

Investigating radio-AGN through high resolution observations of the MIGHTEE fields

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A. Overview of the research project

SUPERVISOR: Dr. Jack Radcliffe (Lecturer at U. Pretoria & Honorary research fellow at U. Manchester)

CO-SUPERVISOR: Prof. John McKean (SARAO SARChI chair at U. Pretoria & Professor at U. Groningen)

AREA OF RESEARCH: Science

PROJECT LEVEL: Doctoral

ABSTRACT:

Deep surveys of the sky are revealing new insights into the evolution of the Universe. In particular, the relationship between the central supermassive black hole and the stars within the host galaxy is of utmost importance if we are to explain the Universe as we see it today. The new and upcoming generation of radio interferometers, such as MeerKAT and the VLA, are key in untangling this relationship as they provide a dust-free window into both AGN and star-formation processes. However, the resolutions provided at present are insufficient to separate the two in the absence of multi-wavelength data. In this PhD project, the candidate will use a purely radio method of identifying AGN via high resolution observations using Very Long Baseline Interferometry (VLBI). By combining these observations with data from the MeerKAT MIGHTEE survey, the candidate will investigate the nature of radio-mode AGN and their relationship with their host galaxies across cosmic time.

B. Details of the research project

SCIENTIFIC MERIT

Deep, wide-field surveys of the sky are yielding profound understanding into the evolution of galaxies. Surveys at long wavelengths, especially radio and far-infrared, play a crucial role as dust and its attendant obscuration is a ubiquitous partner to the merger activity associated with galaxy growth (e.g., Zinn et al., 2011). Studies of these samples suggest that minor mergers and/or cold gas accretion, rather than major mergers are responsible for the growth of these systems (e.g., Elbaz et al., 2011). Given the well-established scaling relations, massive black holes must have been in place early and their episodic growth must manifest through accretion related radiation. A widespread symbiotic occurrence of star formation and AGN growth at high redshifts are expected. Indeed, this is seen in radio and far-IR observations of faint X-ray selected AGN (e.g., Padovani et al., 2009, Mullaney et al. 2012, Rodighiero et al. 2015) and in radio-loud AGN (e.g., Podigachoski et al., 2015). Again, major mergers are not seen to be the dominant mechanism.

There are at least two important issues that still need to be addressed: (1) the nature of galaxies with dust obscured AGN, (2) the physical interplay between nuclear activity and star formation and the role of non-jetted/radio quiet AGN. Concerning the first issue, X-ray selected AGN hosts do not seem to differ from the normal star forming population (e.g., Mullaney et al., 2012). However, little is known about the host galaxies of Compton thick (X-ray obscured) AGN. Analysis of the diffuse X-ray background indicates that a significant fraction (up to ~50%) of AGN are hidden behind Compton-thick obscuration (e.g., Mateos et al. 2017). High resolution radio observations have been proven to be able to identify these AGN (e.g., Casey et al. 2009, Chi et al., 2013).

Concerning the second issue, negative feedback is popular amongst many and must play a role (e.g., Best et al. 2014, 2019) but its occurrence is not without doubt in populations of X-ray and radio selected AGN (e.g., Harrison et al. 2012, Barthel et al. 2012). To resolve this, a clean separation of star-formation and AGN related emission is required. Very Long Baseline Interferometry (VLBI) observations provide an answer to all these questions by providing a high-resolution, dust-free window into AGN activity by isolating compact, high brightness temperature ($> 10^5$ K), AGN cores from star-formation related emission. This is more important in the faint Jy radio regime which is known to have a high fraction of star-forming galaxies and non-jetted/radio quiet AGN whose radio emission is often confined to sub-kpc/sub-arcsecond scales.

Current radio surveys which aim to trace AGN accretion and star formation across cosmic time typically have arc-second resolutions (\sim kpc) which, while necessary to recover the total flux densities of the sources, **cannot** resolve emission from AGN and star-formation within galaxies. These surveys therefore rely on multi-wavelength diagnostics, such as radio-excess, SED fitting, X-ray emission etc., to identify AGN (e.g., Smolcic et al. 2017). However, these diagnostics are often incomplete. For example, Delvecchio et al., (2017) found that ~10% of the VLBI sources in the COSMOS field had no multi-wavelength AGN signatures. This was extended by Radcliffe et al., (2021) who find that no

one classification technique (from optical to IR to X-ray) can reliably identify all VLBI sources in the GOODS-N field as AGN.

PROJECT AIMS

Despite its exquisite sensitivity, MeerKAT will not have the sub-arcsecond/sub-kpc resolution required to cleanly resolve star-formation and AGN related activity. This project will use the newest VLBI calibration techniques to provide a high-resolution component to the MeerKAT-MIGHTEE survey. Initially the project will focus on a survey of the COSMOS deep field using the European VLBI Network (EVN; PI Radcliffe). This survey targets known radio sources to below microJy sensitivities to investigate whether they are harbouring an AGN.

