (their fraction in the complete sample is indicated in brackets):

1. Flat spectrum: $\alpha \geq -0.5$ (8%)
2. Steep spectrum: $\alpha < -0.5$ (91%)
3. Peaked spectrum (gigahertz peaked-spectrum sources, or GPS): with maximum, ν^α approximation is incorrect (1%)

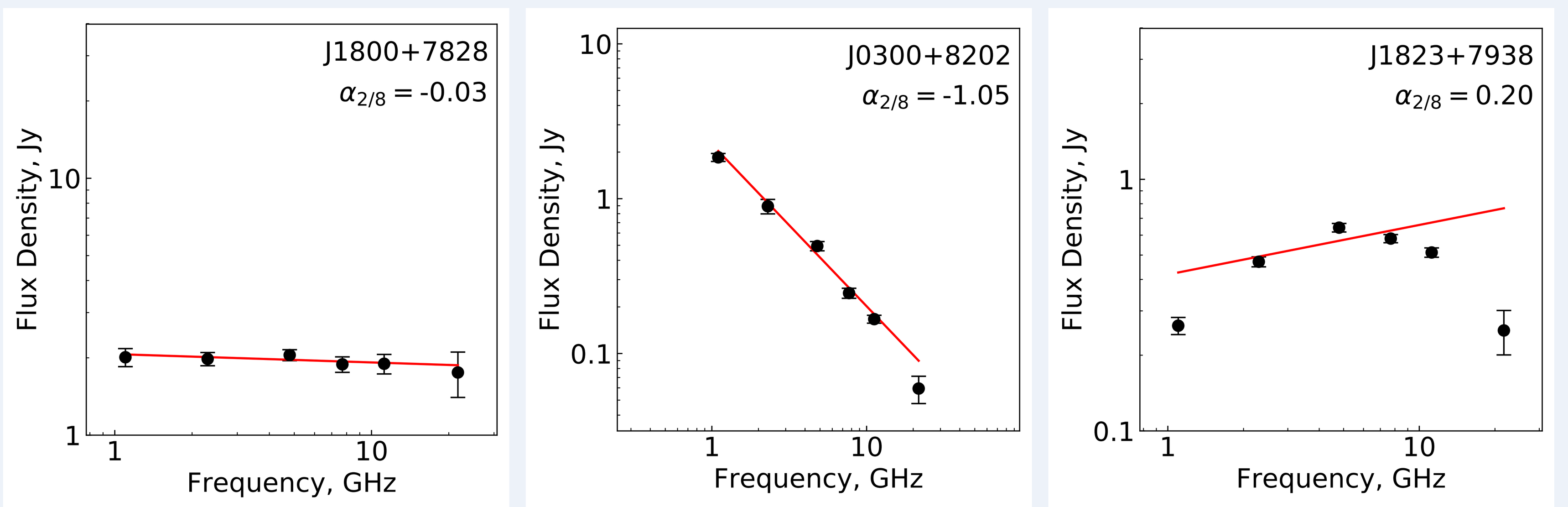

Figure 2: Examples of sources from the sample having flat, steep, and peaked spectrum.

References

Mingaliev, M. G.; Sotnikova, Yu. V.; Bursov, N. N.; Kardashev, N. S.; Larionov, M. G.; 2007, Astronomy Reports, 51, 343.

VLBA Detection vs. Type Of Spectrum

The presence of VLBA detection means that the source has correlated flux density at VLBA scales larger than the detection limit (20 mJy in our experiment). Therefore, it is an evidence of the source compactness.

Table 1: Fractions of the sources with VLBA detections in the complete NVSS flux density limited samples of objects with different shape of spectrum (percents).

Spectral type	Number of objects	VLBA detected of each type, %	
		2.3 GHz	8.6 GHz
Flat	40	100	98
Steep	444	25	14
Peaked	5	100	100

