A Overview of the Research Project Proposal

1 Academic level of research project: MSc

2 Broad field of research: Astronomy/Astrophysics

3 Title of research project: Exploring cosmic dawn from the sub-Antarctic

4 Research project abstract/summary:

Probing Radio Intensity at high-Z from Marion (PRI^{Z}M) is an experiment that will study cosmic dawn in the universe using low frequency (< 150 MHz) observations of redshifted 21-cm emission from neutral hydrogen. The experiment comprises two small antennas that observe the 21-cm signal averaged over a large fraction of the visible sky. Measuring this global signal as a function of frequency/redshift opens a new window into a part of the universe's history that is very poorly understood.

One of the greatest challenges in probing cosmic dawn at low frequencies is terrestrial radio frequency interference (RFI), which swamps the cosmological signal even when the nearest RFI sources are hundreds of kilometres away. PRI^{Z}M has been funded by the South African National Antarctic Programme (SANAP) for deployments to Marion Island, which lies 2000 km from the nearest continental land masses and offers an exceptionally clean RFI environment. PRI^{Z}M was successfully installed on Marion Island during the April 2017 takeover voyage, and the instrument is continuing to observe throughout the Austral winter.

B Supervisor(s) Details

1 Primary supervisor's details

a Title and full name: Prof. Kavilan Moodley

b Name of South African or SKA Partner Country university at which the primary supervisor is a permanent academic staff member:
University of KwaZulu-Natal

c Email address and/or contact telephone number:
kavilan.moodley@gmail.com, 072 447 5499

d Supervision of postgraduate students – details of All the previous and Current postgraduate students Supervised, provided in the Table Format as shown In the Guidelines for the South African Radio Astronomy Observatory Research Project Proposals for Masters and Doctoral Research in 2019.

i Doctoral Students

Name of Student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Kenda Knowles	South Africa	Jan 2013	Dec 2015	Observational Probes Of Merging Galaxy Clusters	Matt Hilton Mathilde Jauzac
Susan Wilson	South Africa	Jan 2013	Aug 2017	Evolution of Galaxy Cluster Scaling Relations Over Half a Hubble Time	Matt Hilton (main supervisor) Nadeem Oozeer
Darell Moodley	South Africa	Jan 2010	Dec 2014	Optimisation Of The Population Monte Carlo Algorithm: Application To Cosmology	
Simon Muya Kasanda	Democratic Republic of Congo	Jan 2007	Dec 2011	Initial Conditions of the Universe: Signatures in the Cosmic Microwave Background and Baryon Acoustic Oscillations	
Ryan Warne	South Africa	Jan 2006	Dec 2010	The Thermal Sunyaev-Zel'dovich Effect as a Probe of Cluster Physics and Cosmology	
Angel Torres-Rodriguez	Spain	Jan 2007	Dec 2008	SKA simulations and cosmological constraints from large HI surveys	
Khadija El Bouchefry	Morocco	Jan 2004	Dec 2008	Multi-wavelength study of radio sources in the universe	Jon Rash (main supervisor)

ii Masters Students

Name of Student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Sinenhlanhla Sikhosana	South Africa	Jan 2015	Dec 2016	Giant Radio Halos and Relics in ACTPol Clusters	Sinenhlanhla Sikhosana
Heather Prince	South Africa	Jan 2014	Dec 2015	Gravitational Lensing Of The Cosmic Microwave Background: Techniques And Applications	Heather Prince
Jethro Ridl	South Africa	Jan 2010	Dec 2012	Weak Gravitational Lensing In The Cosmic Microwave Background: Reconstructing The Lensing Convergence	Jethro Ridl
Devin Crichton	South Africa	Jan 2010	Dec 2011	Probing Missing Baryons Using High Resolution Measurements Of The Cosmic Microwave Background	Devin Crichton
Darell Moodley	South Africa	Jan 2007	Dec 2010	Bayesian Analysis Of Cosmological Models	Darell Moodley
Mokhantso Phoolo	Lesotho	Jan 2006	Dec 2007	Optimal polarization measurements for constraining isocurvature modes	Mokhantso Phoolo
Simon Muya Kasanda	Democratic Republic of Congo	Jan 2005	Dec 2007	Cosmic Microwave Background Anisotropies in Neutrino Isocurvature Models	Simon Muya Kasanda
Ryan Warne	South Africa	Jan 2005	Dec 2005	Optical Observations Of Galaxy Clusters: Photometric Calibration Of Imaging Data From The Southern African Large Telescope	Ryan Warne

2 Co-supervisor / Research Supervisor's details

a Title and full name: Prof. Hsin Cynthia Chiang

b Name of South African or SKA Partner Country university at which the primary supervisor is a permanent academic staff member:
University of KwaZulu-Natal

c Email address and/or contact telephone number: chiang@ukzn.ac.za

d Supervision of postgraduate students – details of All the previous and Current postgraduate students Supervised, provided in the Table Format as shown In the Guidelines for the South African Radio Astronomy Observatory Research Project Proposals for Masters and Doctoral Research in 2019.

