

Mining Mini-Halos with MeerKAT I. Calibration and Imaging

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Radio mini-halos are clouds of diffuse, low surface brightness synchrotron emission that surround the Brightest Cluster Galaxy (BCG) in massive cool-core galaxy clusters. In this paper, we use third generation calibration (3GC), also called direction-dependent (DD) calibration, and point source subtraction on MeerKAT extragalactic continuum data. We calibrate and image archival MeerKAT L-band observations of a sample of five galaxy clusters (ACO 1413, ACO 1795, ACO 3444, MACS J1115.8+0129, MACS J2140.2-2339). We use the CARACal pipeline for direction-independent (DI) calibration, DDFacet and killMS for 3GC, followed by visibility-plane point source subtraction to image the underlying mini-halo without bias from any embedded sources. Our 3GC process shows a drastic improvement in artefact removal, to the extent that the local noise around severely affected sources was halved and ultimately resulted in a 7% improvement in global image noise. Thereafter, using these spectrally deconvolved Stokes I continuum images, we directly measure for four mini-halos the flux density, radio power, size and in-band integrated spectra. Further to that, we show the in-band spectral index maps of the mini-halo (with point sources). We present a new mini-halo detection hosted by MACS J2140.2-2339, having flux density $S_{1.28 \text{ GHz}} = 2.61 \pm 0.31 \text{ mJy}$, average diameter 296 kpc and $\alpha_{1 \text{ GHz}}^{1.5 \text{ GHz}} = 1.21 \pm 0.36$. We also found a ~ 100 kpc southern extension to the ACO 3444 mini-halo which was not detected in previous VLA L-band observations. Our description of MeerKAT wide-field, wide-band data reduction will be instructive for conducting further mini-halo science.

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