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The Radio Fundamental Catalogue. I. Astrometry

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ABSTRACT

We present ...

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1. INTRODUCTION

Talk about DR1 vs DR2 Corr 1
paper I, paper II Corr 2
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2. OBSERVING CAMPAIGNS

VLBI observations are organized in a campaigns that can consider one or more campaign segments called also experiments. A target source or several target sources and several calibrator sources are observed for 1-12 hours in a typical astronomical VLBI experiment. A goal of such a dedicated experiment is to observe either a single source of interest or a small group (let us say, less than ten objects). Such sources are studied in detail at full sensitivity that is achieved for long integration time. This allows to reconstruct high fidelity images and/or get highly accurate source positions. In contrast, tens to hundreds sources are observed in a survey experiment, and a VLBI survey campaign may involve observations of several thousand sources. The goal of survey experiments is to study a population of sources. Inevitably, survey experiments use shorter integration time. That results in poorer images and worse position accuracy than in dedicated experiments, but for a much larger number of objects.

Most of the surveys fall into three categories: pathfinder surveys, follow-up surveys, and high-frequency extensions. The goal of pathfinder VLBI surveys is to detect target sources never observed with VLBI before, to determine their positions at a milliarcsecond level of accuracy, and to reconstruct their images. Since a small VLBI field of view, typically in a range of $10''$ to $5'$ at 2–24 GHz, a blind surveys would be very inefficient since a chance to detect a source with flux density 10–100 mJy are low. Therefore, source selected from those detected in prior connected radio interferometers at resolutions 1–$40''$ or single dish observations at resolutions $0.5'$–$5'$ and are observed in path surveys. Only a fraction of target sources is detected with VLBI pathfinder survey. Depending on the criteria used for source selection the fraction of detected sources, or the yield of the campaign is in a range of 5 to 98% with 59% being the median fraction.

The follow-up VLBI surveys target samples of the sources previously detected in prior pathfinder surveys in order to improve position accuracy or get a higher quality image. The sensitivity of radiotelescopes are higher in a range of 4–9 GHz and source flux density are usually falling with frequency. Therefore, chances to detect a source using given integration time are in general higher at lower frequencies. Sources detected at low frequencies are often followed-up with higher frequencies in the third type of surveys, called high-frequency extensions. The goal of these extensions is

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to get images of the sources at higher frequencies that better characterize the core region, evaluated the suitability of source as a calibrator at high frequencies, and in some cases to improve position accuracy.

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Pathfinder surveys:

1. VLBA Calibrator survey 1 (VCS1), (Beasley et al. 2002); VLBA BB023; S/X bands; 11 segments; since 1994.08.12 through 1997.08.27.
2. VLBA Calibrator survey 2 (VCS2), (Fomalont et al. 2003); VLBA BB071; S/X bands; 2 segments; since 2002.01.31 through 2002.05.14.
3. VLBA Calibrator survey 3 (VCS3), (Petrov et al. 2005); VLBA BP110; S/X bands; 3 segments; since 2004.04.30 through 2004.05.27.
4. VLBA Calibrator survey 4 (VCS4), (Petrov et al. 2006), VLBA BP118; S/X bands; 3 segments; since 2005.05.12 through 2005.06.30.
5. VLBA Calibrator survey 5 (VCS5), (Petrov et al. 2006), VLBA BK124; S/X bands; 3 segments; since 2005.07.08 through 2005.07.20.
6. VLBA Calibrator survey 6 (VCS6), (Petrov et al. 2008), VLBA BP133; S/X bands; 3 segments; since 2006.12.18 through 2007.01.11.
7. VLBA Calibrator Densification 7 (VCS7), (Petrov 2021); VLBA BP171; C/X bands; 17 segments; since 2013.02.08 through 2013.08.01.
8. VLBA Calibrator Densification 8 (VCS8), (Petrov 2021); VLBA BP177; C/X bands; 10 segments; since 2014.01.07 through 2014.02.23.
9. VLBA Calibrator Densification 9 (VCS9), (Petrov 2021); VLBA BP192; C/X bands; 99 segments; since 2015.08.07 through 2016.09.07.
10. Study of the population of steep-spectrum compact radio sources, 1st part (VCS10); VLBA BP242; C/X bands; 19 segments; since 2019.07.24 through 2020.02.11.
11. Study of the population of steep-spectrum compact radio sources, 2nd part (VCS10); VLBA BP245; S/X bands; 6 segments; since 2020.03.02 through 2020.03.23.
12. Completion of Surveys for a Gravitational Lens Search to Explore Dark Matter (VCS11), PI: T. Readhead; VLBA BR235; 18 segments; since 2020.09.11 through 2021.02.16.
13. Northern Polar Cup Survey, Popkov et al. (2020); VLBA BK130; X band; 3 segments; since 2006.02.14 through 2006.02.23
14. A systematic search for inspiraling, binary, and recoiling black holes in nearby galaxies (V2M), Condon et al. (2017); VLBA BC191, BC196, BC201; X band; 94 segments; since 2010.07.15 through 2012.06.05.
15. The VSOP Pre-launch VLBA Observations (VLBApls), (Fomalont et al. 2000); VLBA BH019; C band; 1 segment; 1996.06.05.
16. BB041, PI: T. Beasley; VLBA BB041; S/X bands; 2 segments; since 1995.06.25 through 1995.02.16.
17. Compactness of Weak Radio Sources at High Frequencies, (Majid et al. 2009); VLBA BM252; X-band; 2 segments; since 2006.11.06 through 2006.11.13.
18. VLBA Imaging and Polarimetry Survey at 5 GHz, (VIPS), (Helmboldt et al. 2007; Petrov & Taylor 2011); VLBA BT085; C-band; 16 segments; since 2006.01.03 through 2006.08.12.
19. Low Luminosity gamma-ray blazars (Linford et al. 2012); VLBA S2078, BT110; C-band; 7 segments; since 2009.11.22 through 2010.07.30.

