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High Sensitivity Imaging at Low Radio Frequencies

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Low frequency radio astronomy (< 1 GHz) are impacted by radio frequency interference (RFI) and direction dependent calibration errors (DDEs) which limit the sensitivity and reliability of an observation.

Direction dependent calibration errors (DDEs) are systematic calibration errors that vary in time and direction on the sky. Several instrumental and atmospheric effects, e.g., non-isoplanatic ionosphere [1], azimuthally asymmetric antenna primary beam, time-dependent antenna pointing error [2] etc., cause apparent direction-dependent variation of the sky brightness distribution with time, antennas and baselines even for point sources. These variations results in a violation of the closure quantities which can introduce systematic errors in the imaging and calibration processes. They also violate the assumption implicit in most imaging and calibration algorithms of time invariance of the sky brightness distribution. Various research groups have developed algorithms that correct for one or more of the above errors. We propose here a new method to mitigate these time-varying residuals which is computationally inexpensive and conceptually straightforward. We first carry out a standard CLEAN procedure and generate residual visibilities. Since the errors are generated from the apparent variability of the sky (over a full synthesis observation) we implement the mitigation in both the image and the visibility planes for 5-10 minute segments of data at a time. In the image plane we identify up to 50 of the strongest sources whose residuals are likely to impact image quality and continue CLEANing in a very small box (1-2 beam widths) at their locations independently in each "snapshot", i.e. without subtracting identical components at all times. In the visibility plane we fit and subtract model (residual) fringes, if any, corresponding to the 3-5 strongest sources, independently in each baseline. While these procedures do not improve the reliability of the structures of these strong sources it does reduce their sidelobes across the field, resulting in a significantly lower noise floor and an improved detection of fainter sources.

Radio observations can be impacted by RFI from one or more of a variety of sources with different spectral and temporal characteristics including satellite transmission, mobile telephone signals, electric motors, sparking in transmission lines, etc. We have developed a novel algorithm (named IPFLAG) to identify and flag temporally intermittent (both narrow- and broad-band) RFI in interferometers [4]. Briefly, IPFLAG works by exploiting the redundancy in the 'gridded' UV plane (used while imaging). During a full synthesis observation, multiple baselines of the array can sample visibilities that fall within the same UV-cell [3]. The assumption is made that all the visibilities falling within a particular cell measure a similar sky brightness distribution, and hence any deviations that arise above the thermal noise must be due to RFI. In this manner, RFI can be identified and flagged on a per UV-cell basis, which preserves UV coverage and sensitivity to diffuse emission. A combination of the above methods has yielded reduction of up to 60% in image noise, and a significant improvement in the image fidelity and systematics.

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