Section A: Overview of the Research Project Proposal

1. Title of the research project:

Processing of galaxies in the Virgo filament

2. Broad field of research:

Astrophysics

3. Academic level of the research project:

PhD

4. Research project abstract/summary:

The evolution of galaxies is mainly governed by their star formation activity. Cold and dense gas is fuel for star formation, therefore understanding how, and more importantly, where gas is accreted and depleted is among the fundamentals in evaluating galaxy evolution. Through observations, it is clear that the galaxy environment plays a crucial role in this process. The environmental effect on the gas component of galaxies manifests itself in a multitude of processes such as ram-pressure and tidal stripping, galaxy-galaxy encounters, and removal of the diffuse gas reservoir of galaxies. The dense galaxy clusters have been shown to have a deep impact on the gas phase of galaxies and in accelerating their evolution. However, it has also been found that filaments might already be pre-processing galaxies long before they get channelled towards the cluster centres. Fewer studies on understanding the true impact of filaments in galaxies exist, of note, an important question is whether they deplete or replenish galaxies' cold gas reservoirs.
In this project, the student will participate and partly lead the gas analyses of the Virgo III filament to be observed with MeerKAT. The proximity of this large-scale structure and exquisite MeerKAT data make a perfect laboratory with tools to examine the cold gas content and pre-processing in this environment.

5. Primary supervisor's details

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Section B: Details of Research Project

1. Scientific merit

Galaxies generally fall within two broad categories, i) the active star-forming late-type galaxies and ii) passive non-star forming early-type galaxies. (Strateva+, 2001, AJ, 122, 1861, Brammer+, 2009, The ApJL, 706, L173, Muzzin+, 2013, ApJ, 767, 39). One of the most exciting ongoing research is to understand how star formation in galaxies ceases, hence leading to the build-up of the passively-evolving galaxy population. The environment of galaxies is critical for these investigations. For example, it has been found that the fraction of star-forming galaxies decreases as a function of the distance to cluster centres (Dressler 1980, ApJ, 236, 351, Blanton & Moustakas, 2009, ARA&A, 47, 159). Several physical mechanisms have been proposed to explain this observation, including among others, tidal stripping (Gnedin, 2003, ApJ, 582, 141), ram-pressure stripping (Gunn & Gott, 1972, ApJ, 176, 1), thermal evaporation (Cowie+, 1977, Nature, 266, 501), encounters with other satellites (Moore+, 1996, Nature, 379, 613), and the removal of the diffuse gas reservoir of galaxies (Larson+ 1980, ApJ, 237, 692). However, there is still a lack of observational evidence that will distinguish between the relative importance of the different mechanisms and their sphere of influence.
Interestingly, the suppression (quenching) of star formation seems to occur already at large

distances from the cluster cores. This suggests that galaxies are therefore possibly pre-processed by their environment before they ever fall onto the cluster cores (Einasto+, 2018, A\&A, 610, A82, Salerno+, 2020, MNRAS, 493, 4950). This pre-processing may be occurring at the large cosmic-web filaments which possibly play an important role in quenching star formation. For example, massive and passive galaxies have preferentially been found close to the filament axes.
As important as these filaments are, they still remain poorly explored around galaxy clusters due to the lack of deep imaging and accompanying spectroscopy in these extended regions. Moreover, so far most studies focused only on the consequence of quenching, i.e. the properties of the stellar populations. It is, however, imperative to probe the fuel of star formation, as the gas is ultimately what must be affected to stop star formation.

The aim of the student project is to study galaxy pre-processing using neutral gas (HI) observations of the Virgo III filament associated with the nearby Virgo cluster. There have been hints that HI gas could be removed from galaxies at the periphery of the Virgo cluster (Solanes+, 2002, AJ, 124, 2440, Castignani+, 2021, arXiv:2101.04389). The Virgo III filament is representative of the large scale structures around Virgo, it has been observed with MeerKAT and is sufficiently nearby to be able to evaluate pre-processing in large scale structures with a great level of detail. The main goals of the projects are among others, to look for evidence of;

i) shocks due to ram-pressure, tides, and subsequent perturbations, as well as asymmetries in the main bodies of the galaxies.

ii) winds and/or tidal tails due to gas expelled by the wind or tidal tails in the outskirts of galaxies.

iii) enhanced star formation due to ram pressure by using radio continuum as a tracer for star formation and comparing it with Hα images.

2. Feasibility and resources

The HI data required for this project have already been approved for observations by SARAO. The data is expected to be accessible by the time the student starts their work in 2023. The PhD work will consist of getting acquainted with the data reduction, characterisations and analyses of the HI gas content in the galaxies to address items i), ii), and iii) as outlined in section 1. This includes quantifying the mass of gas at play, quantifying the environments and concluding on the physical mechanisms at play. The PhD work also includes comparing the HI gas properties with the Hα, UV to NIR maps for a complete interpretation of the MeerKAT HI dataset. This will be done in collaboration with a large team of international researchers.

The project has a wealth of ancillary data which is already available and will support this study by enabling the precise measurement of the galaxy sizes, morphologies, stellar masses and star formation rates (SFR) from GALEX UV photometry, SDSS ugriz imaging, optical spectroscopy, and infrared (WISE and/or IRAS) fluxes, and other gas phases such CO and Hα emission from proprietary datasets.
Rhodes University (RATT/RARG) and EPFL have access to several high-performance

computing facilities and sufficient storage, such that there are adequate resources to analyse the data for this project.

A plausible time-frame for the project is as follows:

Year 1: The student will start with a literature study in the first half of 2023 to understand the topic. They will use this time to become up to date with the latest scientific results on the subject and familiarise themselves with the scientific goals of the project, and the scientific questions to be addressed in the dissertation. During this time the student will also familiarise themselves with observational radio astronomy and interferometry (if necessary) and get acquainted with HI data reduction techniques to start the reduction of the MeerKAT dataset.

Year 2: It is expected that the data reduction will be fully completed during this time. The student will then perform source-finding to search for the HI detected galaxies, analyse their distribution and place them in the context of the cosmic large scale structure of Virgo filament. This process will also include collecting and processing the complementary multi-wavelength data required to perform the necessary analyses and address the scientific questions, as outlined. The work will be done in close partnership with a co-supervisor at the collaborating institution (e.g., EPFL) where the student is expected to visit[1] and work with the rest of the team.

Year 3: The student will finalise the results and write up their thesis. At the end of the PhD work, they will present their work at both institutions (Rhodes and EPFL). A paper or two based on this PhD will form part of the work to be conducted in year 2 or will be expected to follow.

In all cases, the student will work in close collaboration with supervisors at Rhodes University and EPFL. This project benefits from an international consortium which will offer the student an opportunity to interact closely with many faculty on the program and to give (remote) seminars on her/his work at the various institutions.

3. SARAO research priority areas

This project is addressing the following SARAO priority area;

- Topics exploiting data projected to be available by 2023-24 from key existing radio astronomy instruments located in South Africa: this is a MeerKAT project.

4. Student academic abilities/skills required

For this project, a candidate would require a Masters degree in astronomy, physics, engineering or a similar discipline. They need to have a working knowledge of scripting languages e.g., Python, Matlab etc, and if not present the candidate must be capable of becoming rapidly familiar with a scripting language of their choice. Some experience with observational radio astronomy, interferometry, analysis of radio astronomical data is desirable but not a requirement.

[1] Depending on travel restrictions