

Section A. Overview of Research Project

1. **Title:** Towards all-sky surveys at milli-arcsecond angular resolutions with wide-field VLBI
2. **Area of research:** Science
3. **Academic level:** Doctoral
4. **Abstract:** Understanding the astrophysical processes associated with star-formation and black hole activity, and testing models for dark matter and dark energy, requires observing the radio sky on extremely small spatial-scales. This is best achieved using the technique of Very Long Baseline Interferometry (VLBI), where radio telescopes separated by great distances are combined to produce sensitive images of the sky at milli-arcsecond (mas) angular resolutions. Unfortunately, the number of radio sources observed at such resolutions, and to a good sensitivity, are extremely limited. For example, data from single pointed observations and some well-studied “famous” fields have provided only a few hundred detections. However, any VLBI experiment has within it the signals from several hundreds of detectable radio sources (on 5 to 200 mas-scales). In this project, a PhD student will develop calibration and imaging algorithms that can be applied to wide-field VLBI experiments involving HartRAO and European VLBI Network stations (and eventually MeerKAT), with the goal of increasing sample sizes to the level where various applications of VLBI can reach their full scientific potential. The methods developed here will be directly applicable to all-sky surveys with SKA-VLBI in the future.
5. **Primary supervisor:**
 - a. Prof. John McKean
 - b. mckean@astro.rug.nl
 - c. South African Radio Astronomy Observatory (SARAO) / University of Pretoria
6. **Co-supervisor / Research Supervisor:**
 - a. Dr. Jack Radcliffe
 - b. jack.radcliffe@up.ac.za
 - c. University of Pretoria

Section B. Details of Research Project

1. Scientific merit:

In recent years, several pathfinder instruments (ASKAP, LOFAR and MeerKAT) have identified millions of new radio sources, laying the ground work for the deep surveys to be carried out with the SKA. These surveys have investigated the co-evolution of supermassive black holes and the triggering of star-formation in the distant Universe through forming large statistical samples (including sub-samples based on morphology, luminosity and host galaxy properties). These large population studies have resulted in many important results and contributed greatly to our understanding of galaxy formation and evolution. However, the vast majority of the detected radio sources remain unresolved in these data, and so, understanding the astrophysical processes at play and testing various models remains challenging. In the age of the SKA, observations from a few

arcsecond to around 300 milli-arcsecond will be possible (with SKA-MID at 1-2 GHz). However, given that the median size of a radio source is ~ 7 kpc (~ 1 arcsec; Muxlow et al. 2020), many radio sources will be marginally resolved, or only limited information about their structure will come from such data. To overcome this, astronomers can use a process called Very Long Baseline Interferometry (VLBI), which connects radio telescopes over vast distances to improve the angular resolution. This comes at the cost of losing information on the large-scale properties of the radio emission and significantly decreasing the area of sky that can be imaged. However, recent improvements in signal-processing and computing has led to the development of wide-field VLBI techniques that can allow several hundred radio sources per observation to be imaged. Thus far, this technique has been best applied to deep data from a few “famous” fields, yielding a handful of detections. To increase the statistics and to find rare types of compact radio sources, it is important to develop an all-sky survey mode for wide-field VLBI experiments that can be routinely applied to any part of the sky.

In this PhD project, the student will build upon work pioneered at the University of Pretoria (e.g. Radcliffe et al. 2021) to develop a generic wide-field VLBI pipeline that can be applied to any part of the radio sky. Currently, most VLBI experiments target a single object, even though the signals from 100s of sources are in the data. This represents a significant waste of resources, but also an opportunity to increase sample sizes by several orders of magnitude. Therefore, this project will develop a commensal VLBI observing programme that works hand-in-hand with regular experiments. This will involve efficiently identifying the locations of radio sources in low resolution data (either from existing catalogues, or from the short-baseline data in the VLBI observations; aka “on-the-fly” selection) and then selecting these targets for VLBI analysis. This will require the student to work closely with other members of the team at UP, who are developing techniques for efficiently creating multiple VLBI datasets from a single observation. Here, the student will develop the initial imaging and target selection for correlation, and build an automated pipeline so that the datasets can be efficiently analysed. This work will have an immediate impact through increasing the number of VLBI detected radio sources by up to 10^4 per year, which will be informative for the work being done at lower angular resolution with MeerKAT, but will also show the importance of having 5 to 200 mas resolution imaging, demonstrating the feasibility and scientific merit of developing an SKA-VLBI array. From these data, the student can potentially investigate the astrophysical processes associated with star-formation, black hole activity, and high-energy phenomena, but they can also test models for dark matter and dark energy using gravitational lensing. The science focus will be left to the interests of the student.

