Radiogalxies with flat spectrum lobes

1 Introduction

We know that usually radiogalaxies have a compact optically thick flat-spectrum core and one or two optically thin extended radiolobes with steep spectrum. Emission from radiolobes is very strong at low frequencies — iconic 3C catalogue was made based on 0.16–0.18 GHz observations, and noticeably fainter at 1.4 GHz. The total flux from a compact core dominates at frequencies 5 GHz and above. When we take a sample of sources selected at high frequencies, we expect to see only emission from the compact core, since emission from radiolobes will be attenuated by one order of magnitude at 20 GHz with respect to 1.4 GHz considering a typical spectral index[1] -0.8.

AT20G catalogue Murphy et al. (2010) lists 5890 sources brighter 40 mJy at $\delta < 0°$ at 20 GHz, with completeness 91% above 100 mJy. Of them 4727, or 80% have been followed up with VLBI and 4323 or 92% have been detected at 8 GHz above 10 mJy level. Reported position accuracy of AT20G is around $1''$, while the position accuracy of VLBI is 0.5–3 mas. Indeed, among 4331 AT20G sources detected with VLBI, 90% AT20G to RFC distances are less than $2''$ and only 3% exceed $4''$ (see Figure 1).

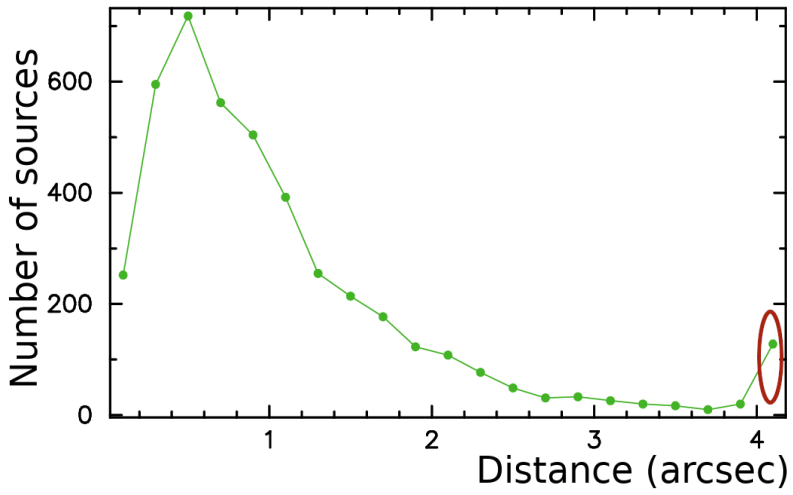

Fig. 1: The distribution of the distances between the AT20G position and VLBA positions from RFC catalogue. Red ellipse shows outliers.

Scrutinizing 83 outliers at declinations $> -40°$ with separations longer than $10''$ brought surprises. Of them, VLASS (Lacy et al. 2019) images were found for 81 objects. Among these 81 objects, 40 had no association on a VLASS images, 3 had association with apparently unrelated objects, and 38 had associations with radio lobes. Among these 38 objects, AT20G lists both the compact core and radio lobe only for AT20G J172034-005824 — they both are approximately equally bright at 20 GHz, while it shows position of only radio lobes for remaining sources. That means that the radiolobe is stronger at 20 GHz than the compact core for these 37 objects.

2 Problem statement

Results of AT20G/VLASS/VLBI comparison can be explained if we accept radio lobes have flat spectrum between 3 and 20 GHz. We found archive VLA image of AT20G J044436-280914 at 14 GHz

[1] Defined as $S \sim f^{+\alpha}$

Table 1: Proposed sources. F_n — total NVSS Condon et al. (1998) flux density at 1.4 GHz, F_t — integrated VLASS flux density at 3 GHz within $10.5'' \times 10.5''$ area, F_a — AT20G flux density at 20 GHz, F_v — VLBI flux density at 8 GHz. Sp ind — spectral index across 3–20 GHz. Units are Jy. *Note:* AT20G J021535-125928 was resolved at NVSS. Sum of fluxes NVSS 021535-125929 NVSS 021539-125933 is shown.

Name	Name	F_n	F_t	F_a	F_v	Sp ind
AT20G J021535-125928	RFC J0215-1259	4.68	0.84	0.314	0.010	**-0.51**
AT20G J044436-280914	RFC J0444-2809	3.26	0.49	0.221	0.029	**-0.41**
AT20G J080852-102831	RFC J0808-1027	2.76	0.28	0.131	0.026	**-0.40**
AT20G J094110-120451	RFC J0941-1205	0.34	0.05	0.044	0.030	**-0.07**
AT20G J105127-091751	RFC J1051-0918	0.96	0.22	0.139	0.077	**-0.24**
AT20G J120401-042247	RFC J1204-0422	2.14	0.42	0.296	0.039	**-0.18**
AT20G J205603-195646	RFC J2056-1956	2.73	0.29	0.159	0.020	**-0.31**
AT20G J213741-143241	RFC J2137-1432	2.42	0.49	0.256	0.098	**-0.50**

and its flux density at 14 GHz is consistent with VLASS/AT20G spectral index -0.41, i.e. flat spectrum. The core of that source is much weaker than the lobe at 14 GHz. We surmise the 37 sources from the AT20G sample belong to a rare class of lobes with flat spectrum. Since normally radio galaxies are selected on the basis of their flux density at low frequencies, may not be easily found.

