Section A: Overview of the Research Project Proposal

1. Title: **New and known mini-halos in the MeerKAT GCLS. Observed properties and statistical studies**
2. Broad field of research: **Science**
3. Academic level of research project: **Doctoral**
4. **Abstract:** Mini-halos are sources of diffuse radio emission found at the core of certain galaxy clusters. Due to their small angular size and low brightness, relatively few have been discovered thus far, but their origin poses a number of interesting astrophysical problems. The MeerKAT Galaxy Cluster Legacy Survey has provided a substantial increase in the number of such sources known. This project aims to follow up on this discovery, and perform an in-depth analysis of MGCLS mini-halos.
5. Primary supervisor: **Prof Oleg Smirnov,** o.smirnov@ru.ac.za, Rhodes University & SARAO
6. Research supervisor: **Dr Tiziana Venturi,** INAF-IRA (Italy)

Section B: Research Project Proposal

Scientific merit. Mini-halos are diffuse steep-spectrum sources typically extended a few hundreds of kpc, and located in the core regions of cool-core relaxed clusters. Such sources pose the problem of the origin of relativistic electrons, whose radiative lifetime is considerably shorter than the diffusion time, hence requiring some form of in-situ re-acceleration. At present, these sources are explained in the framework of sloshing-induced re-acceleration in the central regions of relaxed clusters, where sloshing generates by gravitational interactions which would not disrupt the cluster cool core.

Due to their observational properties (mainly peak brightness and angular size), mini-halos are more difficult to discover compared to the other diffuse cluster scale radio sources (halos and relics), and as a matter of fact, they are fewer in numbers.

The MGCLS has provided a substantial addition to the number of mini-halos known, in particular, three new mini-halos and seven candidates were detected. This increases the number of the current known mini-halos by almost 30%, hence a revision/update of the statistical properties is crucial to investigate the origin of such sources and their relevance in the framework of mass assembly in the Universe.

The proposed PhD project aims to perform a detailed study of the new detections with the following objectives:

1. Derive the observational properties of the new mini-halos;
2. Confirm the nature of the candidate mini-halos;
3. Revise the statistics of mini-halos with the inclusion of the new detections to study the systems in the context of the theoretical models for their formation;
4. Plan follow-up observations with MeerKAT and/or uGMRT in the radio band, and Chandra in the X-ray, to complement the existing information and perform a multiband analysis of the systems to characterize their dynamical status and feed these pieces of information on the current models for the mini-formation in the framework of mass assembly in the Universe.

To address objectives 1 and 2, the information available from the MGCLS will be used. In particular, total intensity images, polarization information and in-band spectral imaging will be enough to perform a detailed characterization of the sources.

To address objective 3, the available literature information will be used as starting point, and the new detections will be included.

To address objective 4, first of all, further radio and X-ray data will be searched in the existing multiband data archives (MeerKAT, uGMRT, VLA, GLEAM, Chandra, XMM) and depending on the missing information, new time requests will be submitted to the relevant observatories.

Timeline

Months 1-12 – Inspect the MGCLS images (total intensity, in-band spectral index and polarization) to objectives points 1 and 2 and provide a full characterization of the sources;

Months 13-16 – Search for existing radio and X-ray data in the archives (objective 4); data reduction and analysis;

Months 17-20 – Proposal preparation to complement the existing information for a complete multiband study;

Months 21-24 – First paper on the outcome of objectives 1 and 2;

Months 25-30 – Revised statistics and comparison with the theoretical expectations (objective 3). Collection of new data from the multiband proposals.

Months 31-36 – Data analysis for the new data, second paper on the statistics and plan for future work.

Feasibility: MGCLS data is already available, and is also already partially stored at Rhodes for reprocessing in the context of other projects.

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

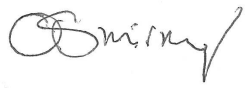
Scientific supervision of the project will be provided by Dr Venturi (INAF-IRA, Italy), and technical supervision by Prof Smirnov (Rhodes). The student is expected to spend some time in Italy at INAF-IRA and Dr Venturi will pay regular visits to South Africa. The supervisors will be able to provide further support for such visits.

Key collaborators / co-supervisors: Dr K. Kolokythas (NWU), Dr K. Knowles (Rhodes).

Link to SARAO research priority areas for 2023: The proposed research project will exploit MeerKAT GCLS 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