South African Radio Astronomy Observatory
Research Project Proposals for Masters and Doctoral Research in 2019

Section A: Overview of the Research Project Proposal

1. Academic level: Masters

2. Field of research: Astronomy / Astrophysics

3. Title: MeerKAT's unobscured view of star formation in the early Universe

4. Abstract:

Abell S1063 is a distant cluster of galaxies, with a total mass of about 100 trillion times that of the Sun. This huge concentration of mass acts as a strong gravitational lens, magnifying the galaxy population behind the cluster. This magnification boosts the apparent brightness of the background galaxies, allowing the detection of objects that are intrinsically very faint, and would otherwise be non-detectable using reasonable amounts of telescope time. This project will exploit recent, deep MeerKAT observations of this cluster to search for distant galaxies with high magnification factors, and investigate the faint population of star-forming galaxies during the peak epoch of star-formation in the Universe. Abell S1063 is one of the Hubble Frontier Fields, and thus has a wealth of publicly available optical and infrared data, as well as high-quality lens magnification models to aid this analysis. Higher frequency radio observations from the Australia Telescope Compact Array in support of this project will also be used.

Section B: Supervisor(s) Details

1. Primary supervisor

a. Name: Prof. Ian Heywood

b. Institution: Rhodes University

c. Contact: ianh@astro.ox.ac.uk

d. Postgraduate supervision:

PhD

Name	Nationality	Start	End	Title	Co-supervisor
Tariq Blecher	South African	2017	2020 (expected)	*Strongly Gravitationally-Lensed Neutral Hydrogen*	Prof. Roger Deane (UP)
Sphesihle Makhathini	South African	2013	2017	*Advanced Radio Interferometric Simulation and Data Reduction Techniques*	Prof. Oleg Smirnov (Rhodes)

MSc

Name	Nationality	Start	End	Title	Co-supervisor
Lerato Sebokolodi	South African	2015	2017	*Automation of source-artefact classification*	Prof. Oleg Smirnov & Dr. Sphesihle Makhathini (Rhodes)

1. Co-supervisor

a. Name: Prof. Oleg Smirnov

b. Institution: Rhodes University

c. Contact: o.smirnov@ru.ac.za

d. Postgraduate supervision:

PhD

Name	Nationality	Start	End	Title	Co-supervisor
Sphesihle Makhathini	South Africa	May 2013	June 2017	*Advanced Radio Interferometric Simulation and Data Reduction Techniques*	Ian Heywood
Marcellin Atemkeng	Cameroon (SA PRP)	Feb 2013	Feb 2017	*Data Compression, Field of Interest Shaping and Fast Algorithms for Direction Dependent Deconvolution in Radio Interferometry*	C. Tasse, G. Foster

Iniyan Natarajan	India	Feb 2013	Dec 2017	*Probabilistic Methods for Radio Interferometry Data Analysis*	K. van der Heyden, J. Zwart
Jonathan Kenyon	South Africa	Jan 2015	Dec 2018	*CubiCal: A fast radio interferometric calibration suite exploiting complex optimisation*	T. Grobler
Theo Ansah-Narh	Ghana	Jan 2015	Dec 2018	*Exploring intensity mapping techniques through simulations*	F. Abdalla, K. Asad
Etienne Bonnassieux	France	Sep 2015	Sep 2018	*Development and Application of New Algorithms for LOFAR & SKA Survey Images*	P. Zarka, C. Tasse
Lerato Sebokolodi	South Africa	Jan 2017	Dec 2019	*A new multiwavelength polarimetric study of Cygnus A*	R. Perley, C. Carilli
Ulrich Mbou Sob	Cameroon	Jan 2017	Dec 2019	*Robust calibration for radio interferometers*	L. Bester
Kelachukwu Iheanetu	Nigeria	Feb 2016	Dec 2019	*Primary beam modelling and holography for radio interferometers*	J. Girard, K. Thorat, S. Makhathini
Gijs Molenaar (part time)	NL	Jan 2017	Dec 2019	*Virtualized and containerized data reduction pipelines*	
Benjamin Hugo (part time)	South Africa	Jan 2017	Dec 2020	*Imaging and calibration for wide-field MeerKAT polarimetry*	G. Bernardi

MSc

Name	Nationality	Start	End	Title	Co-supervisor
Lerato Sebokolodi	South Africa	Jan 2015	Oct 2016	*Source-artefact classification in radio astronomical imaging*	S. Makhathini, I. Heywood
Jonathan Kenyon	South Africa	Jan 2014	Feb 2015	*PyMORESANE: A GPU-accelerated implementation of the MORESANE algorithm*	
Chuneeta Nunhokee	Mauritius	Jan 2013	Dec 2014	*Ghosts and source suppression in radio interferometry*	T. Grobler
Benjamin Hugo	South Africa	Jan 2014	Dec 2015	*Bullseye: GPU accelerated facet-based imager*	J. Gain, C. Tasse

