1 Introduction

2 Primary scientific goal

3 Secondary scientific goal: Population analysis

The secondary goal of the project is to investigate the relationship between compactness, spectral index at kiloparsec scale (angular size at arcsecond level), spectral index at parsec scale (angular size at milliarcsecond level), source size and its morphology at parsec scales from VLBA images and kiloparsec scales using VLA images from NVSS and VLASS. The key scientific questions are

- Which parts of an AGN dominates in emission at different frequencies and different resolutions?
- Can the spectral index be used as a discriminator of radio source properties? If yes, which properties and what are the eliminations?
- How different the statistics of VLBI detected sources drawn from flat-spectrum biased parent samples are different from the statistics drawn from unbiased samples? How many compact sources do we miss? For instance, CRATES catalogue of flat spectrum sources (Healey et al. 2007) was used by *Fermi* mission for associations of γ-rays sources with AGNs. How many AGN associations were missed due to the selection bias?

This will be achieved by analysis of four **complete** samples: 1) the Northern Polar Cap Survey drawn from NVSS (Condon et al. 1998) with flux density limit S(1.4 GHz) > 250 mJy, $\delta > 75°$; 2) Ecliptic band drawn from GB6 and PMN catalogues (Gregory et al. 1996, Wright et al. 1996) at ecliptic latitude $|\beta| < 7.5°$ and S(4.8 GHz) > 70 mJy; 3) AT20G sample Murphy et al. (2010)at $-40° < \delta < 0°$ and S(20 GHz) > 40 mJy; and 4) CLASS sample at $0° < \delta < 75°$ and S(8.4 GHz) > 50 mJy, spectral index $\alpha > -0.5$. In the current we will observe remaining flat-spectrum sources in order to reach completeness of our sample.

We will also observe remaining sources from CRATES catalogue brighter 50 mJy and $\delta > -40°$ that have not been observed before. CLASS is limited only to $\delta > 0°$, while CRATES is the all-sky catalogue. The main motivation is not to miss a gravitational lens or a close binary source in the declination zone $-40° < \delta < 0°$. CRATES is not complete, however observing CLASS and CRATES, we will extend the list of all *known* flat spectrum sources observed with VLBI and brighter 50 mJy at 8 GHz to the area $[-40° < \delta < +90°]$, i.e. 82% the sky. Since all known AT20G sources at $-40°$ have already been observed with VLBA, the list of VLBI detected sources with flat spectrum can be very high. Comparing statistics of detected and non-detected flat-spectrum sources in the declination zone $[0, -40°]$ and $[0, +40°]$, we will estimate the completeness of the sample of VLBI detected sources with flat spectrum in the $[0, -40°]$ zone. Its deviation from the complete sample will provide us a measure of flat spectrum sources missed in the AT20G sample.

We started observing flat spectrum sources in August 1984, and 36 years later we will be in a position to say that there are no known flat spectrum sources brighter 50 mJy at $\delta > -40°$ that have not been observed.

4 Proposed observations

Analysis of prior VLBA surveys, such as BP242 program showed that the overall efficiency is about 20 sources per hour, including overheads for slewing and observations of atmospheric calibrators.

Table 1: Sample of sources observed or to be observed with VLBI. The columns are: the total number of sources in the sample, the number of sources observed with VLBA, the number of of detected sources, the number of non-detected sources, and the number of remaining sources. A given source may be a member of more than one sample.

Sample	# Tot	# Obs	# Det	# Ndt	# Rem
NPCS	482	482	156	326	0
GB6+PMN	5780	5769	2198	3571	11
AT20G	3580	3571	3288	283	9
CLASS	5788	4696	4610	86	1092
CRATES	8521	6732	6504	228	1789
CRATES+CLASS	9496	7284	7049	235	1977

Therefore, we request in total 99 hours at wide C-band receiver, at 4.3 and 7.6 GHz sub-bands simultaneously for observing 1977 targets mentioned above in one scan of 60 seconds at 2048 Mbps in a mode used in VCS7–9 surveys (Petrov in preparation 2020[1]). In order to optimize the use of the VLBA, we request 79 hours in the filler mode and five 4 hour blocks in the non-filler mode. 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. The targets are uniformly distributed over right ascensions, but according to our experience, available filler time in not uniformly distributed. Requested five 4-hour blocks are intended to cover the area that is inaccessible for the filler time. Since we do not know beforehand which area will not be covered with the filler time, we are going to schedule five 4-hour blocks after we use 79 hours of filler time. Therefore, we ask to extend the project over two semesters.

5 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 positions will augment the Radio Fundamental Catalogue and the images will be be submitted to the the Astrogeo VLBI FITS image database.

References

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