The dynamics of the interstellar medium in Hickson Compact Groups

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Section A: Overview of the Research Project Proposal

1. Title of the research project:

The Dynamics of the interstellar medium in Hickson Compact Groups

2. Broad field of research:

Astrophysics

3. Academic level of the research project:

PhD

4. Research project abstract/summary:

Hickson Compact Groups are a special class of galaxy groups. They are characterized by a high density of the group members, which are interacting frequently. About 100 groups of this type are known. In this project, we will study the radio properties of 2 or more HCGs as observed with the MeerKAT telescope. The observations are the deepest available and have the highest spatial resolution achieved for this type of galaxy group. Having ancillary data at our hands we will investigate the type of interaction that characterizes the groups, concentrating on the new radio data, and investigating the kinematics and morphology of the neutral gas through the HI emission line, star formation properties through the radio continuum, and magnetic fields through polarisation. The goal of the study is to get new insights in the characteristics and formation of HCGs, as well as to study galaxy interaction in extreme environments.

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Section B: Details of Research Project

1. Scientific merit

The evolution of galaxies is to a large extent determined by the history of their interactions with other galaxies and the intergalactic medium. The environment is hence a significant parameter for the pathways that a galaxy might evolve into. To form stars, galaxies require cold gas. In looser environments, galaxies tend to grow through the accretion of gas from the cosmic web. The gas gets turned into stars. In denser environments, however, this gas gets heated and diffused into the intergalactic medium through interactions between galaxies and between the galaxies and the intragroup- or intracluster medium, or the feedback from supermassive black holes at their centres. To understand galaxy evolution it is crucial to understand these processes. With time, galaxies stream towards the highest mass concentrations and will therefore end up in galaxy clusters, so they will be exposed to more and more extreme conditions in their surroundings. This will turn them from star forming spiral galaxies to red and dead early type galaxies (ellipticals and lenticulars). It is, however, not clear at all, at which stage these transformations will generally take place and in which numbers. It is well established that the so-called "pre-processing" of galaxies, their evolution within galaxy groups or through individual encounters, plays an important role to get a general picture. The study of the detailed characteristics of galaxy transformations is hence a hot topic in galaxy evolution in general.

While the group environment is typically an intermediate between the field and galaxy clusters, this is not true for Hickson Compact Groups (HCG), which are a rare species among galaxy groups. About 100 groups of this type are known. In fact, the

galaxy density in those groups, which are usually rather isolated entities, can be compared to that of galaxy clusters. Galaxy evolution in Hickson Compact Groups is the most extreme form of preprocessing. HCGs are hence suited to study preprocessing as well as an interesting field to study in general. What will these groups eventually evolve into and what are the mechanisms dominating the interaction in this environment?
Crucial for the study of HCG physics is the role of the interstellar and intergalactic medium in HCGs. In fact, radio observations have contributed significantly to our understanding of HCGs. With their help it was possible to distinguish evolutionary stages where the neutral gas in HCGs gets more and more removed from the individual galaxies and is pushed into the intra-group medium, to finally be heated and removed from the pool of available star forming material (see Fig. 1).

