3rd URSI AT-AP-RASC, Gran Canaria, 29 May – 3 June 2022

Current Deep Wide-field VLBI Surveys of the GOODS-North, COSMOS and SPARCS-North Fields.

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Imaging the entire primary beam of a short baseline array is simple but becomes more complicated at longer baselines due to several effects such as baselines non-coplanarity, smearing and the primary beam effects. Historically, VLBI imaging has been limited by the small field of view (FoV) that only covers a few central arcsecs at GHz frequencies. To image the entire primary beam and to increase the FoV of the VLBI, the ”Wide-Field VLBI” technique is being utilised and has facilitated the observational and computational demands of large deep field surveys which would otherwise be impossible [e.g., 4, 8, 9, 1, 5, 6, 12, 10]. This has been made possible by the development in software correlators and techniques such as the multiple phase centre correlation technique [3, 2, 7], the multiple source self-calibration [9, 11], corrections in the a-projection [13], widening bandwidths and super-computers which enable VLBI observations at extremely high spectral and temporal resolution.

i) Multiple phase centre correlation (MPCC) technique: VLBI is sky sparse and correlating blindly on the whole primary usually results in terabytes of data with ~99.9% noise. Instead, we corre-late simultaneously on multiple positions (phasecentres) pre-selected to cover either the entire primary beam or known radio sources. Therefore, a large number of phase centres can be correlated with high time and frequency resolution in a single correlation pass thereby targeting hundreds of objects in a single run. ii) Multi-source self-calibration (MSSC) technique: we use combined response (via uv stacking) of multiple targets detected across the FoV to derive self-calibration solutions for phase- referenced observations and for very faint (μJy) target sources. iii) Corrections for a-projection: implemented in the Image Domain Gridder (IDG) as part of the wsclean imaging package that corrects for primary beam response while gridding visibilities for heterogeneous arrays such as the EVN. It corrects for primary beam effects with smaller errors than other methods and can also be used to implement more complex beams (e.g. true frequency dependence) and other direction-dependent effects such as the pointing errors and TEC dispersion.

We present some of these techniques making the application of wide-field VLBI imaging possible. We also present some of our recent results from the deep wide-field VLBI surveys of: i) the GOODS-North with the EVN which presents the largest catalogue of VLBI detected sources in the GOODS-North and traces radio AGN to over 7-8 orders of magnitude in radio power and, identifies (46%) missing AGN–X-ray hosts [10]; GOODS-North with the VLBA which provides a comparison between contiguous uniform coverage vs. targeted phase centres using the MPCC technique (Roger et al., in prep, Njeri et al., in prep); discovery of supermassive black hole binaries in the COSMOS VLBA survey [6]; and, SPARCS-North field with the EVN+eMERLIN array which provides a high dynamic first-ever multi-resolution (10-100 of mas) view of the transition between diffuse SF and compact AGN radio emission in extragalactic radio sources (Njeri et al.b, in prep).

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