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Preparing for Solar and Heliospheric Observations with the SKAO

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Like for most other science areas, the Square Kilometre Array Observatory (SKAO) is expected to enable previously inaccessible solar and heliospheric science. The Sun is a surprisingly challenging radio source to image – it has structures spanning a large range of angular scales; the spectral, temporal, and morphological characteristics of the radio emissions are very dynamic; the brightness temperature associated with different emission mechanisms can vary from 10^3 K for gyrosynchrotron emission from CME plasma to 10^{13} K bright type III radio bursts and is superposed on a 10^6 K thermal emission background; and the polarization fraction can vary from <1% to near 100%. Additionally, as it is orders of magnitude brighter than the usual astronomical sources which sensitive modern interferometers are optimized for, and one requires special modifications to the signal chain to ensure meaningful solar observations. These characteristics of solar emission imply that capturing solar emissions with high fidelity requires spectro-polarimetric imaging with high time and frequency resolution and high imaging dynamic range. The SKAO is expected to provide unmatched full Stokes imaging performance even over narrow spectral and temporal slices and also provide other observing modes (e.g. beamforming modes) for higher time and frequency resolution observations.

The Solar and Heliospheric (SH) Science Working Group (SWG) of the SKA India Consortium (SKAIC) has been working in a systematic and sustained manner for more than a decade to prepare for enabling this science with the SKAO [1]. This has mostly taken the form of enabling solar observations with the low frequency precursor for the SKAO, the Murchison Widefield Array (MWA). It is located at the site of the SKAO-Low and has recently completed ten years of science operations. More recently we have been working on enabling solar observations with the mid frequency precursor for the SKAO, MeerKAT. MeerKAT is also located at the site of the SKAO-Mid and this 66 element array with a footprint of 8 km will be subsumed into the SKAO-Mid.

Our approach has been to first develop the tools to enable science and then use them to pursue carefully chosen science targets well matched to the strengths of the instruments and the newly developed analysis capabilities. We have successfully met the challenge of building unsupervised automated imaging pipelines for full Stokes snapshot spectroscopic imaging with the MWA. The outputs from these pipelines represent the state-of-the-art in metrewave solar imaging, marking improvements of one or more orders of magnitude in dynamic range, polarization purity, and fidelity. Our explorations of the novel phase space made accessible by these images have led to multiple interesting studies. These science projects have highlighted multiple previously unappreciated or unknown aspects of well-known active emissions. Some of them tackle challenging problems like detection of expected but weak gyrosynchrotron emission from CMEs and the discovery of the weakest impulsive nonthermal emissions from the quiet Sun reported yet. We have recently developed the capabilities to conduct solar observations with MeerKAT in the UHF and L bands and to conduct triggered solar observations with the MWA. These multifarious efforts are designed to form the necessary stepping stones to SKAO science. Alongside advancing the frontiers of scientific knowledge, we are also working to develop the human resource with the necessary scientific and technical skills. We are also working towards making available suitable analysis tools and generating interest in the larger community to make use of radio observables more mainstream and make the most of the SKAO when it becomes available.

It is worth highlighting that the Indian SH science community is particularly well poised for playing a leading role in this science area. Indian scientists have been leading solar science with SKAO-Low and more recently with SKAO-Mid precursors. They have also been leading the SKAO SH SWG since its inception.

1. D. Oberoi, “Preparing for Solar and Heliospheric Science with the SKAO: An Indian Perspective,” *Journal of Astrophysics and Astronomy*, **44**, 1, June 2023, pp. 1-34, doi:10.1007/s12036-023-09917-z.