The rise and fall of gas in galaxies around galaxy clusters

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Section A: Overview of the Research Project Proposal

1. Title of the research project:

The rise and fall of gas in galaxies around galaxy clusters

2. Broad field of research:

Astrophysics

3. Academic level of the research project:

PhD

4. Research project abstract/summary:

The student will participate and partly lead the analysis of an unprecedented sample of neutral-hydrogen observations of galaxies around some tens of galaxy clusters. As the observations are deep enough to detect the tenuous interface between the galaxies and their environment, this enables the students to gain invaluable insight on the influence of the wider cluster environment on the state of the neutral gas in the observed galaxies. In particular it will be possible to pinpoint transition phases from actively star forming spiral galaxies accreting gas from the environment to red and dead early type galaxies, whose gas has been removed in the violent cluster environment. This type of observational research is crucial to inform galaxy evolution theories.

5. Primary supervisor's details

a. Full name of primary supervisor
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6. Research supervisor's details

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Further co-supervisors:
Dr. N. Gupta, IUCAA, India
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Section B: Details of Research Project

1. Scientific merit

Using a broad brush there are two types of galaxies, the actively star forming (blue) spiral and irregular galaxies, and early type galaxies, which are not star forming but red, mostly structureless, and hence 'dead', as they have lost their star forming material, the gas. It is clear that there must be a more or less rapid transition from the star forming to non-star forming and potentially also vice versa. This depends largely on environmental effects. Larger star forming galaxies generally have to accrete gas from the ambient medium to sustain their ongoing star formation as their gas reservoirs are too small to sustain star formation over their lifetime, while there are external processes that will stop star formation in galaxies and transform them into early type galaxies. A good understanding of these processes is important to support cosmological theories and simulations.

Since it is known that galaxy clusters are the domain of early type galaxies, while galaxy groups and the looser environment along cosmic filaments are the domains of spiral galaxies, the wider surroundings of galaxy clusters is a prime target to study these transformation processes. A survey of the morphology of the neutral hydrogen around galaxies in the vicinity of galaxy clusters (and in the field) would enable us to make a tremendous advancement in the understanding of the processing of gas in galaxies. Neutral hydrogen is the cool phase of the most abundant atom in the universe and observable in the 21 cm radio line with radio telescopes like MeerKAT.

Luckily, MeerKAT has conducted exactly such a survey, the results of which are available to a group of South African researchers, spending roughly 1200 hours of observing time on roughly 150 galaxy clusters, many of which with a redshift accessible to the RFI-free parts of MeerKAT. The field-of-view of MeerKAT and its frequency coverage guarantee that a large parameter space in environmental density is covered. While the velocity resolution of the survey with 44 km/s will allow us to determine the velocity structure of the individual galaxies only roughly, the depth of the survey will nevertheless allow us to see the tenuous neutral hydrogen around the galaxies as they interact with their environment.

In this project the student will participate in characterising the properties of gas in galaxies as they are observed closer and closer to the clusters.
While we expect the data reduction to be finalised by the beginning of the thesis, the student will learn to reduce MeerKAT radio data of cluster observations, to become familiar with the characteristics of interferometric radio observations.
After that, the student will characterise the morphologies of galaxies to find out which processes lead to the loss and, potentially, accretion of gas. Part of this work is the automated detection and analysis of the data, potentially making use of machine learning techniques to identify interacting neutral-hydrogen disks. Depending on the status of the project at the time of the commencement of the PhD thesis, the student will make use of several analysis techniques to determine mass, size, symmetry, and orientation of the gas, to e.g. determine the characteristic radius and cluster properties for which the characteristic transition between types happens typically. A particular emphasis lies on the morphology of the galaxies in the environment of galaxy clusters and their comparison to optical properties. The project is hence an opportunity to participate in an unprecedented survey of neutral hydrogen in galaxies in a denser environment.

2. Feasibility and resources

The spectral line data needed for this Ph.D. project have already been recorded and are accessible to the supervisors pending on the acceptance of a community proposal (Knowles et al.). The RATT/Rhodes HI group (PIs Ramatsoku and Józsa) has been asked to play a main role in the data reduction and analysis of the line data, implying the availability of the data to the group. The individual research projects have to be discussed with the Chief Scientist, but the sample proposal does not indicate competing projects. The data is so massive that even if there is an accompanying similar project, both can be accommodated.
In an initial study the student will be made familiar with a radio data reduction to learn about the specifics of radio data.
If the step is not finished yet the student will then be able to run and tune source-finding software to identify galaxies in the data cubes. Those galaxies which are detected will require a classification and categorisation. In this study the student will in particular parametrise and cross-correlate the properties mass, orientation, symmetry, characteristics of the extraplanar gas, extraplanar gas mass vs. disk gas mass, stellar mass, and star formation properties. A successful systematic characterisation of these properties is each a milestone and the stage of the study will be followed up in 1-2 publications. After this stage, the student will turn to the acquisition of multi-wavelength ancillary data including imaging, and spectra, therefore stellar masses, SFRs, some of these data are already attainable. In addition particularly interesting fields will be proposed for re-observation with MeerKAT to enable detailed kinematical studies. A potential ancillary survey would

target the molecular gas phase in the galaxies (using ALMA) to get a better understanding of the ability of the galaxies to retain gas in various phases.
This will be concluded with a final paper and summary of the work.

RATT/RARG is in possession of several high-performance compute clusters and sufficient storage, such that there are sufficient resources to analyse the data. We expect the bulk of the data to be reduced by the start of the PhD project, such that the student is able to begin the analysis after a brief introduction in radio imaging.

3. SARAO research priority areas

This project is addressing the following SARAO priority areas, ordered by relevance, from top to bottom:

- Data projected to be available by 2021-22 from key existing radio astronomy instruments located in South Africa, with MeerKAT having the highest priority: this is a MeerKAT project.

4. Student academic abilities / skills required

The student should have the ability to write Python scripts and be proficient in Physics. Some experience with the analysis of radio astronomical data, in particular data cubes is highly recommended but not an ultimate requirement. Experience in the kinematical and dynamical analysis of galaxies is welcome.