i Doctoral Students

Name of student	**Nationality**	**Date started Doctoral Degree (Month and Year)**	**Date completed / will complete Doctoral Degree (Month and Year)**	**Title of Research Project / Thesis**	**Co-Supervisor (if Relevant)**
Liju Philip	India	1/2016	12/2018	The Design, Construction and Deployment of PRIZM	Jonathan Sievers
Heiko Heilgendorff	RSA	9/2013	12/2017	The C-Band All Sky Survey Commissioning and Data Analysis	Jonathan Sievers

ii Masters Students

Name of student	Nationality	Date started Doctoral Degree (Month and Year)	Date completed / will complete Doctoral Degree (Month and Year)	Title of Research Project / Thesis	Co-Supervisor (if Relevant)
Bismark Kushiator	Ghana	7/2018	7/2020	HIRAX instrumentation and prototype characterisation	
Nivek Ghazi	RSA	1/2018	12/2019	Exploring cosmic dawn from the sub-Antarctic with PRIZM	
Austin Gumba	Kenya	1/2018	12/2019	Radio Astronomy Receiver Design and Commissioning	Jonathan Sievers
Kabelo Kesebonye	Botswana	1/2017	12/2018	HIRAX commissioning and instrument characterisation	
Johannes Allotey	Ghana	8/2014	12/2016	Commissioning and Characterisation of the C-Band All-Sky Survey Southern Telescope	

C Full Research Project Proposal, written for a professional who is not necessarily an expert in the relevant subfield

1 Scientific merit: describe the objectives of the research project, placing them in the context of the current key questions and understanding of the field.

Observations of redshifted 21-cm emission of neutral hydrogen are a rapidly growing area of cosmology research. Measurements across a wide range of radio frequencies allow us to access redshifts all the way from cosmic dawn up to the formation of the first large-scale structures. At early times, about one hundred million years after the big bang, the formation of the first stars heated the intergalactic medium (IGM), imparting characteristic structure in the temperature of the globally averaged 21-cm sky signal as a function of frequency. As time progressed, the first luminous objects began to reionize the surrounding IGM, creating patchy, spatially varying structure in the 21-cm signal that can be characterized by a three-dimensional power spectrum. This era, known as reionization, took place over the course of several hundred million years, after which the universe became fully ionized. The first detection of the global 21-cm signal was reported in early 2018, and the reionization power spectrum is still undetected to date; many experiments are racing to make radio-frequency measurements of the universe in this slice of its history, an epoch that is ripe for new exploration.

Probing Radio Intensity at high-Z from Marion (PRI^{Z}M) is an experiment that will study cosmic dawn in the universe using low frequency (< 150 MHz) observations of redshifted 21-cm emission from neutral hydrogen. The experiment comprises two small antennas that observe the 21-cm signal averaged over a large fraction of the visible sky. Measuring this global signal as a function of frequency/redshift opens a new window into a part of the universe's history that is very poorly understood.

One of the greatest challenges in probing cosmic dawn at low frequencies is terrestrial radio frequency interference (RFI), which swamps the cosmological signal even when the nearest RFI sources are hundreds of kilometres away. PRI^{Z}M has been funded by the South African National Antarctic Programme (SANAP) for deployments to Marion Island, which lies 2000 km from the nearest continental land masses and offers an exceptionally clean RFI environment. PRI^{Z}M was successfully installed on Marion Island during the April 2017 takeover voyage, and the instrument is continuing to observe throughout the Austral winter.

Given the small scale of PRI^{Z}M, the student who takes on this project will be able to contribute to a wide range of work spanning both instrumentation and analysis. The student may have the opportunity to participate in the April 2019 voyage to Marion Island, where we will perform on-site instrument characterisation and install new antenna hardware to lay the groundwork for measurements at exceptionally low frequencies (< 10 MHz). The student will also have opportunities to analyse data from the winter observations and develop hardware upgrades for future Marion deployments.

2 Feasibility: outline the methods that will be used to achieve the objectives. Provide details on the availability of required data / access to required equipment / availability of research facilities and other resources required. Include any relevant expected intermediate milestones and associated timeframes towards attaining the overall objectives of the project.

In the first year of this project, the student will build expertise in radio astronomy

and 21-cm cosmology. He/she will begin working with PRI^{Z}M subsystems in the lab in preparation for the April 2019 takeover voyage to Marion Island. Following the deployment, the student will perform lab tests of PRI^{Z}M hardware in order to debug any potential instrumental issues and improve the system. The student will also begin learning how to analyse PRI^{Z}M data. In year two, the student will continue lab tests of PRI^{Z}M hardware, including instrumentation for possible future upgrades. He/she will contribute to the analysis of the winter data from Marion.

PRI^{Z}M is a small-scale, self-contained experiment, and the observing programe has been funded through 2020. We have a well established radio instrumentation laboratory with all the necessary equipment for subsystem development and characterization. Data analysis will be performed using UKZN's 1000-core HPC cluster.

3 Link the proposed project to at least one SARAO research priority areas (refer to Annexure 1 of the Application Guide), and explain in some detail how the proposed research will contribute to the priority area(s).

PRI^{Z}M addresses the SARAO research priority area of radio astronomy antennas and receivers. Instrumentation and data analysis for RFI detection and removal will also be an integral component of this project, as the PRI^{Z}M observing environment is exceptionally radio quiet.

4 If relevant, describe any particular qualifications, academic abilities, skills and/or experience that a student should have in order to successfully deliver on the objectives of the research proposed.

The student must have sufficient patience and tenacity to withstand the inefficiencies and bureaucratic hurdles associated with hardware procurement.

D Signatures

1 Signature of the primary supervisor, with date

28 August 2018

2 If relevant, signature of the co-supervisor/research supervisor, with date

28 August 2018