Section A: Overview of the Research Project Proposal

1. Title: **Mining MeerKAT data for scintillators**
2. Broad field of research: **Science**
3. Academic level of research project: **Doctoral**
4. **Abstract:** Interstellar scintillation reveals small-scale structures in the interstellar medium that are difficult to detect by other means. Yet these small-scale structures may hold a significant fraction of the Galaxy's baryonic matter. In this research proposal, the candidate will analyse archival MeerKAT datasets to search for variability on timescales of minutes to hours over the entire field of view. This is expected to reveal rare rapidly scintillating sources, enabling mapping of nearby interstellar scattering structures within ~10 parsec of the Sun.
5. Primary supervisor: **Prof Oleg Smirnov,** o.smirnov@ru.ac.za,
Rhodes University & SARAO
6. Research supervisor: **Dr Hayley Bignall,** Manly Astrophysics (Australia)

Section B: Research Project Proposal

Scientific merit: Sufficiently compact radio sources twinkle, or scintillate, due to scattering in the interstellar medium of the Milky Way. A tiny fraction of these sources exhibit very rapid scintillations – intra-hour variability, rather than the more typical characteristic timescales of days to weeks for refractive interstellar scintillation. In the past few years, widefield instruments operating at 21-30 cm wavelengths, namely Apertif at Westerbork and ASKAP, unexpectedly discovered a number of intra-hour variable (IHV) quasars, including a line of IHV sources revealing a narrow plasma filament. Such rapid variability is most likely caused by scattering within a few parsec of the Sun. Various suggestions have been proposed for the origin of the scattering material, including plasma confined in filaments radially oriented around a hot star; partially ionized cold tidal streams from disrupted hydrogen snow clouds; or structures in the Oort cloud. Understanding the origin of the scattering "screens" may help solve the problem of missing matter, since for example a large population of tiny hydrogen snow clouds would contain a large number of baryons. Such small-scale structures are difficult to detect except by their influence on background sources. Identifying a larger number of IHV sources and determining how they are clustered on the sky would allow detailed study of the population of nearby scattering screens. Although MeerKAT has a smaller field of view than ASKAP or Apertif, it offers exquisite sensitivity, and is accumulating a large amount of data suitable for searching for IHV. With optimal calibration, the search can go much deeper than any existing IHV studies, revealing more faint scintillators. This will allow regions with nearby scattering material to be clearly demarcated on the sky.

Feasibility: Recent work on the RRAT/transient discovery in the Jupiter field (Smirnov et al., in prep.) shows that MeerKAT is capable of measuring lightcurves en masse, across any field, with exquisite sensitivity at the raw visibility sampling rate (i.e., <200 uJy at 8s cadence). This opens up timescales not accessible to any other instrument, and means that any given MeerKAT observation can be commensally mined for fast scintillators, with appropriate pipelines developed during the course of this project, relying on the expertise available within the RATT group.

The commensal nature of this investigation means that a wealth of existing MeerKAT data can be readily exploited, including any Open Time data already available to RATT, as well as a number of Legacy Survey fields. In particular, the following datasets have already been backed up to the RATT cluster (as part of other projects), and will not require access to MeerKAT's tape archive:

- A large fraction of the Galaxy Cluster Legacy Survey pointings
- Several pointings from the Galactic Plane Legacy Survey
- ESO 137, Pictor A, multiple pointings from the Old Devils (Fanaroff et al.) project, A141, Shapley concentration, PGC75143, Mini-halo samples
- Multiple RRAT (& Jupiter) follow-up pointings

Storage and computing resources for this project will be provided by the compute cluster of the Rhodes Centre For Radio Astronomy Techniques & Technologies (RATT).

Timeline

Months 1-12 – literature review, familiarization with existing transient search pipelines

Months 6-18 – development of updated transient detection techniques tuned for the discovery of scintillators;

Months 12-24 – write-up of paper discussing transient search pipelines and initial results;

Months 18-30 – full pipeline processing of available fields;

Months 24-36 – thesis write-up.

Link to SARAO research priority areas for 2023: The proposed research project will exploit a wide variety of MeerKAT data.

Any particular qualifications, academic abilities, skills and/or experience that a student should have in order to successfully deliver on the objectives of the research proposed: familiarity with radio interferometry and observational radio astronomy would be an advantage but it is not strictly required.

Supervisor

Oleg Smirnov 22 February 2023