2. Feasibility:

The data for this project will come, in the first instance, from single-target e-MERLIN+EVN (including HartRAO) experiments that are led by the PI and members of their team. These data are typically extremely sensitive ($\sim 5 \mu\text{Jy}$ / beam) and have baselines sensitive to structure on 700 to 5 mas-scales, with an average beam-size of around 15 mas. These datasets are ideal for probing galaxy structure and formation given the wide-range of angular-scales that they probe. Once the methodology has been demonstrated, we will propose a commensal wide-field VLBI programme that runs in parallel to standard EVN experiments, which will provide the large number of detections needed for the science goals of the project.

In recent years, wide-field VLBI techniques have matured to the point that shallow/wide and deep/narrow surveys have been carried out (Deller & Middleberg 2014; Radcliffe et al. 2021). The basic model of creating multiple-phase centres exists, but this has been reliant on having pre-existing imaging to determine the phase centres and has been limited by the prohibitive processing time at the correlator. The pipelines developed during these surveys already exist, but will need to be modified to take into account the “on-the-fly” source selection proposed here. This should be rather straightforward as pipelines for analysing the e-MERLIN component of the data exist.

The project will also be intensive in terms of the required computing. In the first instance, we will use the facilities provided by IDIA for testing and producing initial results, before using a new compute cluster being procured at the University of Pretoria for joint correlation and data analysis of the large-scale wide-field VLBI commensal project.

3. SRAO research priority areas:

The project directly ties in with the following main SRAO postgraduate research focus areas in 2022:

Topics exploiting data projected to be available by 2024 from key existing radio astronomy instruments located in South Africa.

In particular, this project will use data that involves HartRAO as part of a VLBI array, in the first instance, and then MeerKAT when it becomes available for VLBI.

4. Qualifications, academic abilities, skills and/or experience:

The PhD student should have a background in radio astronomy techniques with an interest in imaging/calibration and pipeline development in Python.

Section C. Curriculum Vitae

Personal Details

Name: Prof. John McKean
Position: (Incoming) SARChI in Very Long Baseline Interferometry (VLBI)
Institution: SARAO / University of Pretoria
Email: mckean@astro.rug.nl

Education

- PhD Radio Astronomy, 2004, University of Manchester
- MSci (Hons) Physics and Astronomy, 1999, University of Glasgow

Awards, Distinctions, Fellowships

- Marie Cure Research Fellowship (2005–2007), Max Planck Institute for Radio Astronomy
- Postdoctoral Scholarship (2003–2005), University of California, Davis
- PPARC (UK) PhD Studentship (1999–2002), University of Manchester

Leadership Positions

- National Facilities (HartRAO) SARChI Chair Holder in VLBI, “*Probing the Nature of Dark Matter with Very Long Baseline Interferometry*”, (R11M)
- NWO-CAS, “*Testing galaxy formation on the smallest scales with gravitational lensing*”, (R9M)

Employment History

- Associated Professor, University of Groningen, 2013—present
- Associated Scientist, Netherlands Institute of Radio Astronomy, 2013—present
- Institute Fellow, Netherlands Institute of Radio Astronomy, 2009—2013
- Institute Fellow, Max Planck Institute for Radio Astronomy, 2005—2008
- Postdoctoral Scholar, University of California

Teaching

- *Introduction to Radio Astronomy*, University of Groningen, BSc Astronomy, 2014—present

Research Interests

- Continuum studies (LOFAR, VLBI)
- Active Galactic Nuclei and star-formation activity (triggering, feedback)
- Gravitational lensing (surveys, dark matter, high redshift Universe)
- Machine learning (source detection and characterisation)

Supervision

- 3 Postdoctoral Fellows (since 2018)
- 11 PhD Students (since 2008)
- 7 MSc Students (since 2016)
- 25 BSc Students (since 2015)

Publication Metrics

- 130 refereed papers (4 in *Nature*, 1 in *Science*)
- 7825 citations
- *h*-index = 45

Select Publications

1. “*A machine learning based approach to gravitational lens identification with the International LOFAR Telescope*”, Rezaei et al., 2021, MNRAS, 517, 1156
2. “*Gravitational lensing in LoTSS DR2: extremely faint 144-MHz radio emission from two highly magnified quasars*”, McKean et al., 2021, MNRAS, 505, L36
3. “*LOFAR imaging of Cygnus A - direct detection of a turnover in the hotspot radio spectra*”, McKean et al., 2016, MNRAS, 463, 3143
4. “*LOFAR: The LOw-Frequency ARray*”, van Haarlem et al., 2013, A&A, 556, A2
5. “*Gravitational detection of a low-mass dark satellite galaxy at cosmological distance*”, Vegetti et al., 2012, Nature, 7381, 341
6. “*High-resolution imaging of the anomalous flux ratio gravitational lens system CLASS B2045+265: dark or luminous satellites?*”, McKean et al., 2007, MNRAS, 378, 109
7. “*The Cosmic Lens All-Sky Survey - II. Gravitational lens candidate selection and follow-up*”, Browne et al., 2003, MNRAS, 341, 13