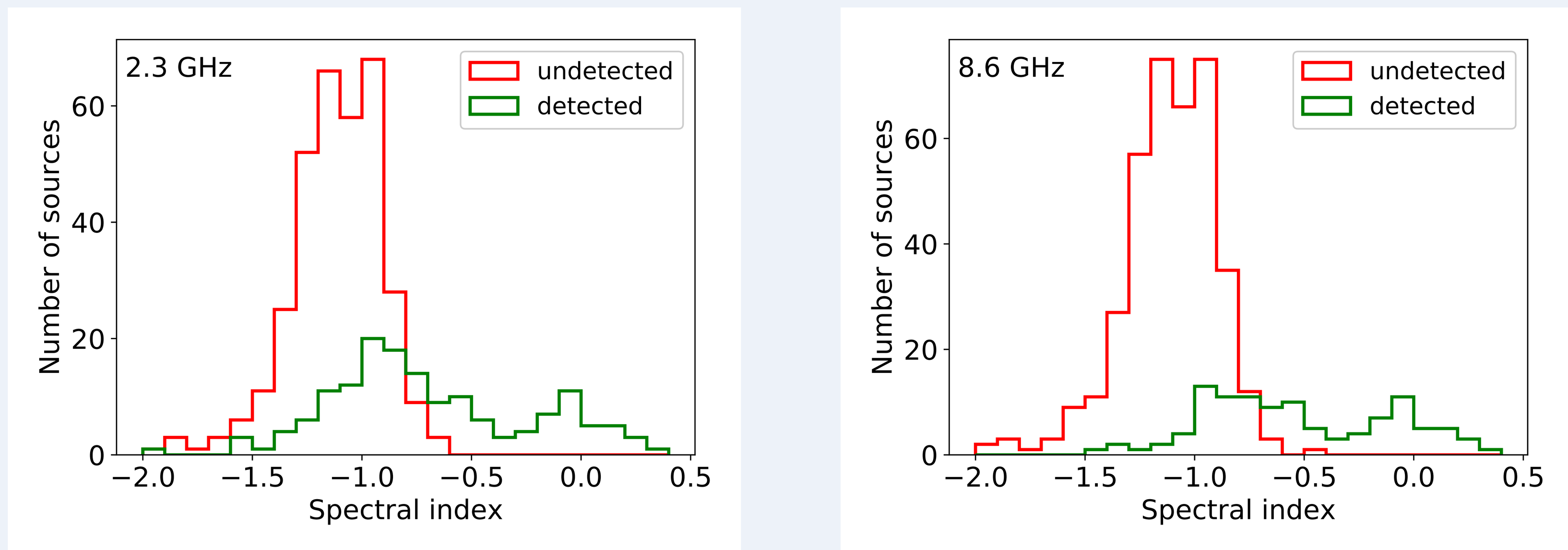

Figure 3: Number of sources in the complete sample not detected by VLBA (red) and detected by VLBA (green) vs. spectral index from RATAN-600 observations.

