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Analysis of the update sample of USS objects and search of candidates to GPS sources in the RZF survey

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Abstract. A deep RATAN-600 Zenith Field (RZF) survey at wavelength $\lambda = 7.6$ cm on the declination of the 3C 84 radio source. In the center of the survey region, 448 objects were detected, and 73 of them have ultra-steep spectra (USS), which are the main indicator for finding possible candidates for distant galaxies. Optical identifications for 31 of the USS objects were made using the SDSS surveys have been used. It turns out that 23 objects are galaxies and 8 are star-forming objects. Photometric redshifts ($z_{\rm ph}$) and radio luminosities at 3.9 and 1.4 GHz ($L_{3.9}$ and $L_{1.4}$) are determined for 31 objects with spectral indices $\alpha < -1.1$, $S_\nu \sim \nu^\alpha$ for objects with published photometric data. In the sample of USS objects, 15 galaxies have $z_{\rm ph} < 0.5$, and 8 of them have relatively high $L_{1.4} > 10^{26}$ W/Hz of type FR II. Seven galaxies at $z_{\rm ph} > 0.5$ are also of type FR II. Five sources are of intermediate type FR I-FR II. Only three radio galaxies at $z_{\rm ph} < 0.5$ turned out to be a rare nearby galaxy with relatively low $L_{1.4} < 10^{25}$ W/Hz (FR I). These radio sources are either located in the dense intergalactic medium of rich clusters or are confined within their host galaxies. Almost all of these sources can be observed with the SAO 6-m telescope. Galaxies with $L_{1.4} > 10^{26}$ W/Hz (FR II) have magnitudes $18 < m_{\rm r} < 23$. The search for Gigahertz Peaked-spectrum (GPS) candidates in the RZF survey was performed, and 29 objects were classified as GPS candidates. The most sensitive radio and optical catalogs, a new blazar candidate catalog, Blazar Radio and Optical Survey (BROS) were used. We propose 7 new candidates for GPS sources and 5 new Megahertz Peaked-spectrum (MPS) sources based on their spectral shape and variability characteristics.

Keywords: surveys; radio continuum: general; radio continuum: galaxies; galaxies: active

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1 Introduction

Objects with ultra-steep spectra (USS) are of particular interest because they are an important selection factor in the search for distant radio galaxies (HzRGs). Such galaxies are usually powerful FR II type galaxies. They are often found in protocluster environments (Tielens et al. 1979). These objects may be associated with the first generation of super massive black holes. Powerful radio galaxies formed in the first 10% of the lifetime of the Universe have been found in very deep surveys at centimeter wavelengths with the RATAN-600 radio telescope (Goss et al. 1992). The spectral index-redshift relation is a key tool in the search for HzRG. Detailed studies were then published in Röettgering et al. (1994). These ones are the basis for important selection factors in distinguishing HzRG. However, the relationship between spectral curvature and redshift remains incompletely resolved. A new method to search for distant AGN with megahertz peaked-spectrum (MPS) sources has been proposed by Bursov et al. (2007). A near-zenith deep survey with RATAN-600 at $\lambda = 7.6$ cm (RZF) in the region $0^h \leq$ R.A. $\leq 24^h$, $40°30'42'' \leq$ Dec $\leq 42°30'42''$ revealed a number of USS radio galaxies (Pariiskii et al. 2019). They could be the candidates for very distant objects. We analyze the updated data of radio sources with USS ($\alpha \leq$ -1.1, $S_\nu \sim \nu^\alpha$), in the central strip of the RZF survey (Dec = $41°30'42'' \pm 2'$).

2 Investigation of the sample of USS sources

We analyzed 73 USS-objects from the sample of 448 sources in the central strip of the RZF catalog. Spectra of 18 objects were power-law shaped. Spectra of 6 sources were approximated with only two points at 1.4 GHz and 3.94 GHz. HzRGs had power-law shaped spectra and did not become steeper at high frequencies (Klamer et al. 2006). However, they can turn over at low frequencies due to synchrotron self-absorption (SSA) and free–free absorption (FFA) (Ker et al. 2012). 25 sources were MPS, suggesting that they could be represented as HzRGs (Coppejans et al. 2015). This sample of USS sources had relatively weak flux densities ($\overline{S}_{3.94} = 6.8$ mJy and $\overline{S}_{1.4} = 34.5$ mJy) at centimetre wavelengths. The flux-density ratio $S_{1.4}/S_{3.94}$ ranged from 1.5 to 10.5. Optical identifications of 31 USS objects were made with the SDSS (DR7, DR12). It turned out that 23 objects are galaxies and 8 are star-forming objects. The radio luminosity (L_ν) of the USS sources allows us to classify their possible nature: a radio galaxy, a radio-quiet AGN, or a star-forming galaxy. The photometric redshifts ($z_{\rm ph}$) for the 31 SDSS objects with color properties havee been determined using the PEGAS model. L_ν were calculated using the formula from Pariiskii et al. (2000).

The radio luminosities at 1.4 GHz ($L_{1.4}$) are in the range $1.51 \times 10^{24} \leq L_{1.4} \leq 17 \times 10^{27}$ W/Hz ($\overline{L}_{1.4} \sim 4.25 \times 10^{26}$ W/Hz). The galaxies with $L_{1.4} \geq 10^{26}$ W/Hz are FR II sources. The galaxies with intermediate $L_{1.4}$ $10^{25} \leq L_{1.4} \leq 10^{26}$ W/Hz can be classified as FR I – FR II objects or mixed FR I / FR.

