Section A: Overview of the Research Project

1. Title of the research project:
Dynamical Detective: Probing the merger state of MERGHERS clusters

2. Broad area of research: Science

3. Academic level of research project: Doctoral

4. Abstract of research project:
This PhD project aims to use existing X-ray imaging and optical photometry/spectroscopy to determine the dynamical state of ~30 Sunyaev- Zel'dovich-selected galaxy clusters observed as part of the MeerKAT Exploration of Relics, Giant Halos, and Extragalactic Radio Sources (MERGHERS) survey. The dynamical state is necessary to accurately characterise diffuse radio emission in the clusters and the multiwavelength data allows the interrogation of relevant merger dynamics, crucial for understanding the formation of the diffuse radio sources.

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

6. Co-supervisor's details: Prof Matt Hilton, matt.hilton@wits.ac.za, University of the Witwatersrand

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, 2021a) programme consists of tiered MeerKAT observations of Sunyaev-Zel'dovich-selected galaxy clusters, with L-band and potentially UHF as well. 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. However, knowing the physical environment of a cluster is an important component in understanding the presence or lack of diffuse cluster emission, and investigating its evolution. The dynamical state of a system is also required to correctly classify any observed diffuse emission in the cluster region.

This project focuses on determining the dynamical state of the MERGHERS targets through the use of multiwavelength data (eROSITA/other X-ray imaging, optical density maps via DES photometry, and available optical spectroscopy). For systems with both imaging and spectroscopic information, the student will produce a model of the merger to study the diffuse radio emission connection in detail. The project is expected to produce a student-led paper on the dynamical state results of the targeted

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

systems.

2. Feasibility:
To date, 52 MERGHERS targets have been observed. All radio data will be processed and imaged before the start of this project. Archival X-ray imaging from Chandra or XMM-Newton exists for 80% of the clusters, with other data to be obtained through new proposals or collaboration with eROSITA. All MERGHERS targets to date lie within the footprint of the Dark Energy Survey which provides photometric data for optical density maps. Spectroscopic data from SALT has been applied for for the MERGHERS targets with a diffuse emission detection in order to probe the line of sight morphology, with additional spectroscopic data to be applied for in 2023/2024.

The student will initially focus on the MERGHERS targets with diffuse emission detections, and extend to all targets if time allows.

The student will have access to RATT/RARG high-performance computing facilities which are more than sufficient for the data processing and storage requirements of the project.

An estimate of the project timeline is as follows:

Months 1 – 6:	Literature review, gathering of multiwavelength data, preliminary processing
Months 7 – 24:	Data processing, i.e., X-ray morphological analysis, creating and analysing optical density maps, spectroscopic data analysis depending on availability), combined dynamical state analysis.
Months 25 – 30:	Prepare a paper on the combined dynamical state analysis - individual systems may be written up separately depending on results
Months 31 – 36:	Thesis writing and submission.

Note: This is a Rhodes University SARAO Group Grant project.

3. SARAO research priority area:
This project exploits data projected to be available by 2024 from key existing radio astronomy instruments located in South Africa, specifically MeerKAT. This is a multi-wavelength project with a direct link to a MeerKAT programme.

4. Specific qualifications / abilities / skills / experience required:
Familiarity with Python is required. Experience with X-ray and/or optical data is advantageous.

Interested students to email the primary supervisor well in advance of application deadlines. Interviews will be undertaken.