Section A: Overview of the Research Project Proposal

1. Academic level of research project (Masters or Doctoral)
   Masters
2. Broad field of research (Engineering or Astronomy/Astrophysics)
   Astronomy/Astrophysics
3. Title of the research project
   Statistical Pilot Study for MERGHERS
4. Full names of supervisor and co-supervisor(s)
   Kavilan Moodley, Kenda Knowles, Matt Hilton
5. University where postgraduate student would be registered
   University of KwaZulu-Natal

Section B: Full Research Project Proposal

Maximum of three A4 pages, written for a professional who is not necessarily an expert in the relevant subfield

1. Scientific merit: describe the objectives of the research project, placing them in the context of the current key questions and understanding of the field.

Galaxy clusters are dynamic environments, with the intracluster medium (ICM) showing evidence of both thermal and non-thermal processes. The latter have been studied through diffuse, faint, steep-spectrum synchrotron emission in the form of radio halos and relics (e.g., Brunetti & Jones 2014, IJMPD, 23, 1430007-98). Halos and relics are typically found in the most massive, merging clusters, shedding light on cluster magnetic fields and the physical processes occurring during these highly energetic events (e.g. van Weeren et al. 2019).

A strong dynamical link has been found with respect to the host cluster: the ~ Mpc-scale emission has exclusively been found in massive ($M_{500} > 4 \times 10^{14}$ Msol) clusters with X-ray and/or optical merger signatures (e.g., Cassano et al. 2013, ApJ, 771, 141). The power of the radio emission has been found to correlate with thermal host cluster properties, with non-detections lying an order of magnitude below the correlation (Cassano et al. 2013), as predicted by one of the leading formation theories (Brunetti & Jones 2014). However, ultra-steep sources are shown to populate the region between the correlation and upper limits, making the dichotomy less clear. Cluster selection also affects the relations: samples selected via their Sunyaev-Zel'dovich signal (SZ; Sunyaev & Zel'dovich 1972, Comm. on Astrophys. and Space Physics, 4, 173) show a higher detection rate than X-ray-selected samples (Cuciti et al. 2015, A&A, 580, A97), which may be due to the different timescales of boosting the SZ vs X-ray emission during mergers.

Although over a hundred clusters have been studied to date in terms of diffuse emission, they have been heterogeneously selected, with all homogeneous samples restricted to high mass clusters at low to medium redshift (Cuciti et al. 2015). Diffuse emission has been detected in a handful of higher redshift or lower mass systems (Lindner et al. 2014; Knowles et al. 2016), however these have mostly resulted from single-target programmes, and no larger statistical study has yet been observed.

With the increased sensitivity of available radio telescopes, the next step in advancing the understanding of diffuse emission and imposing stronger constraints on formation models is to expand the thus far limited discovery space by observing a homogeneously selected, statistical sample of clusters with broader redshift and mass ranges. This will allow for studies into the evolution of radio scaling relations with redshift, as well as an investigation into whether the current scaling relations hold at lower mass and higher redshift. Given the complex nature of its origin, expanding the discovery space will also invariably lead to discoveries of new types of diffuse emission as the physical environments being probed are different: higher redshift clusters are younger than those at lower redshift, based on the hierarchical view of structure formation (Sheth & Tormen 2002, MNRAS, 329, 61), and lower mass merging systems have a smaller turbulent energy pool than higher mass systems (Kravtsov & Borgani 2012, ARA&A, 50, 353). Extending statistical samples into these wider ranges will result in an improvement in the understanding of the lifecycle of diffuse cluster radio emission.

The MERGHERS (MeerKAT Exploration of Relics, Giant Halos, and Extragalactic Radio Sources; Knowles et al. 2017, POS, arXiv:1709.03318) project aims to be the first large-scale radio follow-up of ~ 100-200 clusters with extended selection ranges. MERGHERS will target a mass-selected AdvACT (Henderson et al. 2016, JLTP, 184, 772) sample of SZ-detected clusters which will be blind to the cluster dynamical state. As preparation for the MERGHERS project, we have obtained L-band MeerKAT observations of 20 AdvACT clusters which show indications of merger activity through multiwavelength data. Each cluster has a relatively short exposure time (1-2 hours).

In this project we will use this pilot project data to investigate MeerKAT's feasibility to carry out a large cluster study. To do this we will (a) potentially detect new diffuse emission sources and derive resulting science such as constraining models of their formation mechanisms as well as derive statistics for the pilot sample, and (b) confront the challenges related to short exposures such as poor uv-coverage and deconvolution artifacts.

2. Feasibility: outline the methods that will be used to achieve the objectives. Provide details on the availability of required data / access to required equipment / availability of research facilities and other resources required. Include any relevant expected intermediate milestones and associated timeframes towards attaining the overall objectives of the project.

As mentioned above, MeerKAT data for 20 AdvACT clusters is either in hand or will be observed by the beginning of 2020. All of these clusters are new targets in diffuse emission studies and therefore have a high probability of producing new results.

At UKZN we have a pipeline in place for reducing MeerKAT data, and as such, the student should be able to start with the scientific analysis of the data in the first year.

Students and postdocs based at UKZN have access to a High Performance Computing facility (https://www.acru.ukzn.ac.za/~hippo/) and a 64 processor shared-memory machine with more than 700 GB of RAM.

3. Link the proposed project to at least one SARAO research priority areas (refer to Section 4 of the Application Guide), and explain in some detail how the proposed research will contribute to the priority area(s).

Science topics exploiting MeerKAT data projected to be available by 2020-21.

4. If relevant, describe 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.

None – processing and data analysis with various software will be learned during the project.