1 Motivation

Analysis of early single dish radioastronomy blind surveys revealed that the source distribution over spectral index defined as $S \sim f^{+\alpha}$ is bi-modal with a peak at around -0.9 (steep spectrum population) and -0.2 (flat spectrum population). This is generally accepted that sources from the second population, also known as flat spectrum radio sources or flat spectrum radio quasars (FSRQ), are compact AGNs powered by the synchrotron emission. VLBI surveys of flat-spectrum radio sources with $\alpha > -0.5$ showed that most of them have high compactness defined as the ratio of the correlated flux density at milliarcsecond resolutions from flux density at 10–100″ resolutions. But then a curious student may ask: what about steep spectrum sources with $\alpha < -0.5$? Are they AGNs? Deep VLA surveys, f.e. Condon et al. (2012) provides the answers: all observed radio sources, regardless of their spectral index, with flux densities down to 1 mJy are mainly AGNs. Are they compact? We can answer this question: some of them have compact core. How many? And then we stumble. Known VLBI surveys have a heavy bias towards flat spectrum sources selected from parent single-dish or connected array catalogues. The VLBI surveys were optimized to provide the highest yield of detections, and flat spectrum sources were considered low hanging fruits. By 2014 the pool of known flat spectrum sources was mainly depleted. When we lifted selection of targets by the spectral index, we found that the detection rate was still around 50%. Now we know that detection of compact emission from of steep spectrum sources from surveys with 10–100″ resolutions is not an exception. But we still cannot answer even a simple question: how many steep spectrum sources are compact due to a heavy bias in known VLBI samples. Do flat spectrum sources form a distinct population in the AGNs zoo, or steep spectrum is just an indicator of the significant emission from the jet and extended radio lobes *in addition to* flat spectrum emission from the core?

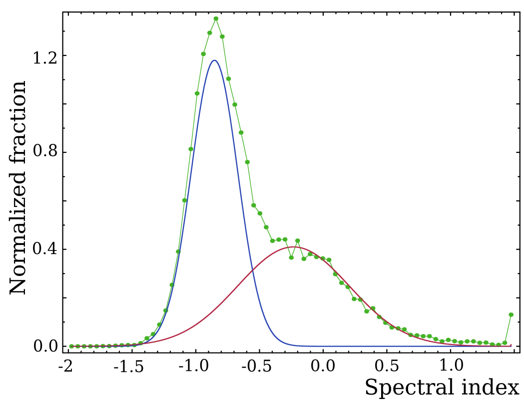

Fig. 1: The distribution of spectral indices between 4.85 and 1.4 GHz from GB6 and NVSS catalogues with resolutions 210″ and 40″ respectively (**green line**). **The blue line** shows the contribution of the steep spectrum source population, and **the red line** shows the flat spectrum source population.

2 Problem statement

It is not practical to conduct an unbiased all sky survey. However, it is within an arm reach to get a complete, unbiased flux limited sample in two relatively large areas. First, a zone with ecliptic latitude $\beta \in [-7.5^\circ, 7.5^\circ]$ was observed with the VLBI ecliptic plane survey (Shu et al. 2017). The parent catalogue is GB6 and the detection limit of the survey was 13–18 mJy. By 2019 only 616 sources brighter 70 mJy were not observed. Second, a zone with $\delta \in [-40^\circ, 0^\circ]$ was observed in a number of VLBI surveys with detection limit 10–12 mJy. Only 742 sources from the AT20G catalogue brighter 40 mJy were not observed with VLBI.

VLBA observations of missing 1358 sources will make two unbiased flux-limited samples of over 2000 sources each.

Table 1: Source count among the GB6 sample $|\beta| > 7.5^\circ$, $F_{4.85\ GHz} > 70$ mJy and AT20G sample $\delta > -40^\circ, F_{20\ GHz} > 40$ mJy.

Sample	# Tot	# Obs	# Det	# Non-det	# Targets
GB6	5756	5140	1958	3182	616
AT20G	3572	3830	2543	287	742
Total					1358

3 The goal of the project

4 Prior observations

5 Proposed VLBA observations

Analysis of prior VLBA surveys, such as VCS9 program for observing 10766 sources showed that the overall efficiency is about 17 sources per hour, including overheads for slewing and observations of atmospheric calibrators. Therefore, we request in total 84 hours at wide C-band receiver, at 4.3 and 7.6 GHz subbands simultaneously for observing 1358 targets in one scan of 60 seconds at 2048 Mbps in a mode used in VCS7–9 surveys (Petrov in preparation 2019[1] In order to optimize the use of the VLBA, we request 60 hours in the filler mode and six 4 hour blocks in the non-filler mode. The targets are uniformly distributed over right ascension, but the filler time available in 2012–2018 was not uniformly distributed. The filler time schedules will be generated by the array operators on-demand using the web-based tool that we have developed and used in past filler projects. Requested six 4-hour blocks are intended to cover the area that is inaccessible by the filler time. Since we do not know beforehand which area will not be covered with the filler time, we are going to schedule six 4-hour blocks after we use of 60 hours of filler time. Therefore, we ask to extend the project over two semesters.

As a commensal science, the newly detected sources in the ecliptic plane will be used for space navigation and VLBI observations of interplanetary spacecrafts. The newly detected sources from AT20G will be useful as ALMA calibrators since they are brighter 40 mJy at 20 GHz.

6 Data release plan

We wave the proprietary period. Images and source positions will be available from the project web site immediately upon processing, typically with a lag of one month of observations. Upon completion the project the the positions will augment the Radio Fundamental Catalogue and the images will be be submitted to the the Astrogeo VLBI FITS image database.

References

Condon et al., 2012, ApJ, 758, 23C
Shu F., et al. AJ Supl, 2017, 230:13 (10pp).

[1]See the on-line project report at http://astrogeo.org/vcs9