The inclusion of *e*-MERLIN within these observations will allow the candidate to perform one of the first studies into the nature of the sub-kpc jets within these objects, while also enabling investigations into the star-formation content of these galaxies through direct comparison to MeerKAT. These data will also provide information on Compton-thick AGN hosts, radio-quiet/non-jetted AGN, and serendipitous discoveries, such as supernovae, binary supermassive black holes, and gravitational lenses, which have been seen in other VLBI surveys. Moreover, deep and wide-area VLBI observations will enhance the output of MeerKAT spectral emission and absorption line surveys, such as LADUMA and MALS.

FEASIBILITY

All objectives outlined in the previous sections are obtainable with current software and facilities available. The data required for this project has already been observed and was delivered to the primary supervisor in 2021. The primary supervisor is an expert in this type of interferometric data with a proven track record, therefore they are suitable to guide the candidate in succeeding with the goals of this project.

The candidate will be joining the vibrant and growing group at the University of Pretoria and the recent acquisition of the SARChI chair (Prof. McKean) will rapidly improve the group's focus upon VLBI science and techniques. This will enable the candidate to develop in a supportive environment where there is significant expertise in high resolution radio surveys.

The candidate will require high performance computer access to complete this project. This will be provided through the ilifu compute cluster under the partnership that the University of Pretoria has with the Inter-university Institute for Data Intensive Astronomy (IDIA). We also have servers at the University of Pretoria, and compute power provided by the University of Manchester which is available through the primary supervisor's affiliation. The various software required is mostly containerised, allowing the candidate to easily shift data between resources with minimal disruption to their progress.

RELATION TO SARAO PRIORITIES

This project is highly applicable to two of SARAO's key priorities for 2024, namely MeerKAT and HartRAO. HartRAO participated in the observations of the COSMOS field using the European VLBI Network. MeerKAT will be used extensively via the analysis of data from MIGHTEE, one of MeerKAT's key science projects.

STUDENT REQUIREMENTS

This project will involve a large amount of data reduction and some programming. Knowledge of radio interferometric data reduction and the associated software packages would be useful.

C. CV of the primary supervisor

Dr. Jack F. Radcliffe

LECTURER AT THE UNIVERSITY OF PRETORIA

& HONORARY RESEARCH FELLOW AT THE UNIVERSITY OF MANCHESTER

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Summary

A dedicated, proactive lecturer at the University of Pretoria (NRF rated - Y1) whose research interests encapsulates both technical and scientific aspects, with a strong focus on high-resolution radio observations. A unique specialist in wide-field VLBI surveys of faint AGN, previous research has included pioneering radio interferometric calibration routines, radio transient and variability studies, and investigations of star-formation in galaxies. Experience in software development individually, and as part of a team, has been obtained through the development of the multi-source self-calibration technique, European VLBI Network primary beam correction scheme, and the co-founding of the e-MERLIN CASA pipeline. Extensive teaching experience has been obtained through 6 years of lecturing and workshop development for the Development in Africa with Radio Astronomy (DARA) project, the foundation, design and conduction of the inaugural radio astronomy lecture programme for postgraduate students and the re-design of the undergraduate Observational Astronomy course at the University of Pretoria. A proven scientific communicator, presentations have been given national and international conferences, colloquia, and outreach events across the world. Active and productive collaborations have been established and developed across the globe, including the founding of the Square Kilometre Array VLBI simulations task force.

Publications

Summary – 17 peer-reviewed publications, all of which are in high-impact journals (impact factor > 5). Radcliffe has a *h*-index of 8 and is the first author in ~30% of these publications. Below each publication is a short summary of the paper. Papers in preparation, where Radcliffe is a key contributing author and will be submitted in the next 12 months, are included to illustrate current research trajectory.

