Section A: Overview of the Research Project Proposal

1. Academic level of research project
Masters

2. Broad field of research
Astronomy

3. Title of research project
Optical spectroscopy of the LADUMA field

4. Research project abstract/summary
The LADUMA (Looking At the Distant Universe with the MeerKAT Array) survey is one of the large MeerKAT projects, which aims to study galaxy evolution by detecting the neutral gas in galaxies out to redshifts of ~1.4. Many of the LADUMA projects will stack subsamples of galaxies that are not individually detected and will rely heavily on spectroscopic redshift measurements to select and measure the properties of the galaxies in the stack. To increase the spectroscopic completeness for fainter higher redshift galaxies, we have undertaken a SALT multi-object spectroscopic survey over the past few semesters. In this project, the student will reduce the SALT spectra and measure redshifts for galaxies in the LADUMA field, improving the tools available for the data reduction and quality control. They will analyse the completeness and identify samples for early LADUMA science and further follow-up.

Section B: Supervisor Details

1. Primary supervisor's details
a. Title and full name
Dr Sarah Blyth

b. Name of South African or SKA Partner Country university at which the primary supervisor is a permanent academic staff member
University of Cape Town

c. Email address and/or contact telephone number
sarblyth@ast.uct.ac.za

d. Supervision of postgraduate students – please provide the details of all the previous and current postgraduate students supervised.

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)

Julia Healy	SA	Jan 2017	Dec 2020	Using HI Stacking to determine the cosmic neutral gas density at intermediate redshift	Marc Verheijen (University of Groningen)
Tshiamiso Makwela	SA	Jan 2018	Dec 2020	The impact of visualisation of 3D astronomy objects in school learning	Saalih Allie (UCT), Dale Skippers (UCT)
Gerald Balekaki	Ugandan	Jan 2016	Jun 2019	A robust online RFI database for SKA	Michelle Kuttel (UCT), Anja Shroeder (SAAO)
Narges Hatamkhani	Iranian	Aug 2016	Dec 2019	Unveiling of the newly discovered Vela Supercluster	Renee Kraan-Korteweg (UCT)
Jamie Bok	SA	Jun 2015 (upgraded from MSc)	Dec 2019	Probing the role of HI content and environment on the galaxy main sequence	Tom Jarrett (UCT), Michelle Cluver (Swinburne), Rosalind Skelton (SAAO)
Tom Mutabazi	Ugandan	Jul 2012	Jul 2015	The distance to the Norma cluster and its relation to the Great Attractor	Patrick Woudt (UCT)

ii. Masters Students

Name of student	**Nationality**	**Date started Masters Degree (Month and Year)**	**Date completed / will complete Masters Degree (Month and Year)**	**Title of Research Project / Thesis**	**Co-Supervisor (if relevant)**
Nazir Makda	SA	Aug 2017	Dec 2018	Ultra-diffuse galaxies in Stripe 82 Clusters	Rosalind Skelton (SAAO)
Nadine Hank	SA	Feb 2018	Dec 2019	Exploring HI asymmetries in galaxy mergers with simulations	Nathan Deg (UCT)
Julia Healy	SA	Jan 2015	Jun 2017	Using HI Stacking to study galaxy properties in the nearby Universe	Ed Elson (UCT)
Christopher Schollar	SA	Jan 2012	Jun 2015	RFI Monitoring for the MeerKAT Radio Telescope	Michelle Kuttel (UCT), Anja Schroeder (SAAO)
Scott Badenhorst	SA	Jan 2011	Jun 2015	Acceleration of the noise suppression component of the DUCHAMP	Michelle Kuttel (UCT)

				source-finder	
Riona Ramraj	SA	Jun 2012	Jun 2014	Exploring star-formation in dwarf galaxies at z~1	David Gilbank (SAAO)
Zara Randria-manakoto	Madagascan	Jun 2009	Dec 2010	Super star clusters and star formation in interacting galaxies	Petri Vaisanen (SAAO)

1. Co-supervisor's details

a. Title and full name
Dr Rosalind Skelton

b. Name of the university/institute at which the co- supervisor is a permanent academic/research staff member
South African Astronomical Observatory (SAAO)

c. Email address and/or contact telephone number
ros@saao.ac.za, 0214609355

d. Supervision of postgraduate students – please provide the details of all the previous and current postgraduate students supervised.

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)
Jamie Bok	South African	July 2016	Dec 2019	Probing the role of HI content and environment on the galaxy main sequence	Sarah Blyth, Tom Jarrett

ii. Masters Students

Name of student	Nationality	Date started Masters Degree (Month and Year)	Date completed / will complete Masters Degree (Month and Year)	Title of Research Project / Thesis	Co-Supervisor (if relevant)
Nazir Makda	South African	Feb 2017	Dec 2018	Ultra diffuse galaxies in Stripe 82 clusters	Sarah Blyth

Section C: Full Research Project Proposal

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.

