Section A: Overview of the Research Project

1. Title of the research project:
Spectral studies of MERGHERS cluster sources

2. Broad area of research:
Science

3. Academic level of research project:
Doctoral

4. Abstract of research project:
The MeerKAT Exploration of Relics, Giant Halos, and Extragalactic Radio Sources (MERGHERS) project is a planned large-scale radio cluster follow-up, observing ~200 clusters over a wide range of mass and redshift. The first tier data for MERGHERS is in-hand and producing new diffuse emission detections. To understand the electron populations seeding the diffuse synchrotron emission and put constraints on/test the currently favoured formation models, we need to spatially probe their spectral index distributions. In this project, the student will perform spectral index studies of MERGHERS diffuse emission detections using data from MeerKAT and the GMRT. At least one student-led publication is expected from the results.

5. Primary supervisor's details: Dr Kenda Knowles, k.knowles@ru.ac.za, Rhodes University

Section B: Details of Research Project

1. Scientific merit:
Diffuse cluster radio emission comes in several forms - radio halos, radio relics, mini-halos - with each classification having a different proposed formation mechanism related to the dynamical state of the host cluster. Historically, cluster samples targeted for diffuse emission searches were restricted to low redshift, massive systems. The target selection criteria must be broadened in order to take a step forward in understanding the formation and evolution of diffuse cluster radio sources. The MERGHERS[1] (Knowles et al., 2016, 2021) programme consists of tiered MeerKAT observations of Sunyaev-Zel'dovich-selected galaxy clusters. The aim of MERGHERS is to perform statistical and evolution studies of diffuse cluster emission over wide redshift and mass ranges using a sample of ~200 clusters, with each tier serving as a well-selected subsample. Clusters are selected from the Atacama Cosmology Telescope's DR5 catalogue, which is blind to the cluster dynamical state.

The current MERGHERS data (33 cluster targets, all observed at L-band) contain ~20 diffuse emission sources, many of which are newly discovered. To understand the populations of electrons seeding the observed synchrotron emission and put further constraints on diffuse emission formation mechanisms, we need to probe the spatial morphology of the source's spectral index through observations at two or more radio frequencies. A handful of the MERGHERS clusters hosting diffuse emission have archival lower frequency radio observations with the Giant Metrewave Radio Telescope (GMRT). Through the various 2022 proposal calls for MeerKAT and the GMRT, we will work to obtain lower frequency data for

[1] MeerKAT Exploration of Relics, Giant Halos, and Extragalactic Radio Sources

the remaining host clusters, with a reasonable expectation of success given previous experience and outputs.

In this project the student will study the spectral properties, both integrated and spatial morphology, of the MERGHERS diffuse emission detections by combining the L-band MeerKAT data with available and newly-acquired lower frequency data. The analysis will probe the properties of the seed electrons giving rise to the diffuse structures, and provide tests for the currently favoured formation mechanisms. The student will have the opportunity to write observing proposals for MeerKAT and the GMRT in the first year of the project, should all low frequency data not be in hand by the start of the project. This project is expected to produce at least one publication on the results, with systems written up individually depending on their relative impact.

2. Feasibility:
Of the 33 MERGHERS targets in hand, 13 have been published (Knowles et al. 2021a), with 12 diffuse emission detections. The tier 1 MERGHERS data obtained in mid-to-late 2021 is in-hand and will be fully processed and imaged by the start of this project. If the tier 2 proposal to be submitted in 2022 is successful, additional detections are expected by 2023/2024. The student will reduce some of the MeerKAT data independently to gain crucial data reduction skills. A handful of the MeerKAT detections have low frequency GMRT data available through the archive. The GMRT data for the remaining systems is being applied for in cycle 43 (July 2022) and has a reasonable expectation of being awarded based on previous GMRT work and the high-impact nature of the study. Follow-up proposals will be submitted as needed based on the time awarded. Pipelines for processing wideband GMRT data are in place and have been tested on band-3 data (Sikhosana et al. 2021).

The student will have access to RATT/RARG high-performance computing facilities for all data reduction and processing. An estimate of the project timeline is as follows:

Months 1 - 3:	Literature review, gathering of archival GMRT data, familiarising the student with the required software.
Months 4 - 18:	Pipeline processing of archival GMRT data, submission of GMRT proposals for any outstanding targets (if required), data reduction of two or three MeerKAT datasets for skills development.
Months 19 - 30:	Combined analysis of GMRT and MeerKAT results, preparation and submission of at least one paper on the outcomes.
Months 31 - 36:	Thesis writing and submission.

3. SARAO research priority area:
Topics exploiting data projected to be available by 2023-24 from key existing radio astronomy instruments located in South Africa, specifically MeerKAT.

4. Specific qualifications/abilities/skills/experience required:
Familiarity with radio interferometry principles and observational radio astronomy is highly advantageous, although not strictly required.