PUBLISHED, ACCEPTED & SUBMITTED

- 2023 **Flux density systematics arising from irregular interferometric point spread functions, J. F. Radcliffe, A. P. Thomson, R. J. Beswick, (+ 3 authors)** *MNRAS submitted*
- Outlines the flux density systematics that occur when an irregular point spread function is used.
Important for upcoming radio arrays.
- SPARCS-North Survey: Exploring the resolved μJy extra-galactic radio source population with EVN+e-MERLIN, A. Njeri, R. J. Beswick, J. F. Radcliffe, (+ 8 authors)([link](#))** *MNRAS, 519, 2, 1732*
- First wide-field VLBI survey using a combined EVN+e-MERLIN array focusing on the SPARCS-N field.
- 2022 **An ultra-deep multi-band VLA survey of the faint radio sky (COSMOS-XS): the radio luminosity function to redshift ~ 5 , D. van der Vlugt, H. S. B. Algera, (+ 7 authors including J. F. Radcliffe)([link](#))** *ApJ, 941, 10*
- New study at the faint end of the radio luminosity function down to sources with sub-microJy flux densities and high redshifts.
- A super-linear 'radio-AGN main sequence' links mean radio-AGN power and galaxy stellar mass since $z \sim 3$, I. Delvecchio, E. Daddi (+ 17 authors including J. F. Radcliffe)([link](#))** *A&A, 668, A81*
- Paper showing that the radio AGN power is related to the stellar mass of the galaxy.
- Software and techniques for VLBI data processing and analysis, M. Janssen, J. F. Radcliffe, & J. Wagner ([link](#))** *Universe, 8(10), 527*
- Latest updates on VLBI data, processing and results.
- Identifying active galactic nuclei via brightness temperature with sub-arcsecond International LOFAR Telescope observations, L. Morabito, F. Sweißen, J. F. Radcliffe (+ 10 authors)([link](#))** *MNRAS, 515, 4, 5758*
- First publication showing LOFAR-VLBI observations can be used to identify active galactic nuclei.
- 2021 **The radio emission from active galactic nuclei, J. F. Radcliffe, P. D. Barthel, M. A. Garrett, (+ 3 authors)([link](#); [press release](#))** *A&A, 649, L9*
- Ground-breaking observations that finally reveals (after 30 years) that the radio emission in radio-quiet AGN is related to star-formation rather than the central supermassive black-hole.
- Nowhere to hide: Radio-faint AGN in GOODS-N – II. Multi-wavelength AGN selection techniques and host galaxy properties, J. F. Radcliffe, P. D. Barthel, M. A. Garrett, (+ 3 authors)([link](#))** *A&A, 649, A27*
- Second paper in series that reveals that high-resolution radio observations remain key in identifying a true consensus of AGN activity across cosmic time.
- An Ultra-deep Multi-band VLA Survey of the Faint Radio Sky (COSMOS-XS): Source Catalog and Number Counts, D. van der Vlugt, H. S. B. Algera, (+ 7 authors including J. F. Radcliffe)([link](#))** *ApJ, 907, 1, 5*
- COSMOS-XS is the deepest radio survey ever conducted with sub-microJy sensitivity. This paper presents the survey and source counts. JFR was key in reducing, imaging and analysing these data.
- 2020 **A Multi-wavelength Analysis of the Faint Radio Sky (COSMOS-XS): The Nature of the Ultra-faint Radio Population, H. S. B. Algera, D. van der Vlugt, (+ 8 authors including J. F. Radcliffe)([link](#))** *ApJ, 903, 2, 139*
- Second paper from the COSMOS-XS survey investigating the multi-wavelength properties of the faintest radio sources. JFR was key in data analysis.

The e-MERLIN Galaxy Evolution Survey (e-MERGE) – Overview and Survey Description, T. W. B. Muxlow, A. P. Thomson, **J. F. Radcliffe**, (+ 33 authors) ([link](#)) *MNRAS*, 495, 1, 1188
 - First paper from the e-MERGE e-MERLIN legacy project that investigates galaxy evolution through high-resolution radio observations. JFR was key in reducing, imaging and analysing these data.

Searching for Obscured AGN in z~2 Submillimetre Galaxies, H. Chen, M. A. Garrett, S. Chi, (+ 13 authors including **J. F. Radcliffe**) ([link](#)) *A&A*, 638, A113
 - Investigation into dusty sub-millimetre galaxies using VLBI revealed obscured AGN in ~25% of sources.

2019 **An insight into the extragalactic transient and variable microJy radio sky across multiple decades**, **J. F. Radcliffe**, R. J. Beswick, A. P. Thomson, (+ 3 authors) ([link](#)) *MNRAS*, 490, 3, 4024
 - First paper revealing that the radio variability of the faintest radio sources across decadal timescales is extremely rare (<2%).

2018 **Nowhere to hide: Radio-faint AGN in GOODS-N – I. Initial catalogue and radio properties**, **J. F. Radcliffe**, M. A. Garrett, T. W. B. Muxlow, (+ 6 authors) ([link](#)) *A&A*, 619, A48
 - Pioneering wide-field observations of the GOODS-N deep field using VLBI that almost triple the number of previously detected radio-AGN in the field.

Measuring the size evolution of distant, faint galaxies in the radio regime, L. Lindroos, K. K. Knudsen, F. Stanley, (+ 5 authors including **J. F. Radcliffe**) ([link](#)) *MNRAS*, 476, 3, 3544
 - Novel *uv* stacking techniques revealed that star-formation in distant, faint galaxies is typically concentrated in the centre of the objects.

2017 **The e-MERGE Survey – I. JVLA 5.5 GHz observations of the GOODS-North Field**, D. Guidetti, M. Bondi, I. Prandoni, (+ 8 authors including **J. F. Radcliffe**) ([link](#)) *MNRAS*, 471, 1, 210
 - Deep 5 GHz radio observations revealed, for the first time, that a large proportion of galaxies detected contained active supermassive black holes.

2016 **Multi-source self-calibration: Unveiling the microJy population of compact radio sources**, **J. F. Radcliffe**, M. A. Garrett, R. J. Beswick, (+ 4 authors) ([link](#)) ([source code](#)) *A&A*, 587, A85
ASCL 1709.007
 - Publicly available direction-dependent calibration routine for wide-field VLBI observations that allows any possible field to now be observed with VLBI arrays. The code to perform this is publicly available and in use by the community.