20. 1FGL Active Galactic Nuclei at parsec scales, PI: Y. Kovalev; VLBA S3111; X-band; 3 segments; since 2010.12.05 through 2011.01.09.

21. 2FGL Active Galactic Nuclei at Parsec Scales, PI: Y. Kovalev; VLBA S4195; X-band; 3 segments; since 2013.05.07 through 2013.06.22.

22. 2FGL AGNs at parsec scales, 2nd survey, (Schinzel et al. 2015); VLBA BS241; X-band; 7 segments; since 2015.02.16 through 2015.07.01.

23. VLBI follow-up of Fermi sources, (Schinzel et al. 2015); VLBA S5272; X-band, 4 segments; since 2013.08.06 through 2013.12.05.

24. 3FGL at parsec scales, (Schinzel et al. 2017); VLBA S7104; X-band; 9 segments; since 2016.06.27 through 2016.07.26.

25. VLBA Survey of unassociated gamma-ray objects in the 7-year Fermi/LAT catalog, PI: F. Schinzel, VLBA BS262; C/X bands; 21 segments; since 2018.04.08 through 2018.07.24.

26. VLBA Survey of unassociated gamma-ray objects in the 7-year Fermi/LAT catalog, 2nd survey; VLBA SB072; C/X bands; 31 segments; since 2018.08.25 through 2019.02.17.

27. The VLBA Galactic Plane Survey (VGaPS), (Petrov et al. 2011a); VLBA BP125; K band; 3 segments; since 2006.02.04 through 2006.10.20.

28. The EVN Galactic Plane Survey (EGaPS), (Petrov 2012); EVN EP066; K band; 1 segment; 2009.10.27.

29. Detection of the background position noise due to non-stationary of the Galactic gravitational field, PI: L. Petrov, KVN GAJI; K/Q bands; 5 segments; since 2018.09.25 through 2018.12.29.

30. VERA Galactic Plane Survey, PI: L. Petrov; VERA; K band; 2 segments; since 2007.01.30 through 2007.03.21.

31. Asian VLBI Galactic Plane Survey, PI: L. Petrov; EAVN AP001; K band; 4 segments; since 2018.10.09 through 2019.01.28.

32. A search for high-frequency calibrators within 10 degrees of the Galactic center, PI: L. Petrov; KVN N20LP01; K/Q bands; 14 segments; since 2020.03.05 through 2020.06.16.

33. Searching for candidate radio sources for the GAIA astrometric link (OBRS-1), (Petrov 2011); VLBA+EVN GC030; 1 segment; 20080307.

34. Searching for candidate radio sources for the Gaia astrometric link and Global VLBI observations of weak sources (OBRS-2), (Petrov 2011); VLBA+EVN GC034,GB073; 7 segments; since 2010.03.23 through 2012.05.27.

35. Search for SOuthern Fermi Unassociatied sources (SOFUS), PI: L. Petrov; LBA SOFUS; X-band; 2 segments; 2017.04.07 through 2017.07.10.