We would like to confirm that these radio galaxies have unusual spectrum. We propose to observe them at 1.4, 3, 5, 8, 15, 22, and 43 GHz in order to compute spectral energy distribution (SED) and the turnover frequency of all components: radio lobes and the compact core. We anticipate that high resolution images at 15–43 GHz will reveal clues to the process that results in an usual SED, in particular to identify a hot spot and a diffuse emission. We surmise that it is a hot spot that may have flat spectrum, why the spectral index of the diffuse emission may be steeper.

We selected 8 radiogalaxies that have different shape and spectral index of their radiolobes in a range of $[-0.51, -0.07]$. All they are marked as extended in AT20G. If their flat spectrum will be confirmed, we will need examine possible explanations. One of the consequences of the existence of the population of flat spectrum radio galaxies is that they should be accounted in the population analysis. Statement "if we see a given source at high frequency, it is the core", may not be always true.

References

Condon, J. J. et al., AJ, 115, 1693
Lacy, M. et al., 2019, accepted by PASP, https://arxiv.org/abs/1907.01981
Murphy, T. et al., 2010, MNRAS, 402, 2403.

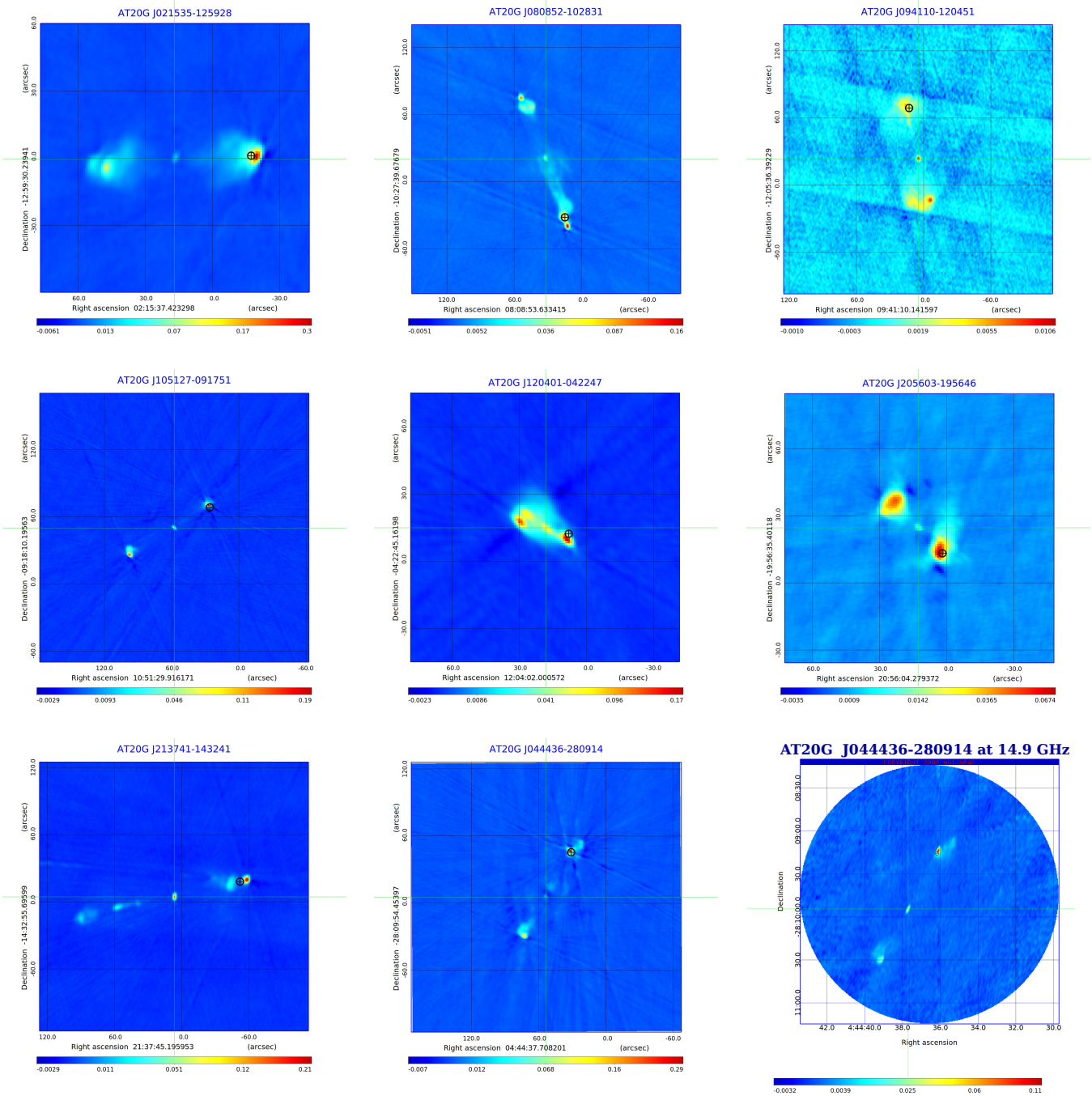

Fig. 2: Images of peculiar sources from VLASS (except the figure in the bottom right) at 3 GHz. The cross-hair in the center of an image shows VLBI position. $\oplus$ symbol shows AT20G position. The image in the bottom right corner is from archive VLA observations at 14 GHz.