IN PREPARATION

- Data-intensive radio astronomy**, E. Vardoulaki (+ 80 authors including **J. F. Radcliffe**)
 - New book (est release Q2 2023) outlining methods of dealing with the new large data from radio astronomy. JFR wrote the section on VLBI and SKA-VLBI.
- Calibrating wide-field VLBI data using VPIPE**, **J. F. Radcliffe** (+ 4 authors)
 - Outlines a new calibration pipeline to process VLBI data using the latest techniques and algorithms.
- The VLBA CANDELS GOODS-North Survey – I. Survey Strategy, Design, Processing, and Catalogues**, R. P. Deane, **J. F. Radcliffe** (+ 14 authors)
 - First paper of the series outlining the ambitious survey with the VLBA to process and image the entire primary beam at milli-arcsecond resolution
- The VLBA CANDELS GOODS-North Survey – II. Wide-field source catalogue comparison with e-MERLIN and EVN**, A. Njeri, **J. F. Radcliffe**, (+ 12 authors)
 - Novel investigation of detected source properties across 3 orders of magnitude in angular resolution. Paper lead by co-supervised DARA PhD student Ann Njeri.
- Primary beams of heterogeneous interferometric arrays – I. Issues, challenges and considerations**, **J. F. Radcliffe**, A. Keimpema, Z. Paragi, (+ 12 authors)
 - This paper deals with the issues associated with heterogeneous elements in an interferometric array illustrated through a host of theoretical arguments and simulations. These issues have important implications for future arrays including the SKA.
- Primary beams of heterogeneous interferometric arrays – II. 1.6 GHz beam measurements of EVN and e-MERLIN stations**, **J. F. Radcliffe**, A. Keimpema, Z. Paragi, (+ 12 authors)
 - Second paper in the series providing the first 1.6 GHz beam maps of EVN and e-MERLIN stations thus allowing future wide-field observations to mitigate the issues highlighted in Paper I.

Employment Experience

Lecturer

UNIVERSITY OF PRETORIA (UP)

2021 – present

South Africa

Key Responsibilities & Achievements:

- Research into high-resolution studies of distant galaxies, continuing the work set out during the previous fellowship.
- Re-designed, coordinates and lectures the undergraduate Observational Astronomy course, comprising of lectures, workshops, assignments & exams, at UP.
- Contributed and lead grant proposals to help grow the group reputation and size.

SARAO Postdoctoral Fellow & Lecturer (part-time)

2019 – 2021

UNIVERSITY OF PRETORIA (UP)

South Africa

Key Responsibilities & Achievements:

- Funded by the South African Radio Astronomy Observatory (SARAO) that focused upon galaxy evolution through pioneering high-resolution interferometric observations of the COSMOS field that is complemented by exquisite data from MeerKAT. ([link to research proposal](#)).
- Founded, designed, and delivered the postgraduate Radio Astronomy course, comprising of lectures, workshops, assignments & exams, at UP.
- Key contributions to the UP astrophysics group. e.g., contributed to the research direction and grant proposals.

Research Associate

Jan – Jun 2019

UNIVERSITY OF MANCHESTER

United Kingdom

Key Responsibilities & Achievements:

- UK Research and Innovation (UKRI) Global Impact Accelerator Accounts (GIAA) funded research associate on 'Enhancing and expanding the impact and sustainability of the Development in Africa with Radio Astronomy (DARA) graduate training programme in sub-Saharan Africa'.
- Developed teaching materials including lectures, workshops and tutorials for DARA training and collated materials taught by lecturers from multiple international institutions. These have had a large impact as shown by their use in various other radio astronomy courses.

Education

Ph.D. in Astrophysics

2014 – 2019

UNIVERSITY OF MANCHESTER & UNIVERSITY OF GRONINGEN (JOINT DEGREE)

United Kingdom & the Netherlands

- Thesis – 'Nowhere to hide: identifying AGN in the faint radio sky' ([link to thesis](#)).
- Supervisors: M. A. Garrett, P. D. Barthel, R. J. Beswick & T. W. B. Muxlow.
- The work in this Ph.D. investigated the role of faint Active Galactic Nuclei in galaxy evolution using high-resolution radio observations. Such observations provided one of the widest and deepest, high resolution observational studies of the distant universe. Techniques developed as part of this work, such as MSSC, have been influential in developing VLBI survey capabilities, the decadal planning of VLBI, and implications for future SKA and MeerKAT VLBI surveys.

M.Sci. Honours & ARCS in Physics

2010 – 2014

IMPERIAL COLLEGE LONDON

United Kingdom

- First Class Honours (74.6%) & Associate of the Royal College of Science (ARCS)
- Masters Thesis – 'Proof of concept for a new optical method of performing oscillatory rheology'.