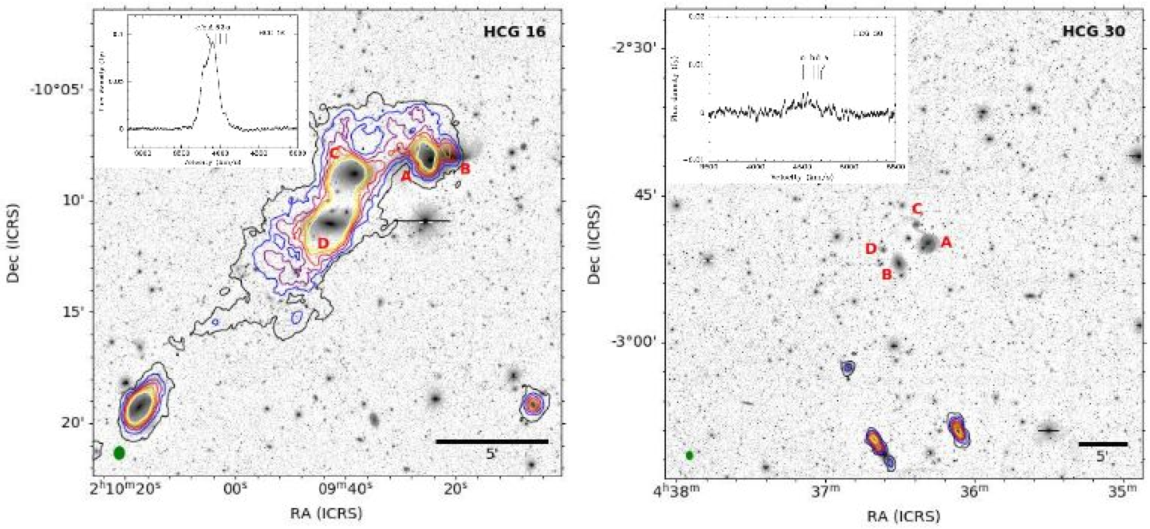

Fig. 1: Two potential targets for the PhD work as observed in the 21cm line of the neutral atomic hydrogen with the Very Large Array and the Greenbank Telescope: HGC 16 on the left has undergone major interactions and much of the neutral gas can be found between the galaxies. HCG 30 on the right has already lost a lot of its gas. However, the Greenbank observations indicate that there is an underlying HI component that is not seen by the Very Large Array. MeerKAT will possibly be able to detect this component.

While previous radio studies exist, none of them have reached the depth and resolution that can now be achieved with the new MeerKAT observations that will be taken in the course of 2021 and that are at our disposal. The PhD project will focus on the characterization of the neutral gas and the radio continuum properties as observed with our MeerKAT observations for at least 2 HCGs. Is there an underlying reservoir of neutral gas in HCGs that has not yet been detected? The 21cm line as observed with MeerKAT traces the neutral gas, and it is possible to study how and at which rate that gas enters the intragroup medium. The radio continuum traces star formation and hence allows to study to what degree the star formation has been suppressed in the group galaxies. It will also potentially serve to study nuclear activity in the galaxies and hence provide detailed data which can be used to learn whether and to which degree active galactic nuclei, supermassive black holes at the centres of the galaxies, interact with the intragroup medium and the interstellar medium in the galaxies, depleting even more cold gas from the group as a hole.

Finally, polarization information in the radio continuum will enable us to study the magnetic fields in the groups and to investigate whether they play a role in the evolution of the HCGs studied.
It is hence expected that the Phd project, a collaboration between the Instituto de Astrofísica de Andalucía, the South African Radio Astronomy Observatory, and Rhodes University, will result in new insights about extreme galaxy interactions in general and the evolution of HCGs as individual objects.

2. Feasibility and resources

The spectral line data needed for this Ph.D. project are being gathered as part of MeerKAT project SCI-20210212-LV-01. Six HCGs will be observed in 32768 wideband channel mode. This will ensure that both the intergalactic HI and the continuum will be observed at high sensitivity and (hence) resolution, unprecedented for HCGs. The student will first concentrate on two HCGs. We will decide later if more studies are possible in the scope of a PhD work. The radio data alone and ancillary data collected by our group provide sufficient material for a PhD thesis. The exchange between the institutes in the scope of the PhD project will be supported by a Spanish Science and Industry Endowment Fund grand (RTI2018-096228-B-C31) and a potential continuation of a currently active "iCOOP" fund to enhance SKA science.

RATT/RARG is in possession of several high-performance computing clusters and sufficient storage, such that there are sufficient resources to analyse the data. IAA is in possession of a suitable HPC SKA prototype cluster. While a data cube as produced by MeerKAT can be very large, there are various techniques to reduce the data volume (it is e.g. not required to analyse the full bandwidth at full frequency resolution). We are using the very successful CARACal data reduction pipeline, partly developed by RATT, such that we can guarantee that the student will either be able to rapidly reduce the data or will have already reduced data at hand. The scientific supervisors and the broader scientific team connected to the project are firmly experienced and involved in software development for the techniques used to conduct the proposed analysis.

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. Experience in the kinematical and dynamical analysis of galaxies is welcome.