Section A: Overview of the Research Project

1. Title of the research project:
Radio halo/mini-halo upper limits with MeerKAT

2. Broad area of research:
Science

3. Academic level of research project:
Masters

4. Abstract of research project:
Clusters that do not host detectable diffuse radio emission still carry a wealth of information on the latter's formation mechanism, particularly where the clusters exhibit dynamical signatures. One prediction of the radio halo turbulent reacceleration model is a bimodal population in the radio power/X-ray plane, where non-detections are separate from halo-hosting clusters. To place these clusters in the context of the scaling relations, one needs to determine upper limits based on the cluster properties. We will determine radio halo and/or mini-halo upper limits for the non-detections in the MGCLS through image- and visibility-injection techniques and investigate these in the context of the cluster dynamical state. At the Masters level, this ambitious project is likely to produce a journal publication. The student must be familiar with Python coding.

5. Primary supervisor's details:
Dr Kenda Knowles, kendaknowles.astro@gmail.com, Rhodes University

Section B: Details of Research Project

1. Scientific merit:

Sensitive radio observations of galaxy clusters across a wide range of cluster mass and redshift will advance our understanding of the effect of different physical environments on the evolution of diffuse cluster sources and the cosmic ray processes and magnetic fields that drive them. Clusters that do not host detectable diffuse emission still carry a wealth of information on the latter's formation mechanism, particularly where the clusters exhibit dynamical signatures. One prediction of the radio halo turbulent reacceleration model is a bimodal population in the radio power/X-ray plane, where non-detections are separate from halo-hosting clusters. To place these clusters in the context of the scaling relations, one needs to determine upper limits based on the cluster properties.

The first data release (DR1) of the MeerKAT Galaxy Cluster Legacy Survey (MGCLS) provides L-band data for 115 galaxy clusters, 63 of which have no visible centralised diffuse emission. In order to perform statistical analyses of the radio halos and mini-halos in MGCLS, radio upper limits need to be determined for these systems. The student will work with the supervisor and other members of the MGCLS consortium to create a (semi-)automated pipeline for upper limit determination, following the standard process which uses simulated halo injections, and test viability of image-injection techniques for when visibilities are not available (as expected in the SKAO era). As upper limit determination can be a time-consuming process, the clusters to which the student applies their process will be prioritised based on a ranked list of targets, e.g., by non-detections with disturbed dynamical state indicators.

2. Feasibility:

All MGCLS DR1 images are available for immediate testing of image-based injection techniques. All MGCLS data is available via the SARAO archive, with reprocessing of the visibilities being carried out by teams at Rhodes University. Calibrated visibilities will therefore be available for a subset of the clusters at the start of the project, with more being made available by RATT team members in the early stages of the project.

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, familiarising with the MGCLS catalogue and current upper limit determination techniques. Identification of a subset of MGCLS clusters for this project.
Months 7 – 12:	Development and testing of (semi-)automated pipeline to generate halo upper limits using the visibility injection technique.
Months 13 – 20:	Investigation of image-based upper limits and comparison against visibility-injection results. Preparation of a paper on the results.
Months 21 – 24:	Thesis writing and submission. Submission of paper.

3. SARAO research priority area:

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

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

Familiarity with Python is required. Experience with working with MeerKAT visibilities is advantageous.

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