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: 'Finding the faintest supermassive black holes through advanced calibration' Primary supervisor	University of Pretoria
2022–23	Jayde Bhana , Project: 'A first look at sub-kiloparsec relativistic jets in distant, high redshift galaxies' Primary supervisor	University of Pretoria
2022–23	Llewellyn Coetzer , Project: 'Determining the true sensitivity of radio telescopes through beam-mapping' Primary supervisor	University of Pretoria
2021–22	Anneke van der Dussen , Project: 'A binary supermassive black hole in GOODS-N' Primary supervisor	University of Pretoria
2021	Zane Lentz , Project: 'Analysis of a serendipitous supernovae candidate identified in the GOODS-N field' 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) , 'Identifying AGN in the faint radio sky'.	Dwingeloo, the Netherlands
2019	Hartebeeshoek Radio Astronomy Observatory (HartRAO) , 'Finding AGN in the faint radio sky: A high-resolution perspective'.	Gauteng, South Africa
	Kapteyn Thesis Colloquium, University of Groningen , 'The faint radio population in GOODS-N'.	Groningen, the Netherlands
	Jodrell Bank Centre for Astrophysics, University of Manchester , 'Finding AGN in the faint radio sky: A high-resolution perspective'.	Manchester, UK
	University of Cape Town , 'Finding AGN in the faint radio sky: A high-resolution perspective'.	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 , 'The next generation of high-resolution surveys with SKA-VLBI' (O).	Gauteng, SA
	Inter-university Institute for Data Intensive Astronomy retreat 2022 , 'Wide-field VLBI at the University of Pretoria' (O).	Cape Town, SA
	Annual conference of the African Astronomical Society 2022 , 'Teaching interferometry to the next generation of African astronomers' (O).	Virtual
	VLBI in the SKA-era , 'Wide-field VLBI surveys in the SKA-era' (O).	Virtual
2021	SARAO postgraduate scholarship conference 2021 , (C).	Virtual
	SKA Pathfinders Radio Continuum Surveys X , 'The challenges associated with the beams of interferometers - a warning to the SKA-era' (O).	Virtual
	High Energy Astrophysics in Southern Africa 2021 , 'Active galactic nuclei in the faint radio sky' (O).	Virtual
	National Astronomy Meeting 2021 , 'Square pegs in round holes. - Accurate photometry for the SKA-era' (invited, O).	Virtual
	European VLBI Network Symposium 2021 , (A)	Virtual
2020	SARAO postgraduate scholarship conference 2020 , 'Preparing for MIGHTEE-VLBI wide-field surveys' (P, link).	Virtual
2019	SARAO postgraduate scholarship conference 2019 , 'Identifying AGN in the faint radio sky' (O).	Durban, South Africa
	SKA-VLBI key science projects and operations workshop , 'Wide-field VLBI in the SKA era' (invited, O, fully funded).	Manchester, UK
2018	European Week of Astronomy and Space Science 2018 , 'Nowhere to Hide: Wide-field VLBI with the EVN' (P, link).	Liverpool, UK
2016	SKA2016: Continuum Science Working Group Meeting , 'Lessons learned: An EVN & e-MERLIN perspective' (invited, O).	Goa, India
	SKA2016: Science for the SKA Generation , 'There's Nowhere to Run, Nowhere to Hide' (O).	Goa, India
	SKA Pathfinders Radio Continuum Surveys 2016 , 'Isolating AGN Using Wide-field VLBI & e-MERLIN Observations' (invited, O).	Goa, India
	e-MERLIN and Jodrell Bank Observatory: A radio astronomy facility for the SKA era , 'Isolating AGN using wide-field VLBI and e-MERLIN' (invited, O).	Manchester, UK
	European Week of Astronomy and Space Science 2016 , 'There's Nowhere to Run, Nowhere to Hide... Hunting for AGN Using Wide-field VLBI' (invited, O).	Athens, Greece
	National Astronomy Meeting (NAM) 2016 , 'The e-MERGE Legacy Survey - an e-MERLIN+JVLA Ultra-Deep Survey' (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 *University of Manchester*
policy changes

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