Five sources with $z_{\rm ph} > 0.5$ and $L_{1.4} > 10^{26}$ W/Hz can be classified as radio-loud AGNs (Verkhodanov et al. 2009). Fifteen galaxies are FR II-type sources, with six of which are nearby objects $z_{\rm ph} < 0.5$). Four sources out of six with intermediate $L_{1.4}$ are nearby galaxies. Three of them with $L_{1.4} \leq 10^{25}$ W/Hz are of the FR I type. Such sources are very rare and are mostly found in regions of high baryonic density. A possible explanation is that nearby USS radio sources are almost exclusively located in rich clusters of galaxies.

3 The search of candidates to GPS objects in RZF survey

The gigahertz peaked-spectrum (GPS) and Compact-Steep spectrum (CSS) sources are compact, powerful radio sources with well-defined peaks ($\nu_{\rm int}$) in their radio spectra. The peaked-spectrum (PS) sources could be very young radio galaxies that will evolve into CSS sources on their way to becoming large radio galaxies. The PS and CSS sources could be compact because they are confined (and enhanced in radio power) by interaction with dense gas in their environments. Alternatively, PS sources may be transient or intermittent. There are 3 classes of objects adjacent to GPS, which differ in their spectral maxima: CSS with $\nu_{\rm int} < 0.5$ GHz, High Frequency Peaker (HFP) with $\nu_{\rm int} > 5$ GHz, MPS with ($\nu_{\rm int} < 1$ GHz). The peaks in the spectra are probably due to SSA, although FFA through an inhomogeneous screen may also play a role. GPS galaxies and quasars were researched with RATAN-600 (Sotnikova et al. 2019).

The most sensitive radio and optical catalogs, a new blazar candidate catalog, the Blazar Radio and Optical Survey (BROS), were used.

The search for candidates to GPS objects was carried out at RZF survey (N=745) and small sample of 21 of them turned out to be candidates to ones. Optical candidates for 21 RZF objects were found using the SDSS and GAIA surveys. Among the selected sources, 8 GPS objects are galaxies. 6 of the sources in the sample are QSOs, 2 of them turn out to be GPS objects. One source according to the BROS catalog is a candidate to GPS object - QSO. One is defined as AGN. 5 objects with $\nu_{\rm int} < 500$ MHz are CSS class, one with $\nu_{\rm int} > 5$ GHz is HFP, the rest are defined as MPS with $\nu_{\rm int}\ <\ 1$ GHz. Our sample is relatively weak with $\overline{S}_{3.9} = 52$ mJy. Spectral indices were found for 9 sources and photometric distances, L_{ν}, were calculated. The L_{ν} of the considered sources vary from 6×10^{42} erg/sec up to 2×10^{44} erg/sec.

4 Conclusion

Using the updated RZF catalog at 3.94 GHz, we detected 73 sources with steep spectra at Dec = $41°30'42'' \pm 2'$. Cross-identification with the optical surveys (SDSS DR7, DR12) was performed. Photometric redshifts were obtained for 31 objects. It was found that 23 sources are galaxies and 8 are star-forming objects, mainly nearby galaxies. These radio sources are either located in a dense intergalactic medium of rich galaxy clusters or are confined within their host galaxies. Fifteen galaxies with $L_{1.4} \geq 10^{26}$ W/Hz are FR II-type sources, objects with intermediate luminosities $10^{25} < L_{1.4} < 10^{26}$ W/Hz are of mixed FR I − FR II types. The remaining three galaxies with $10^{24} < L_{1.4} \leq 10^{25}$ W/Hz are rare USS FR I sources and are almost exclusively located in rich clusters of galaxies.

8 GPS objects turn out to be galaxies. 6 of the sources in the sample are QSO, 2 of them are GPS objects. 5 objects with $\nu_{\rm int} < 500$ MHz are CSS, 1 with $\nu_{\rm int} > 5$ GHz is HFP, the rest are MPS with $\nu_{\rm int} < 1$ GHz. Our sample is relatively weak with $S_{3.9} = 52$ mJy.

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References

Bursov N.N., Pariiskii Y.N., Maiorova E.K., et al., 2007, Astronomy Reports, 51, p. 197

Coppejans R., Cseh D., Williams W. L., et al., 2015, Monthly Notices of the Roy. Astron. Society, 450, p. 1477

Goss W.M., Parijskij Y.N., Soboleva N.S., et al., 1992, Astronomicekij Zhurnal, 69, p. 673

Ker L.M., Best P.N., Rigby E.E., et al., 2012, Monthly Notices of the Roy. Astron. Society, 420, p. 2644

Klamer I.J., Ekers R.D., Bryant J.J., et al., 2006, Monthly Notices of the Roy. Astron. Society, 371, p. 852

Pariiskii Y.N., Semenova T.A., Temirova A.V., et al., 2019, Astronomy Reports, 63, p. 212

Parijskij Y.N., Goss W.M., Kopylov A.I., et al., 2000, Astronomical and Astrophysical Transactions, 19, p. 297

Röettgering H.J.A., Lacy M., Miley G.K., et al., 1994, Astronomy and Astrophys. Supplement Series, 108, p. 79

Sotnikova Y.V., Mufakharov T.V., Majorova E.K., et al., 2019, Astrophysical Bulletin, 74, p. 348

Tielens A.G.G.M., Miley G.K., Willis A.G., 1979, Astronomy and Astrophys. Supplement Series, 35, p. 153

Verkhodanov O.V., Trushkin S.A., Andernach H., et al., 2009, Data Science Journal, 8, p. 34