

Section A: Overview of the Research Project

1. Title of the research project:

Studying diffuse cluster emission evolution with MERGHERS

2. Broad area of research:

Science

3. Academic level of research project:

Doctoral

4. Abstract of research project:

This PhD project aims to study the cosmic evolution of diffuse cluster radio emission using cluster data from the MeerKAT Exploration of Relics, Giant Halos, and Extragalactic Radio Sources (MERGHERS) survey. With the majority of statistical samples in the literature restricted to low redshift systems, probing the higher redshift phase space in a systematic way is crucial to probing the evolutionary properties of the radio sources and the physical mechanisms which drive them. The project will perform a statistical study of the first two tiers of MERGHERS clusters (56 targets at mid-to-high redshift) and compare to literature data to probe the redshift evolution of diffuse cluster emission.

5. Primary supervisor's details:

Dr Kenda Knowles, kendaknowles.astro@gmail.com, 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 MERGHERS¹ (Knowles et al., 2016,2021) programme consists of tiered L-band and UHF MeerKAT observations of Sunyaev-Zel'dovich-selected galaxy clusters. A key 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 first two tiers of the MERGHERS project consist of 56 mid to high redshift clusters. By comparing the MERGHERS data with observed samples at lower redshift, we can begin to study the evolution of the occurrence rates of diffuse cluster emission and their scaling relations with cluster properties. Understanding the evolutionary properties, if any, of diffuse radio sources is critical for understanding how they are formed and evolve through cosmic time.

This project focuses on analysing existing MERGHERS data for extended diffuse cluster radio emission

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

and using the results in conjunction with literature results from other SZ-selected surveys (e.g. Cuciti et al 2021) to study evolution in the sample statistical properties. The student will work closely with Dr Kenda Knowles and other members of the MERGHERS collaboration to reduce and analyse the radio images (processed images for all first tier targets are already available), identify faint extended emission, investigate in-band spectral indices, and extract the faint source properties. The student will mine the literature for compatible datasets and combine them with the MERGHERS sample to create well-defined sub-samples at different redshifts. Finally, the student will perform a statistical investigation of the (sub)samples, looking for evolution in mass or redshift. The project is expected to produce at least one publication on the results of the statistical analysis.

2. Feasibility:

Processed radio images for all 56 MERGHERS tier one and tier two targets will be available by the start of the project. The student will reprocess some of the tier two data to develop/improve MeerKAT data reduction skills.

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, preliminary data processing

Months 7 – 24: Radio data processing for a subset of the tier two systems, extraction of diffuse radio emission properties for the full sample

Months 25 – 30: Study evolution in scaling relations using a comparison of the MERGHERS sample with lower redshift samples from the literature

Months 31 – 36: Thesis writing and submission

3. SARA research priority area:

This project exploits data projected to be available by 2025/26 from key existing radio astronomy instruments located in South Africa, specifically MeerKAT.

4. Specific qualifications / abilities / skills / experience required:

Knowledge of Python programming and Unix platforms is required. Familiarity with continuum MeerKAT data reduction is advantageous.

Interested students to email the supervisor well in advance of application deadlines. Interviews will be undertaken no later than two weeks before internal submission deadlines.