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

Bluebild: A next generation radio interferometric imager applied to solar observations

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Our Sun and its million kelvin hot solar corona produce both coherent and incoherent radio emission that enhances our understanding of the solar atmosphere and associated magnetohydrodynamics. Observing the Sun in the radio regime is a difficult task due to the wide field-of-view, extended time scales, and extreme range of brightness temperatures of observable phenomena. The Murchison Widefield Array (MWA) is one of the ideal instruments for this task owing to its high spectral, time, and spatial resolution and unprecedented sensitivity. The current procedure for MWA solar studies involves calibrating and then imaging the visibilities observed from telescope observations. The imaging step is usually executed with software derived from the CLEAN family of algorithms. These algorithms calculate an approximate “dirty image”, assuming that all radio sources in the sky are point sources, and then iteratively subtract distortions called “dirty beam” around these points. There are two principal drawbacks to the continued use of the CLEAN family of algorithms for solar MWA observations - (1) Their iterative nature makes them unsuitable for the large datasets that the MWA produces and (2) they are not intrinsically suited to imaging morphologically complex features, such as those observed on the Sun.

We propose the Bluebild algorithm, which offers a more robust and efficient way to calculate the sky intensity distribution, as an alternative to the CLEAN family of algorithms. Bluebild is a spherical imager which has been developed for utilisation in interferometric applications. It uses principle component analysis to calculate the sky intensity matrix in a series of different energy levels or eigen-images. This allows for easy denoising through filtering low energy eigen-images and can also be used to study diffuse emission distinctly from strong emission by recombination of the eigen-images in statistically optimal ways. With low computational complexity and its strongly parallel execution, Bluebild is an excellent candidate for the next-generation of data-heavy radio-astronomy imaging. Given that the MWA can create up to 10^5 images of the sun per second, the Bluebild algorithm is an ideal imaging algorithm for the instrument, allowing for fast and efficient imaging of extended structures across different dynamic ranges, owing to easy separation of coronal emission into different eigenimages based on its origin.

We demonstrate the capabilities of Bluebild when run on solar radio maps of frequency between 100 and 240 MHz from the Murchison Widefield Array. These maps probe thermal bremsstrahlung in the solar corona. The Bluebild output image shows extended emission from the solar corona and compares favourably to the output from WSClean. Further, the extended emission from the solar corona is separated in Bluebild eigenimages, allowing for easier detection. These results show the advantages of the Bluebild algorithm over the CLEAN family of algorithms. Decomposition of interferometric observations into multiple eigenimages can thus be employed to aid in the detection and observation of other astrophysical phenomena, such as diffuse emission from galaxy clusters, where extended features are observed.