36. VLBI Ecliptic band survey with the CVN (VEPS-1), (Shu et al. 2017); CVN VEPS; X band; 17 segments; since 2015.02.13 through 2017.12.14.

37. Bessel Calibrator Search (BeSSel), (Immer et al. 2011); VLBA BR145; X-band; 34 segments; since 2009.11.16 through 2010.08.29.

38. Bessel Calibrator Search follow-on, PI: M. Reid; VLBA BR149; X-band; 13 segments; since 2012.08.07 through 2013.08.04.

39. The Bologna Complete Sample of Nearby Radio Sources, (Liuzzo et al. 2009); VLBA BG069, BG094, BG158; 2 segments; since 1997.04.06 through 2000.01.22.

40. Densification of the International Celestial Reference Frame: Results of EVN Observations, (Charlot et al. 2004); EVN EC013, EC017; S/X bands; 3 segments; since 2000.05.31 through 2003.10.17

41. A VLBA Survey of Flat-Spectrum FIRST Sources, (Ulvestad et al. 1999); VLBA BU007; C band; 1 segment; 1996.12.19

42. Caltech Jodrell Bank snapshot survey, (Britzen et al. 2007); VLBA BB119; C band; 3 segments; since 1999.11.21 through 1999.11.26.

43. LBA Calibrator Survey-1 (LCS–1), (Petrov et al. 2011b); LBA V254, V271; X band; 4 segments; since 2008.02.05 through 2009.12.12

44. LBA Calibrator Survey–2 (LCS–2), (Petrov et al. 2019); LBA V271, V441, V493; X band; 14 segments; since 2010.03.11 through 2016.06.28.

    Astrometric follow-ups:

45. Regular Geodesy with VLBA (RDV), (Petrov et al. 2009), VLBA RV, RDV, BR, TC, BW, RDG, WAP, CN18, CN19; S/X bands; 189 segments, since 1994.07.08 through 2020.07.07.

46. S/X Astrometry Program, (Fey & Charlot 1997), VLBA BF025; S/X bands; 2 segments; since 1997.01.10 through 1997.01.11.

47. VLBA Ecliptic Plane Survey (VEPS-1), (Shu et al. 2017); VLBA BS250; S/X bands; 4 segments; since 2016.03.22 through 2016.05.19.

48. VLBA Ecliptic Plane Survey 2 (VEPS-2), PI: F. Shu; VLBA BS264; S/X bands; 6 segments; since 2018.03.21 through 2018.06.15.

49. VLBI Ecliptic Plane Survey followup, PI: L. Petrov; CVN VEPS-F; S/X bands; 2 segments; since 2018.01.24 through 2018.02.10.

50. Probing milliarcsecond optical structure through VLBI observations of Gaia detected AGNs, PI: L. Petrov; VLBA BP222,BP236; X/S bands; 38 segments; since 2018.05.15 through 2020.04.19.

51. Revealing milliarcsecond optical structure through VLBI observations of Gaia detected AGNs at Southern Hemisphere, PI: L. Petrov; LBA V561; S/X bands; 2 segments; since 2017.06.16 through 2018.03.14.

52. Second epoch VLBA Calibrator survey (VCS-II) (Gordon et al. 2016); VLBA BG219; S/X bands; 9 segments; since 2014.01.04 through 2015.03.17.

53. Third epoch VLBA Calibrator survey (VCS-III); PI: A. Fey; VLBA UF001; S/X bands; 20 segments; since 2017.01.16 through 2017.10.21.

54. Fourth epoch VLBA Calibrator survey (VCS-IV), PI: D. Gordon; VLBA UG002; S/X bands; 24 segments; since 2018.01.18 through 2019.01.21.

55. SOuthern Astrometry Program, PI: L. Petrov; LBA AUA; S/X bands; 24 segments; since 2017.08.22 through 201.91.204.

    High frequency extensions:

56. K-band KVN calibrator survey, PI: J. A. Lee; KVN N13JL01, S14JL01; K-band; 7 segments; since 2013.09.04 through 2014.12.24.

57. K/Q survey, (Lanyi et al. 2010; Charlot et al. 2010); VLBA BR079,BL115,BL122,BL151,BL166; X/K/Q bands; 14 segments; since 2002.05.15 through 2011.02.05.

58. UD001 K-band astrometry, PI: A. de Witt; VLBA UD001; K band; 24 segments; since 2017.01.08 through 2018.07.22.

59. Improving the K-band Celestial Reference Frame in the North; PI: A. de Witt; VLBA BJ083; K band; 5 segments; since 2015.07.21 through 2016.06.20

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