A-levels & GCSEs

2003 – 2010

SIR JOHN TALBOT'S TECHNOLOGY COLLEGE

United Kingdom

- 4 A-levels and 12 GCSEs, all of which achieved a grade of A or A*

Grants, honours & awards

2023–	NRF Rating (Y1) , peer-reviewed rating from South Africa's National Research Foundation (NRF) that rates individuals on the quality and impact of their research outputs over the past eight years. Radcliffe was awarded the top-tier (Y1) of the young researcher category.	
2022	RADIOBLOCKS - New science in radio astronomy , Large European Commission grant (shared between 33 institutions) to apply cutting-edge technology to enhance the entire data chain, from receiver to final output	10 M EUR / 178 M ZAR
	Pretoria travel mobility grant , granted to facilitate travel between UP, the University of Manchester, and the Square Kilometre Array Organisation	50 k ZAR
	SARAO undergraduate scholarship , scholarship to support three undergraduate students over the course of their degree.	1.5 M ZAR
	Research seed funding , funding to support research and teaching activities at the University of Pretoria.	85 k ZAR
Est. 2019–	Dr Jack Radcliffe award for Physics , award given each year to the student with the best attainment in the Physics GCSE at Sir John Talbot's Technology College.	
2019–	Honorary research fellow , prestigious accolade given by the University of Manchester to promote further collaboration between the researcher and the University.	
2019–22	SARAO postdoctoral fellowship , awarded by the South Africa Radio Astronomy Observatory to perform independent research.	~ 1.45 M ZAR / 74k GBP
	RadioNet TNA , awarded to give invited talk at the 2019 SKA-VLBI workshop.	~ 1k EUR / 830 GBP
2016–19	Ubbo Emmius scholarship , awarded by the University of Groningen for students to pursue a Ph.D.	~ 43k EUR / 36k GBP
2014–16	STFC Ph.D. scholarship , awarded by the Science and Technologies Facilities council to conduct a Ph.D. at the University of Manchester.	~ 26k GBP

2010–14 **Imperial College London undergraduate bursary**, awarded by Imperial College London to support undergraduate study.

~ 20k GBP

Teaching experience

Summary – Lectured astronomy for over 6 years and taught and assessed students for over 6 years. Founded, developed, gave and assesses the radio astronomy postgraduate course at the University of Pretoria and redesigned the Observational Astronomy undergraduate course. Currently supervising 8 students (as both primary and co-supervisor), with one student project successfully completed to date.

2021–	Lecturer , for the Observational Astronomy 3rd year undergraduate course (PHY 300). - Course designed to teach students about observational astrophysics with a focus on the optical and radio regime in alignment with South Africa's astronomy direction. - Re-designed and taught this course. The course comprises of 40 lectures, 8 workshops, and is assessed through a combination of assignments and exams.	University of Pretoria
2019–21	Founder & lecturer , for the Radio Astronomy postgraduate Honours course. Course designed to teach Honours students single-dish and interferometric radio astronomy. This provides an ideal introduction to postgraduate research. - Founded, designed, developed, and gave the postgraduate lecture course. The course comprises of 12x2hr lectures, workshops and is assessed through a combination of assignments and exams.	University of Pretoria
2016–21	Lecturer & course coordinator , for the Development in Africa with Radio Astronomy (DARA) project (link). - Designed and developed the Unit 4 (data reduction) lectures and workshops on interferometric data reduction and analysis. - Taught interferometric data reduction in Zambia and Botswana over the last 4 years and scheduled to lecture for Unit 2 at HartRAO in South Africa this year. - Built the DARA repository website and curated all materials - Built VLBI tutorials that are now the official VLBI CASA data reduction guide for the National Radio Astronomy Observatory (USA).	
2017	Teaching assistant , Observational astronomy undergraduate course - Helped students take data using the 1m optical telescope at the University of Groningen, for their observational astronomy practical assessments.	University of Groningen
2014–16	Demonstrator , First year undergraduate laboratory - Taught and assessed undergraduate students in the first year Physics laboratory.	University of Manchester

ACADEMIC SUPERVISION

* denotes students that have submitted or will submit within the next 28 days.

PH.D.

2023–	Celestin Herbe-George , Project: 'Testing AGN evolution and feedback with wide-field VLBI' Co-supervisor w/ J.P. McKean, R. Morganti	University of Pretoria / Groningen
2022–	Kelvin Wandia , Project: 'Deep, wide-field VLBI of faint cosmic radio sources' Co-supervisor w/ M. A. Garrett, J. McKean	University of Manchester
2018–22	Dr Ann Njeri , Project: 'High resolution observations of faint radio sources' Co-supervisor w/ R. P. Deane, R. Beswick	University of Manchester

MASTERS

2023–	Sibongumusa Wiseman , Project: 'Investigating star-formation and supernovae in Messier 82' Primary supervisor w/ D. Williams, R. Beswick	University of Pretoria
2022–	Anneke van der Dussen , Project: 'Searching for binary supermassive black holes in wide-field VLBI data' Primary supervisor w/ R.P. Deane	University of Pretoria
2021–	Thephilus Matsepene , Project: 'Resolving AGN feedback in high redshift starbursts' Primary supervisor	University of Pretoria
2020–	Paul Wilsenach* , Project – 'The helical radio jet structure in the blazar PKS 1502+106' Co-supervisor w/ R. P. Deane	University of Pretoria
2020–	Stefro Millard , Project – 'The parsec-scale radio emission in binary supermassive black hole candidate J1502SE/W' Co-supervisor w/ R. P. Deane	University of Pretoria
2019–	Nkululeko Qwabe , Project – 'MeerKAT VLBI capabilities and sub-arraying strategies' Co-supervisor w/ R. P. Deane	University of Pretoria
2021–2022	Kelvin Wandia , Project: 'SETI using wide-field VLBI' Co-supervisor w/ M. Garrett, A. Siemion	University of Manchester