The LADUMA (Looking At the Distant Universe with the MeerKAT Array) survey (PIs: Blyth, Holwerda & Baker) is one of the approved Large Survey Projects for MeerKAT. The survey aims to probe the evolution in the gas content of galaxies by observing their HI emission over more than 2/3 the age of the universe by observing a single pointing that encompasses the extended Chandra Deep Field-South for over 3000 hours. Since HI emission is typically weak, many of our analyses will rely on coadding/stacking the HI spectra of galaxies below the LADUMA direct detection threshold to determine the average HI properties of galaxies in different sub-samples. To do this we require accurate redshift information based on optical spectroscopy. Photometric redshifts do not have sufficient accuracy to ensure that our stacking results are reliable, which is why it is imperative to use spectroscopic redshifts for stacking-based analyses (Maddox et al. 2013). Spectroscopic redshifts will also enable us to measure the environments in which galaxies are located. Environmental density is known to be one of the important driving factors for differences in the morphologies and star formation rates of galaxies, but how it impacts the evolution of galaxies is not yet fully understood.

Significant numbers of spectroscopic redshifts have been obtained by our team over the past few years, with a campaign on the AAT measuring ~8000 redshifts for reasonably bright galaxies at low redshifts. To extend the spectroscopic coverage to higher redshifts, we have undertaken a SALT multi-object spectroscopy campaign over the past two years to measure additional redshifts for fainter galaxies, selecting galaxies most likely to lie in the redshift range $0.4 < z < 0.5$ based on their photometric redshifts. This redshift range is particularly interesting for two reasons related to the design of MeerKAT's receivers. First, a measurement of HI emission in this range will set the high redshift record; second, this range falls in the overlap of coverage between MeerKAT's L-band and UHF-band receivers, meaning it will be observed for 100% of the survey, with L-band data expected to start coming in already by the end of 2018.

This project involves using the PySALT python package to reduce the SALT spectroscopic data that has already been obtained, to measure galaxy redshifts. Fifteen masks have been observed, with 11 of them observed in two separate visits. Single visits of the first few masks observed were reduced to verify the survey strategy, but systematic data reduction, redshift measurement and verification of the redshifts for the full data set is still needed. By combining multiple exposures through the same mask we expect to be able to increase the S/N and measure redshifts for fainter targets. The student will extend the available pipeline code to optimally stack data taken in separate visits and could adapt existing code from another multi-object spectroscopy facility to create a graphical interface that will allow us to quickly and easily visually inspect and classify the quality of SALT spectra and redshift fits. Using the available multi-wavelength catalogues of the LADUMA field and simulations (Elson et al. 2016), the student will explore parameter space to selecting interesting new samples for future LADUMA science, analyse the completeness of the spectroscopic surveys, which will be important for a wide range of upcoming LADUMA science projects, and optimize the designs for next SALT observations.

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.

High-level breakdown of activities:
First year:

- Use PySALT python code to wavelength calibrate and extract optical spectra of galaxies in the LADUMA field from SALT
- Optimize a technique for stacking multiple exposures to extract fainter sources
- Measure redshifts by cross-correlating with template spectra
- Adapt existing code to display 1D and 2D spectra and fitted models to efficiently check the quality of the spectra and redshift fits

Second year:

- Use code developed in first year to analyse any additional data obtained
- Estimate the completeness of the spectroscopic coverage on the LADUMA field as a function of redshift, magnitude, stellar mass etc.
- Design new masks for SALT multi-object spectroscopy of LADUMA samples
- Write up thesis and publishable catalogue of redshifts

Data availability and analysis techniques
Multi-wavelength catalogues, photometric redshifts, and simulations are already available for the LADUMA field. SALT spectroscopy from our ongoing programme 2017-1-MLT-014 (PI: Blyth) is already in hand, and further data is expected to be taken over the course of the project. The data obtained to date is expected to yield approximately 150 redshift measurements, with an additional ~120 per semester over the next year. Tools are available to reduce and analyse the data, but the methods can be improved and automated by adapting existing code.

Facilities
Dr Skelton is a SALT astronomer and will be able to provide access to the facilities at SAAO/SALT. The student will have the opportunity to visit the Sutherland site to obtain optical observing experience. As a UCT student working on a LADUMA-related project with one of the Principal Investigators of the survey (Dr Sarah Blyth), the student will have access to IDIA cloud computing resources to work with their data as well as the cluster computing facilities at SAAO. They will also have access to a desk and the usual internet and library access afforded to all postgraduate students at SAAO and UCT.

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).

The proposed project links to the SARAO research priority:
6. Science topics that involve the exploitation of MeerKAT data projected to be available by 2019 - 2020. (Multiwavelength projects that are directly linked to approved MeerKAT Large Survey Projects will be considered.)

This project is directly linked to one of the MeerKAT Large Surveys, LADUMA. It will make use of existing ancillary multi-wavelength data and SALT data obtained specifically for LADUMA. The measured redshifts will allow for stacking of LADUMA HI MeerKAT data at intermediate redshifts, and a study of the spectroscopic completeness and sample selection will be made use of by the LADUMA team for a range of projects to be undertaken with the first L-band data in 2019-2020.

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.

Experience with optical spectroscopic data reduction and good programming skills, particularly in python, would be an advantage, but the required skills can be acquired during the MSc if necessary.

Section D: Signatures

1. Signature of the primary supervisor, with date

_____ 31 August 2018

Dr. Sarah Blyth Date

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

_____ 31 August 2018

Dr. Rosalind Skelton Date