Compactness vs. Spectral Index

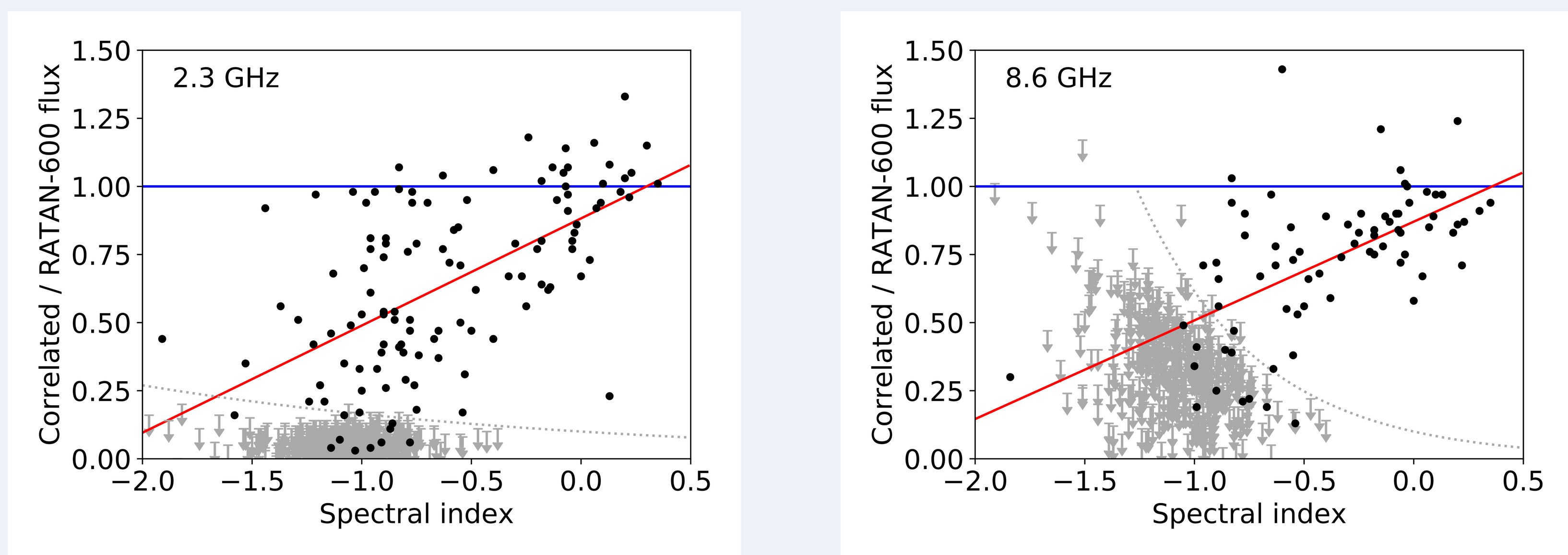

Figure 4: Relation between the compactness parameter, defined as the ratio of the total correlated VLBA flux to the RATAN-600 (integral) flux, and the spectral index (**black dots**). The two parameters show significant correlation (the least-square fit is plotted by **red line**). Upper limits for the sources not detected by VLBA are marked by **gray arrows**. **Blue line** marks the limiting compactness value of 1.0. Non-physical values of compactness > 1 are caused by the flux errors and sources variability (observations at VLBA and RATAN-600 were not simultaneous).

Size vs. Spectral Index

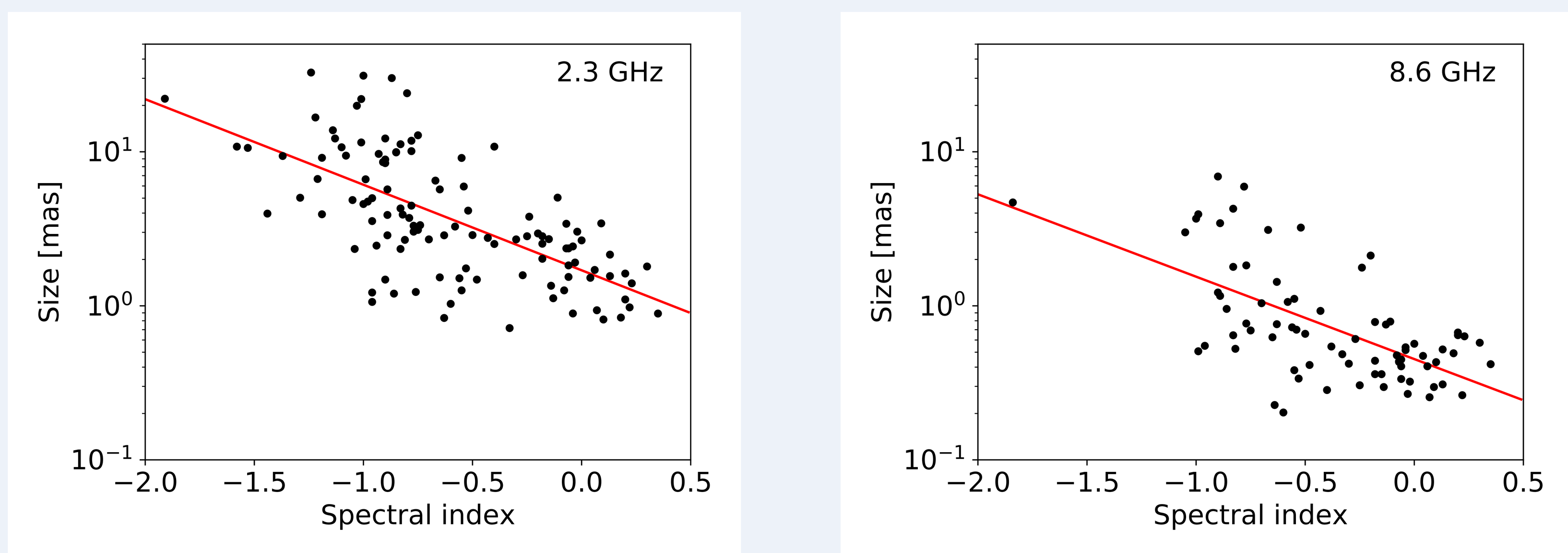

Figure 5: Relation between the size of the fitted Gaussian core and the spectral index (**black dots**). By the **red line** the least-square fit is plotted. This figure, as well as compactness vs. spectral index plot above, shows that flat spectrum sources tend to be more compact in general, however, significant fraction of steep-spectrum sources also has small size (and large compactness).