HONOURS

2023–	Katelyn Jordaan , Project: 'Investigating proto-planetary disks with new wide-band VLBI receivers' Primary supervisor	University of Pretoria
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2022–23	Titan Harth , Project: <i>'Finding the faintest supermassive black holes through advanced calibration'</i> Primary supervisor	University of Pretoria
2022–23	Jayde Bhana , Project: <i>'A first look at sub-kiloparsec relativistic jets in distant, high redshift galaxies'</i> Primary supervisor	University of Pretoria
2022–23	Llewellyn Coetzer , Project: <i>'Determining the true sensitivity of radio telescopes through beam-mapping'</i> Primary supervisor	University of Pretoria
2021–22	Anneke van der Dussen , Project: <i>'A binary supermassive black hole in GOODS-N'</i> Primary supervisor	University of Pretoria
2021	Zane Lentz , Project: <i>'Analysis of a serendipitous supernovae candidate identified in the GOODS-N field'</i> Primary supervisor	University of Cape Town

Colloquia, conferences & workshops

Summary – 34 national and international colloquia, conference, and seminar talks of which 12 were invited. Lecturer for three workshops to date and part of the science organising committee for a further two workshops.

COLLOQUIA

2020	Netherlands Institute for Radio Astronomy (ASTRON) , <i>'Identifying AGN in the faint radio sky'</i> .	Dwingeloo, the Netherlands
2019	Hartebeeshoek Radio Astronomy Observatory (HartRAO) , <i>'Finding AGN in the faint radio sky: A high-resolution perspective'</i> .	Gauteng, South Africa
	Kapteyn Thesis Colloquium, University of Groningen , <i>'The faint radio population in GOODS-N'</i> .	Groningen, the Netherlands
	Jodrell Bank Centre for Astrophysics, University of Manchester , <i>'Finding AGN in the faint radio sky: A high-resolution perspective'</i> .	Manchester, UK
	University of Cape Town , <i>'Finding AGN in the faint radio sky: A high-resolution perspective'</i> .	Cape Town, South Africa

CONFERENCES

(O) - oral presentation, (P) - poster presentation, (C) - session chair, (LOC) - local organiser, (SOC) - scientific organiser, (A) - attended

2022	SKA Pathfinders Radio Continuum Surveys XI , <i>'The next generation of high-resolution surveys with SKA-VLBI'</i> (O).	Gauteng, SA
	Inter-university Institute for Data Intensive Astronomy retreat 2022 , <i>'Wide-field VLBI at the University of Pretoria'</i> (O).	Cape Town, SA
	Annual conference of the African Astronomical Society 2022 , <i>'Teaching interferometry to the next generation of African astronomers'</i> (O).	Virtual
	VLBI in the SKA-era , <i>'Wide-field VLBI surveys in the SKA-era'</i> (O).	Virtual
2021	SARAO postgraduate scholarship conference 2021 , (C).	Virtual
	SKA Pathfinders Radio Continuum Surveys X , <i>'The challenges associated with the beams of interferometers - a warning to the SKA-era'</i> (O).	Virtual
	High Energy Astrophysics in Southern Africa 2021 , <i>'Active galactic nuclei in the faint radio sky'</i> (O).	Virtual
	National Astronomy Meeting 2021 , <i>'Square pegs in round holes. - Accurate photometry for the SKA-era'</i> (invited, O).	Virtual
	European VLBI Network Symposium 2021 , (A)	Virtual
2020	SARAO postgraduate scholarship conference 2020 , <i>'Preparing for MIGHTEE-VLBI wide-field surveys'</i> (P, link).	Virtual
2019	SARAO postgraduate scholarship conference 2019 , <i>'Identifying AGN in the faint radio sky'</i> (O).	Durban, South Africa
	SKA-VLBI key science projects and operations workshop , <i>'Wide-field VLBI in the SKA era'</i> (invited, O, fully funded).	Manchester, UK
2018	European Week of Astronomy and Space Science 2018 , <i>'Nowhere to Hide: Wide-field VLBI with the EVN'</i> (P, link).	Liverpool, UK
2016	SKA2016: Continuum Science Working Group Meeting , <i>'Lessons learned: An EVN & e-MERLIN perspective'</i> (invited, O).	Goa, India
	SKA2016: Science for the SKA Generation , <i>'There's Nowhere to Run, Nowhere to Hide'</i> (O).	Goa, India
	SKA Pathfinders Radio Continuum Surveys 2016 , <i>'Isolating AGN Using Wide-field VLBI & e-MERLIN Observations'</i> (invited, O).	Goa, India
	e-MERLIN and Jodrell Bank Observatory: A radio astronomy facility for the SKA era , <i>'Isolating AGN using wide-field VLBI and e-MERLIN'</i> (invited, O).	Manchester, UK
	European Week of Astronomy and Space Science 2016 , <i>'There's Nowhere to Run, Nowhere to Hide... Hunting for AGN Using Wide-field VLBI'</i> (invited, O).	Athens, Greece
	National Astronomy Meeting (NAM) 2016 , <i>'The e-MERGE Legacy Survey - an e-MERLIN+JVLA Ultra-Deep Survey'</i> (O).	Nottingham, UK

