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Source list adjustment for the population study of steep-spectrum radio sources

1 Introduction

Our project "Study of the population of the steep-spectrum compact radio sources" BP242 was accepted for 2019B semester. The project aimed observation with VLBA of 1350 target sources from two samples drawn from AT20G and GB6 catalogues to reach completeness at given flux density limits without a filtering according to spectral index. As a result, we expected to have three samples drawn from NVSS, AT20G, and GB6 that are observed with VLBI in prior projects and BP242. Statistics of detection and non-detection will be used for achieving scientific goals: to investigate the relationship between compactness, spectral index at kiloparsec scale (angular size at aresecond level), spectral index at parsec scale (angular size at milliarcsecond level), source sizes, and their morphology at parsec scales from VLBA images and kiloparsec scales using VLA images from NVSS and VLASS.

This project was suitable to the filler mode: we developed software for scheduling, and the array operator generates observing blocks using the back-end via web interface. However, according to our previous experience, there are zones that have low chances to be observed in the filler mode. Therefore, we requested to run 70% of the project in the filler mode and 30% in a non-filer mode. The TAC allocated 60 hours in the priority C and 24 hours in priority B.

2 Source list adjustment of BP242

We have processed all 14 segments, 65 hours, in priority C by 2019.12.12. The current project status and results are available at http://astrogeo.org/vcs10. We realized that we observed 99% target sources. Two factors contributed to higher than anticipated number of observed sources: 1) filler time blocks were allocated more favorably; 2) we have managed to improve efficiency of the scheduling procedure.

We have 19 hours that were allotted in priority B but not used. We proposed to make adjustment in the source list keeping the scientific goals intact. We request 24 hours in priority B (as it was allotted, but not yet used) and ask for 24 hour extra time in priority C, thus changing original request of the filler time from 60 hours to 84 hours.

2.1 Extension of the source list in the ecliptic band

We have identified 920 sources in right ascensions 14.0 – 22.0 hours within 7.5° of the ecliptic plane that were observed at a three station CVN network and not detected, but were not previously observed with VLBA. We would like to observe them within 24 hour of priority B. This list is a subset of the bigger list of 5756 objects that were observed with CVN in the framework of the VLBI Ecliptic Plane Survey (VEPS). BP242 observed 616 objects that VEPS did not observed, but we did not re-observe those VEPS sources the CVN observed. There are several factors that prompted us to re-observe *some* VEPS source:

1. We assume the detection limit of VEPS is around 20 mJy (10 mJy in BP242). We would like to make a robust assessment of the VEPS detection limit using VLBA observations as the ground truth.

2. VEPS observed each target in two scans at a 3-element network. A failure of two antennas will result in a false negative. We would like to evaluate the rate of false negative.

3. We used positions from our parent catalogue GB6 as a priori. In September 2019, after we started BP242 observations, VLASS images that cover over 95% of our survey area have been released. Many sources in BP242 were detected far away from the a priori position: 20″–200″. Although short accumulation periods and high spectral resolution reduced losses due to smearing to the minimum, the failure in detection because the target was on the edge of the main beam need to be assessed. We will use VLASS a priori positions for the remaining observations.

4. We would like to make an independent check of flux density estimates from the CVN.

5. The CVN observations were made only in X-band. BP242 observations are made in 4.1/7.4 GHz. We would like to use spectral index of the core in our analysis.

6. It will be beneficial for the goals of our project to have more sources with images in order calibrate CVN detection statistics. The CVN provided from 1 to 2 scans of a 3-element array, which is not sufficient for making images.

2.2 Extension of the source list in the polar cap

Our scientific analysis will be based on processing three samples drawn from the NVSS, GB6, and AT20G. We have observed with VLBA the NVSS sample of 504 sources brighter 250 mJy at $\delta > +75^\circ$ in 2006 (project BK130) at 256 Mbps. Comparison of positions of detected sources with VLASS showed that many of them were found at large distance from a priori positions. We do not know how many sources were not detected not because their correlated flux density is below the limit that we assume in our analysis, but because of beam attenuation, time and bandwidth smearing. The limitations of the hardware correlator caused noticeable bandwidth and time smearing. Therefore, we propose to observe 429 sources that were not detected at X-band in BK130 using a priori from VLASS.

The purpose of these observations:

1. Assess robustness of detection statistics from previous narrow-band observations.

2. To re-assess sources detected in S-band only in BK130: we lost detection at X-band for some sources because of poor a priori, not because their X-band correlated flux density is below the detection limit, and we want to know how many sources were affected.

3. To homogenize detection limit for all three samples: NVSS, GB6, and AT20G. At the moment, detection limit of the GB6 and AT20G samples from CVN+VLBA observations is at least 20 mJy, but it is 35 mJy from the NVSS sample.

Since these sources are at declination above 75 degrees, they are well suited for filler time.

2.3 Why director discretion time

We take great care to use the precious VLBA resource in the most efficient way. That is why we routed 70% requested time into the filler mode. We anticipated that after finishing the filler part, we will need re-evaluate scheduling because it is not possible to predict which sources will be observed in the filler time and which will not. And that is just happened. Emergence of VLASS catalogue which impact on the goals of our project exceeded our expectations prompted us to increase the source list in order to maximize the scientific output.

The TAC commented on BP242: "Proposal weaknesses: There was some concern about the limited additional number of sources to be studied compared to the sizes of existing catalogues." We do our best to address TAC comments by spending as little as possible additional resources.

We asked 6 hours more in priority B because an additional session in the filler mode was scheduled than it was needed. It was already too late to cancel it when we learned it.

We wrote in BP242 proposal "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." Since it remained only one month before the end of semester, we ask not to cut off the project at 01 February 2020 and extend it in 2020A.

Our total request for this project, 49 hours, includes 19 hours that was allotted but not yet used for BP242.

We waive proprietary period. Results will be put on the project web page immediately.