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The MeerKAT Data Challenge & The CARACal Pipeline

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1 Extended Abstract

The MeerKAT radio telescope [1] is a new instrument constructed in the Karoo desert of the Northern Cape province of South Africa. MeerKAT was inaugurated in mid-2018, and has already begun science operations. MeerKAT is a 64-element interferometer array with a maximum baseline of 8 km. A 20-dish "MeerKAT+" extension, a joint project with Germany, will be added to the array in the near future, increasing the maximum baseline to 18 km. Each element of the array consists of a fully steerable 13.5 m offset Gregorian dish, with a feed indexer providing space for up to four receivers. L-band (900–1670 MHz) and UHF-band (580–1015 MHz) receivers have been fully commissioned, while S-band (1750–3500 MHz) receivers are undergoing installation. The MeerKAT correlator is capable of producing full-band data in 1024-, 4096- and 32k-channel modes. The first MeerKAT Open Time call in 2019 resulted in over 30 projects being awarded telescope time. The results of a second open time call were being evaluated as this abstract was being submitted.

Thanks to its extremely sensitive cryogenic receivers, a single MeerKAT dish has an SEFD at L-band that is comparable to a (much larger) VLA dish. Effectively, MeerKAT provides the spatial frequency coverage of VLA's B+C+D configurations combined (MeerKAT+ will push this close to even A-configuration), with a larger field of view (FoV), a similar per-baseline sensitivity, and about twice the number of baselines (with most of the surplus occurring at short baselines). This makes it particularly sensitive to extended low surface brightness emission.

As a Square Kilometre Array (SKA) precursor instrument, MeerKAT provides a number of challenges, dealing with which paves the way towards the SKA. While the offset Gregorian optics ensure that DDEs due to primary beam (PB) rotation are mitigated, the large FoV, bandwidth, and extreme sensitivity of the telescope mean that second-order instrumental effects are easily detectable, and can limit the achieved science if not calibrated properly. Extended emission is detected in almost every field, and can present a thorny deconvolution problem. Finally, the sheer volume of data coming from the instrument ($\sim$0.25 Tb per hour, in the more "economical" 4k-channel mode) can be a major computational problem.

In recent years, largely due to the pressure of other SKA precursors and pathfinders, many novel software packages have been developed in the community to address various aspects of the above problem. However, no software package offers an end-to-end solution (the ubiquitous CASA comes closest, implementing many of the necessary processing steps, but lacks some specific calibration and imaging functionality). We have therefore found it necessary to develop heterogeneous data processing pipelines, composed of a patchwork of packages from different sources. This effort has resulted in the Containerized Automated Radio Astronomy Calibration (CARACal) pipeline [2], jointly developed by SARAO, Rhodes, INAF-OAC, ASTRON, U. Bochum and others. CARACal aims to combine best-of-breed data processing and visualization packages into a single pipeline framework, by wrapping them into a series of isolated software containers that, in principle, can be deployed on any system with minimum software dependencies. CARACal is now being routinely applied to MeerKAT open time data (e.g. [3]), as well as data from other telescopes.

References

[1] J. Jonas and MeerKAT Team, "The MeerKAT Radio Telescope", *Proceedings of MeerKAT Science: On the Pathway to the SKA*, Jan. 2016, p. 1

[2] G. Józsa et al., "CARACal: The Containerized Automated Radio Astronomy Calibration Pipeline", in *Astronomical Data Analysis Software & Systems XXX*, ASP Conf. Ser., in press

[3] M. Ramatsoku et al., "Collimated synchrotron threads linking the radio lobes of ESO 137-006", 2020, Astronomy & Astrophysics Letters, 636, L1