2015	UK SKA Science Meeting , 'Towards the nJy Regime at the Highest of Resolutions' (O).	Manchester, UK
	Bonn-Dwingeloo Neighbourhood Meeting, ASTRON , 'Wide-field VLBI with the EVN' (O).	Dwingeloo, the Netherlands
	The many facets of extragalactic radio surveys , 'Nowhere to Hide - Wide-field VLBI of GOODS-N' (O).	Bologna, Italy
	NAM 2015 , 'Wide-field VLBI - Finding Radio Weak AGN' (O).	Llandudno, Wales
	Back at the Edge of the Universe , (A).	Sintra, Portugal

SEMINARS

2022	COIL-COP, University of Pretoria , 'Teaching the next generation of African radio astronomers through the DARA programme' (invited).	Pretoria, South Africa
2021	PSANA seminar, University of Pretoria , 'You are not alone. An astronomer's guide to good mental health during your postgraduate degree' (invited).	Pretoria, South Africa
2020	Kapteyn Wednesday Lunch Talk, University of Groningen , 'Development in Africa with Radio Astronomy' (invited).	Groningen, the Netherlands
2018	National Radio Astronomy Observatory (NRAO) Lunch Talk , 'The faint radio population in GOODS-N' (invited).	Socorro, USA
2017	Kapteyn Monday Lunch Seminar , 'The AVN, EVN and the next generation of radio astronomers'.	Groningen, the Netherlands
2016	JBCA Internal Seminar, University of Manchester , 'Nowhere to Hide - Wide-field VLBI of GOODS-N'.	Manchester, UK

WORKSHOPS

2022	European Radio Interferometry School 2022 , (O, SOC)	Dwingeloo, the Netherlands
2020	CASA VLBI workshop 2020 , 'Wide-field imaging' (O, SOC)	Virtual
2019	European Radio Interferometry School 2019 , 'Self-calibration' & 'Wide-field VLBI' (O)	Gothenberg, Sweden
2015	European Radio Interferometry School 2015 , (A)	Munich, Germany

Competitively awarded observing proposals

Summary – Radcliffe has obtained time on multiple major radio astronomy instruments across the world totalling 100s of hours. Radcliffe currently/is involved in the three largest projects on the European VLBI Network.

PRINCIPAL INVESTIGATOR

2022	A new window on radio AGN with e-MERLIN, EVN and LOFAR , Instrument: EVN. Time awarded: 200 hr
2020	The final frontier in wide-field surveys – mapping the primary beam of the EVN , Instrument: EVN. Time awarded: 12 hr
2017	The nature of the microJy variable source population in GOODS-N , Instrument: VLA. Time awarded: 10 hr
	DDT: Precise astrometry of the phase calibrator source J1234+6158 , Instrument: e-MERLIN. Time awarded: 24 hr
	EVN-COSMOS: Taming AGN & star-formation across cosmic time , Instrument: EVN. Time awarded: 72 hr
2016	DDT: Source identification around VLBI-detected gravitational lenses , Instrument: e-MERLIN. Time awarded: 12 hr

SIGNIFICANT CONTRIBUTING INVESTIGATOR

2022	Testing AGN evolution and feedback by combining the ILT and e-MERLIN/EVN , PI: McKean. Instrument: EVN. Time awarded: 200 hr
	Monitoring the old, discovering the new; mas-scale radio emission in M82 , PI: Williams. Instrument: EVN. Time awarded: 48 hr
2020	Unravelling the role of faint radio AGN across the infrared-radio correlation , PI: Delvecchio. Instrument: VLBA. Time awarded: 90 hr
2019	Resolving the core/jet Structure of the giant radio galaxy ESO422-G028 , PI: Riseley. Instrument: EVN & LBA. Time awarded: 16 hr
	Exploring the resolved microJy radio source population with EVN+eMERLIN , PI: Njeri. Instrument: EVN. Time awarded: 24 hr
2018	What drives outflows and negative feedback? - High resolution imaging of molecular gas in the SMBH-binary merger NGC6240 , PI: Beswick. Instrument: e-MERLIN. Time awarded: 24 hr
	The sizes and spectral indices of ~800 radio-detected galaxies in GOODS-N , PI: Thomson. Instrument: VLA. Time awarded: 42.5 hr

