Section A: Overview of the Research Project Proposal

1. Academic level of research project:

Masters

2. Broad field of research:

Astrophysics

3. Title of the research project:

Diffuse emission study of El Gordo with MeerKAT

4. Research project abstract/summary:

El Gordo is a massive merging galaxy cluster at z=0.87, originally discovered using the Atacama Cosmology Telescope. It hosts a double set of radio relics and a central radio halo. In this project we will make use of the new deep MeerKAT L-band data to improve on existing studies of the diffuse emission in this system. The student will reduce and image the MeerKAT data, and extract source properties for the various diffuse emission structures, including in-band spectral index maps of the sources. While this project is self-contained, the skills learned here can be applied to other radio datasets in the future.

Section B: Supervisor(s) Details

1. Primary supervisor's details

a. Title and full name:

Dr Matthew James Hilton

b. Name of the South African university at which the primary supervisor is based:

University of KwaZulu-Natal

c. Email address and/or contact telephone number:

hiltonm@ukzn.ac.za / 031 260 2233

d. Supervision of postgraduate students

i. Doctoral Students

Name of student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project/Thesis	Co-supervisor (if relevant)
Kenda Knowles	RSA	02/2013	02/2016	Observational Probes of Merging	K. Moodley (main

				Galaxy Clusters	supervisor) M. Jauzac
Susan Wilson	RSA	02/2013	08/2017 (note: internal examiner took 6 months to respond after submission; Susan worked as a teacher full time during write up)	Evolution of Galaxy Cluster Scaling Relations Over Half a Hubble Time	N. Oozeer
Sinenhlanhla Precious Sikhosana	RSA	09/2017	09/2020	Diffuse Radio Emission in ACTPol Clusters	K. Moodley (main supervisor) K. Knowles

ii. Masters Students

Name of student	Nationality	Date started Masters Degree (Month and Year)	Date completed / will complete Masters Degree (Month and Year)	Title of Research Project/Thesis	Co-supervisor (if relevant)
Brian M. Kirk	USA	08/2013	06/2014	Southern African Large Telescope Observations of Sunyaev-Zel'dovich Effect Selected Clusters from the Atacama Cosmology Telescope	C. Cress
Nhlakanipho Kwazi Mthembu	RSA	02/2014	09/2016	Dynamical Mass Estimates of Sunyaev-Zel'dovich Effect Selected Clusters in the Millenium Gas Simulations	
Zahra Essack	RSA	02/2017	01/2018	Searcing for Exoplanets Using the Transit Method	

2. Co-supervisor details

a. Title and full name:

Dr Kenda Leigh Knowles

b. Name of the South African university at which the primary supervisor is based:

University of KwaZulu-Natal

c. Email address and/or contact telephone number:

kendaknowles.astro@gmail.com / 031 260 8096

d. Supervision of postgraduate students

i. Doctoral Students

Name of student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project/Thesis	Co-supervisor (if relevant)
Sinenhlanhla Precious Sikhosana	RSA	09/2017	09/2020	Diffuse Radio Emission in ACTPol Clusters	K. Moodley (main supervisor) M. Hilton

3. Co-supervisor details

a. Title and full name:

Dr Devin Crichton

b. Name of the South African university at which the primary supervisor is based:

University of KwaZulu-Natal

c. Email address and/or contact telephone number:

crichtond@ukzn.ac.za / 031 260 8097

Section C: Full Research Project Proposal

1. Scientific merit:

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 halo and relics (e.g., Brunetti & Jones 2014). 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. 2017).

To date, few examples of diffuse cluster radio emission have been found at high redshift ($z > 0.4$), where inverse Compton losses are expected to dominate over the synchrotron. However, a few discoveries have been made in this epoch, the most notable of which is that in the ‘El Gordo’ cluster, a massive system at $z=0.87$ discovered by the Atacama Cosmology Telescope (Menanteau et al. 2012) which is undergoing a plane-of-the-sky merger. Using multi-wavelength radio data from the GMRT and ATCA instruments, Lindner et al. (2014) discovered a powerful double radio relic system with a centralised radio halo. Their data allowed them to probe the non-thermal components of the ICM at high redshift for the first time. Since their discovery, ‘El Gordo’ has been followed up with several multi-wavelength instruments. The most recent study combined Chandra X-ray data with re-analysed GMRT data to study the more powerful of the two radio relics in this system, measuring a strong shock at this position (Botteon et al. 2016).

The recently completed MeerKAT instrument is exceptionally well-suited to studying extended

diffuse emission in clusters, given its array configuration and remarkable sensitivity. As part of their commissioning activities, MeerKAT obtained full track synthesis observations of ‘El Gordo’ at 1.4 GHz. With an approximate sensitivity of 4 μJy/beam, this data provides new frequency coverage of this system with excellent sensitivity.

In this project we will use the new and proprietary MeerKAT data to study the radio halos and relics of ‘El Gordo’ at 1.4 GHz and provide a new view of this interesting system. Given the data quality and sensitivity, it is likely that new features in the diffuse emission will be seen.

2. Feasibility:

As mentioned above, MeerKAT data reaching an RMS depth of ~4 uJy have already been obtained.

The student will work to produce radio continuum imaging of El Gordo allowing for the detection of extended, diffuse emission and extract fluxes, sizes, and spectral index maps for the diffuse emission. It is hoped that the student will lead a short, original research paper describing the results within 12-18 months of commencing the MSc.

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. The proposed supervisor has a CPRR grant (2018-2020) and UKZN funds that can be used to purchase more equipment (e.g. disk space) as needed.

References: Botteon, A. et al., 2016, MNRAS, 463, 1534 • Brunetti, G. & Jones, T.W., 2014, IJMPD, 23, 30007 • Lindner, R.R. et al., 2014, ApJ, 786, 49 • Menanteau, F. et al., 2012, 748, 7 • van Weeren, R.J. et al., 2017, Nat.As., 1, 0005.

3. SARAO priority areas:

Science topics that involve the exploitation of MeerKAT data projected to be available by 2019-2020.

4. Student academic abilities / skills required:

None - processing and data analysis using Python will be learned during the project.