Section A: Overview of the Research Project

1. Title of research project:
HI in large scale structure in the LADUMA field

2. Broad area of research:
Science

3. Academic level of research project:
Master's

4. Abstract
Large spectroscopic galaxy surveys (e.g. the Sloan Digital Sky Survey), have uncovered the large scale structure of the universe, known as the 'cosmic web'. Galaxies are preferentially found in higher density regions, such as galaxy clusters or groups, or in the intermediate density filaments which connect groups and clusters. The filaments, clusters and groups surround relatively empty regions known as voids where very few galaxies are located. In addition, an important driver of galaxy evolution is environment, with higher density regions being sites of various processes which affect the colours, star formation rates, morphologies, and neutral hydrogen gas (HI) content of galaxies. While the optical properties of galaxies in filaments have been studied by various authors, less is known about the neutral gas content of filaments. Recent studies (e.g. Kleiner et al, (2016), Luber et al. (2019), Blue Bird et al., (2020)) have focused on the HI content of galaxies in filaments in the local universe but deeper HI observations are required to probe this observable at higher redshifts. The LADUMA (Looking At the Distant Universe with the MeerKAT Array) survey will observe HI in galaxies back to when the Universe was less than one third of its current age using the MeerKAT radio telescope which will enable us to study the HI in galaxies in different environments, well beyond the local universe.

5. Primary supervisor's details:

a) **Full name of primary supervisor:** Sarah Blyth
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c) **University:** University of Cape Town

Section B: Details of the Research Project

1. Scientific merit:

While the dense regions of galaxy clusters and groups are well-known sites of galaxy evolution processes, the role of the intermediate density filaments, and the dominant processes affecting galaxy evolution within them, is less clear. Recently it has been shown that galaxies inside filaments seem to have on average higher stellar masses than galaxies located outside filaments (e.g. Laigle et al., 2017, Malavasi et al., 2017), as well as redder colours (e.g., Kuutma et al., 2017, Luber et al., 2019). Some studies have shown that galaxies inside filaments seem to have their spins aligned with the filaments in which they are located (Tempel et al., 2013) and this might be connected to gas accretion within filaments.

In addition to the stars, an important component of galaxies is their neutral hydrogen gas, HI, which forms the raw fuel for eventual star formation. To get a full picture of the processes driving galaxy evolution in filaments, it is therefore important to understand how the HI is affected in galaxies inside filaments. Recently, various studies (e.g. Kleiner et al., 2016, Luber et al., 2019, Odekon et al., 2018) have investigated the HI content of filament galaxies in the local universe. For example, Kleiner et al (2016) found that high stellar mass galaxies had higher HI masses if located inside filaments than if located far from filaments. However Luber et al. (2019) found that the gas fraction of galaxies seems to increase with increasing distance from filaments. Further investigations to probe the processes removing and adding gas to galaxies inside filaments are needed. The LADUMA L-band dataset will be ideal to probe the HI content of galaxies in filaments beyond the local universe.

The goals of this project will be to identify filaments in the LADUMA volume and to use the first L-band data from the LADUMA survey to measure and compare the HI content of galaxies inside and outside filaments at different redshifts.

2. Feasibility:

Data availability and analysis techniques:
The project will make use of data from the first set of LADUMA 32k L-band data as well as the existing ancillary data in the field including optical and photometric redshift catalogues and photometry across a range of wavebands.

To identify filaments, the software package DisSperSE (Sousbie, 2011) will be used. This package has been widely used in the recent literature in both simulated and observational data and has been found to be reliable. It has also been used by a current student of Blyth's to study a nearby galaxy reference volume for LADUMA and has been very successful in identifying filaments in the volume. The student will also collaborate with other team members working on group and cluster identification for comparison with filament-finding results.

Once filaments have been identified, samples of galaxies inside and outside filaments will be identified and their photometric (ancillary data sets) and gas (LADUMA data) quantities studied. If galaxies are not directly detected in HI (e.g. at the higher redshifts), the HI stacking technique will be used to quantify the average HI in the subsamples.

Over the past years, the LADUMA team have put together a database consisting of thousands of optical redshifts of galaxies in the LADUMA field which will be used for the filament identification and for HI stacking. The student could also be involved in additional spectroscopic campaigns at higher redshifts (e.g. on SALT).

Resources and equipment:
As a LADUMA team member, the student will have access to the IDIA compute facilities where the LADUMA data will be processed and analysed. Being at UCT will enable the student to interact with IDIA researchers and technical experts who will be able to help support the computing aspects. As a student in the Department of Astronomy, the student will also have access to the usual desk and office space, internet access and library access afforded to all postgraduate students.

High level breakdown of activities:
- Identify appropriate redshift slices, based on available team redshift (spectroscopic and photometric) catalogues, within which to look for possible filaments (2022)
- Collaborate with other LADUMA team members investigating and identifying different galaxy environments in the LADUMA field to identify filaments and become familiar with DisPerSE software. (2022)
- Quantify and compare the properties (photometric and HI) of galaxies inside and outside identified filament structures. (2022 – 2023)
- Write up thesis (2023)

3. Relevance to SARAO research priority areas:
This project falls squarely under the priority area: “Topics exploiting data projected to be available by 2022-23 from key existing radio astronomy instruments located in South Africa. […] MeerKAT is the highest priority area.”
This project will utilize data from the MeerKAT Large Survey Project, LADUMA. A considerable quantity of data (L-band) is already in hand and first datacubes are expected to be ready during 2021. Therefore the data will be in hand by the time this project starts.

4. Skills/experience useful to the student on this project:
Good python programming skills will be needed and experience in analyzing and working with HI data cubes will be an advantage. However, the student will learn these skills on the project if they have not yet had this experience.

Assoc. Prof. Sarah Blyth, February 2021