- An ultra-deep multi-frequency survey of galaxy evolution**, PI: Algera. Instrument: VLA. Time awarded: 180 hr
- Filler time VLBA survey of the UDS field: a VLBI pilot for MeerKAT-MIGHTEE**, PI: Deane. Instrument: VLBA. Time awarded: 47.5 hr
- Morphological identification of sources in the Northern SPARCS field**, PI: Wrigley. Instrument: e-MERLIN. Time awarded: 144 hr
- Spatially-resolved star formation in two bright ($S > 100 \mu\text{Jy}$) radio-detected sub-mm galaxies in ELAIS-N2**, PI: Thomson. Instrument: e-MERLIN. Time awarded: 64 hr
- 2017 **Pilot study: Morphological identification of sources in the Northern SPARCS field**, PI: Wrigley. Instrument: e-MERLIN. Time awarded: 28 hr
- Deep field classification of galaxies within the Lockman Hole**, PI: Wrigley. Instrument: e-MERLIN. Time awarded: 72 hr
- Low Frequency Insights into the Radio Continuum - Star Formation Rate Relation**, PI: Hindson. Instrument: LOFAR. Time awarded: 16 hr
- 2016 **41.95+57.5 An Enigmatic Compact Radio Source in M82 Revisited**, PI: Muxlow, Instrument: e-MERLIN, Time awarded: 12 hr

Professional Responsibilities & Collaborations

Summary – Radcliffe is an active, senior member of multiple major research collaborations and has founded multiple projects. His leading international research profile means he is regularly invited to join and play a senior role in multiple collaborations.

- 2022– **Partner contact**, for the National Astronomy and Space Science programme
- 2022– **Member**, University of Pretoria high performance computing steering committee
- 2022– **Member**, South African Astronomy Community Task Team (ACTT)
- National committee that organises operational aspects of Astronomy in South Africa and deals with strategic issues
- 2022– **Co-investigator**, Evolutionary map of the Universe project with the Australian SKA precursor
- 2022– **Co-investigator**, LOFAR VLBI collaboration
- 2022– **Founder & Chair**, SKA-VLBI simulations task force
- Multi-national working group investigating SKA-VLBI operational capabilities to influence SKA observing modes and infrastructure
- 2020– **Scientific referee**, for the e-MERLIN Time Allocation Committee (TAC)
- 2019– **Referee**, for leading high-impact, peer-reviewed journals (MNRAS, A&A & Nature)
- 2019–21 **Organiser**, of the University of Pretoria group meetings & colloquia
- 2019– **Core member**, of the MeerKAT (SKA pathfinder) VLBI working group (Chair: Deane [UP] & Agudo [IAA-CSIC])
- 2019– **Co-investigator**, of the MeerKAT (SKA pathfinder) deep field survey (MIGHTEE, PI: Jarvis [Oxford] & Taylor [Cape Town])
- 2018– **Core member**, SKA-VLBI Science Working Group
- 2016– **Co-investigator**, of the SKA Extragalactic Continuum Science Working Group investigating galaxy evolution through deep radio continuum imaging (PI Sargent [Sussex])
- 2016– **Co-investigator**, of SPARCS (SKA Pathfinders Radio Continuum Surveys) (PI Norris [ANU])
- Core member**, of the e-MERGE Survey – the e-MERLIN Galaxy Evolution Survey
- Allocated 918 hrs of e-MERLIN time as the largest e-MERLIN legacy projects. e-MERGE consortia comprises >100 international investigators, and the project is producing the deepest radio images of the sky with e-MERLIN probing star-formation and AGN activity back to redshift 5 and beyond
- 2016–18 **Co-organiser**, Wednesday lunch talk series *University of Groningen*
- 2015–16 **Co-organiser**, Jodrell Autumn Computing Seminar series (JACS)
- Designed, organised and delivered seminars for new arrivals to the astronomy group in Manchester. *University of Manchester*
The JACS seminars exist to this day
- 2015–16 **Chair**, Postgraduate Committee at Jodrell Bank Centre for Astrophysics
- Represented postgraduates of the astronomy group at the University of Manchester, helping influence policy changes *University of Manchester*

Skills

- Astronomical Software** AIPS (expert), Parseltongue (expert), CASA (expert), ds9 (intermediate), IRAF (basic) & GALFIT (basic)
- Programming Languages** Python (expert), HTML/CSS (expert), LaTeX (expert), Bash/Cshell (expert), C++ (intermediate), Fortran (intermediate) & Java (basic)

Operating Systems	Linux/UNIX (expert), macOS (expert), Windows (intermediate)
Software	Microsoft Office, git, docker, singularity, slack
Statistical Modelling	Multivariate modelling (through Bayesian Monte-Carlo Markov Chain samplers & standard 1st. square)
Machine Learning	CNNs, encoders and k -means clustering analysis through TensorFlow and scikit-learn

Outreach

Summary: Radcliffe has conducted a range of outreach activities ranging from public lectures & Q&As to public demonstrations.

- Astronomy talks for Sir John Talbot's Technology college
- Delivered workshops on UCAS University applications to secondary schools
- Invited talks & activities for Rodeheath Primary School & Elworth Hall for the *Out of this World* project
- Outreach for ALMA at the Manchester Festival of Light
- Science Busking as a volunteer for UoM Physics Outreach.
- Participated at the ScienceX outreach event in Manchester.

References

References available upon request