Ulrich Mbou Sob	Cameroon	Jan 2015	Dec 2016	*Calibration and Imaging with Variable Radio Sources*	T. Grobler, S. Sirothia
Tariq Blecher	South Africa	Jan 2015	Mar 2017	*MeqSilhouette: a mm-VLBI simulator*	R. Deane
Alexander Akoto-Danso	Ghana	Jan 2015	Sep 2018	*Wide-field VLBI surveys: implementing efficient algorithms to open discovery space*	R. Deane, G. Bernardi
Cyndie Russeawon	Mauritius	Jan 2018	Dec 2019	*Parameterized solvers for pointing errors and ionospheric calibration*	F. Abdalla
Lexy Andati	Kenya	Jan 2018	Dec 2019	*Visualization frameworks for interferometric pipelines*	
Simphiwe Zitha (part time)	South Africa	Jan 2016	Dec 2018	*Machine learning methods for calibrating radio interferometric data*	Arun Aniyan
Antonio Peters	South Africa	May 2017	May 2019	*Primal-dual solvers and dimensionality reduction techniques for radio data*	L. Bester
Athanaseus Ramaila (part time)	South Africa	Jan 2016	Dec 2018	*A Practical Survey of Novel and Legacy Radio Interferometry Imaging Algorithms and Packages*	S. Makhathini
Sakhile Masoka (part time)	South Africa	Jun 2018	Jun 2021	*Distributed gridding and baseline-dependent averaging for radio interferometry data*	M. Atemkeng, S. Perkins

Section C: Full Research Project Proposal

1. Scientific merit

Radio observations are a critical method for studying the evolution of galaxies across cosmic time. The use of radio to study a galaxy has at least four key advantages: (i) detection of radio emission associated with star-formation; (ii) providing arguably the best tracer of supermassive black hole activity; (iii) the use of polarimetric measurements in order to probe magnetic fields in galaxies and the intergalactic medium; (iv) the use of radio spectral lines to trace gas dynamics, coupled with the fact that radio interferometers are natural integral-field spectrographs.

This project will focus on the first two of these in order to use MeerKAT to probe galaxies that are intrinsically very faint in the distant Universe. This view on the faint population is achieved with a combination of two things, namely the high sensitivity and wide field of view that MeerKAT provides, coupled with observing a target field that is a strong gravitational lensing cluster containing a mass of about 100 trillion suns. Einstein tells us that this huge concentration of mass curves spacetime around it, and for certain critical lines of sight, provides a magnifying effect for objects that lie behind the cluster. This allows the detection of very distant objects that would otherwise go undetected without the use of very large amounts of telescope time.

The target itself is the galaxy cluster Abell S1063. This cluster is the southernmost of the six Hubble Frontier Fields, which have been the subject of a 560-orbit Hubble Space Telescope campaign with similar science goals, namely the detection of the most distant and faintest galaxies in the Universe via a combination of deep observations and natural gravitational lensing advantages, attempting to get a first look at the science that will become routine with the James Webb Space Telescope. As such the target field has a huge amount of publicly available multi wavelength data that will be used to properly classify the MeerKAT radio detections, including many spectroscopic and photometric redshifts. Existing higher frequency radio data from the Australia Telescope Compact Array (PI: Heywood) is also available for this project. Crucially, the public data also contain detailed lensing models that allow the inversion of the gravitational lensing effects in order to recover the intrinsic properties of the lensed objects.

By combining the MeerKAT data with the broader set of observations, the student will identify high redshift galaxy candidates, measure their intrinsic radio brightnesses and spectral indices, and collate their optical properties. This will allow a study of the star-formation and AGN properties in starburst galaxies out to a redshift of ~4, as well as fainter Milky-Way-type galaxies at a redshift of ~1. Any radio detections with extremely high magnification will be identified as potentially being at very high redshift, and worthy of follow-up with instruments such as ALMA. Pushing studies of galaxy evolution across cosmic time into the first billion years of the Universe is a key goal of modern astrophysics.

2. Feasibility

The data for this project are already in-hand, as MeerKAT has observed Abell S1063 as part of its full-array commissioning program. These data have been approved by SARAO for use in this project. The ancillary data are all in-place and publicly available. The field has been observed with ATCA using L/S and C/X bands. Thus the student can immediately begin to extract the science yield from this project, although in the interests of building expertise in radio interferometric techniques, the raw MeerKAT data will be obtained so that the student may reprocess it in pursuit of the maps required to generate in-band spectral indices.

The Radio Astronomy Technologies and Techniques (RATT) group established at Rhodes maintains a cluster consisting of 8 “fat” nodes (512GB RAM, 16-48 CPUs per node) with plenty of attached storage. The student will have access to this cluster, which is entirely adequate for the proposed project.

A plausible time-frame for the project is as follows:

Year 0 — 0.5: Literature review in the relevant scientific and technical areas. Familiarisation of the student with the hardware and software required to process the MeerKAT data. Familiarisation of the student with radio / optical cross-matching techniques. Extraction of the radio source catalogue from the MeerKAT data.

Year 0.5 — 1: Cross-matching of the radio source catalogue with the ancillary data, and production of radio spectral index measurements for the detected objects using the MeerKAT and ATCA data. Use of the lensing models to determine magnification factors and produce master catalogue of intrinsic radio / optical properties including spectral index and redshift.

Year 1 — 1.5: Analysis of master catalogue, placing results in the context of previous radio / optical studies in this area. Identification of high redshift / high magnification candidates.

Year 1.5 — 2: Collate and finalise results, and write up thesis.

3. SARAO research priority areas

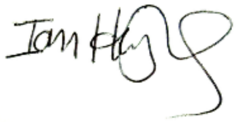
6. Science topics that involve the exploitation of MeerKAT data projected to be available by 2019- 2020.

8. Interferometric Data Processing and Analysis, including calibration and imaging.

4. Requirements of candidates

For this project a candidate would require an undergraduate degree in physics, engineering or similar discipline. A working knowledge of Linux operating systems and the Python language is desirable, and if not present the candidate must be capable of rapidly becoming familiar with both.

Section D: Signatures



Ian Heywood
31 August 2018