Research Proposal: Feeding galaxies: The interplay between gas and star formation in nearby galaxies

1. Introduction

The cessation of star formation in galaxies, commonly known as "quenching," remains a critical issue in extragalactic astronomy with profound implications for understanding galaxy evolution. This process is intricately linked to the depletion or removal of cold gas reservoirs, which are essential for star formation (Bell, 2008; Trussler et al., 2020). Identifying the mechanisms responsible for quenching, particularly in satellite galaxies within large galaxy clusters, continues to be a key challenge in the field (Peng et al., 2015; Balogh et al., 2016).

One of the central questions in this area is determining which physical processes are responsible for halting star formation. It is well-established that the cold gas reservoir must be affected first, but the exact mechanisms remain a topic of debate (Boselli & Gavazzi, 2006; Kennicutt & Evans, 2012). Environmental effects are thought to play a significant role, especially in satellite galaxies within massive clusters. These galaxies are subjected to various external forces that can disrupt their ability to form stars (Gunn & Gott, 1972; Abadi et al., 1999; Rhee et al., 2017).

A prominent mechanism proposed for quenching in these environments is ram-pressure stripping, where cold gas is forcibly removed from the star-forming regions of galaxies as they move through the hot intracluster medium (ICM). This process has been observed in nearby galaxy clusters, providing strong evidence that environmental factors are crucial in quenching star formation in satellite galaxies (Chung et al., 2009; Jáchym et al., 2014; Cramer et al., 2020). However, it is still unclear whether active stripping is a widespread and necessary process to halt star formation or if quenching occurs because these galaxies can no longer replenish their cold gas reservoirs, a process known as starvation (Peng et al., 2015; Fillingham et al., 2016; Trussler et al., 2020).

Recent studies have shown that the quenching process can vary significantly depending on galaxy mass and environment. For example, Bahe and McCarthy (2014) used cosmological hydrodynamical simulations to demonstrate that ram-pressure stripping is particularly effective at removing interstellar matter from satellite galaxies in dense cluster regions. This process significantly contributes to the cessation of star formation, especially in lower-mass galaxies. Meanwhile, more massive galaxies may experience a more prolonged quenching process, suggesting that while environmental factors are crucial, the timing and extent of these effects can vary considerably (Rhee et al., 2017; Trussler et al., 2020).

This research aims to address these questions by exploring the mechanisms that lead to the quenching of star formation in satellite galaxies within large galaxy clusters. By leveraging data from the **MAUVE (MUSE and ALMA Unveiling the Virgo Environment)** and **WALLABY (Widefield ASKAP L-band Legacy All-sky Blind surveY)** surveys, this study will provide new insights into the environmental processes that drive the cessation of star formation in these galaxies. **Both MAUVE and WALLABY are ongoing surveys, ensuring a rich and continuously updated dataset that will be available from the very start of this research.**

2. Aims of the Research

This research aims to explore the mechanisms that lead to the quenching of star formation in satellite galaxies within large galaxy clusters. The specific objectives are:

- To investigate the impact of the cluster environment on the cold gas content and star formation activity of galaxies.
- To characterize the physical processes responsible for the removal or depletion of cold gas in satellite galaxies.
- To understand the role of gas accretion in sustaining or halting star formation in cluster galaxies.

3. Significance of the Research

Understanding the mechanisms behind star formation quenching is crucial for explaining the evolution of galaxies within clusters. This research will contribute to the broader field of extragalactic astronomy by providing detailed insights into the environmental processes that drive quenching, with a focus on the role of the interstellar medium and the impact of galaxy mass. The findings could have significant implications for our understanding of galaxy evolution, particularly in dense environments like galaxy clusters.

4. Methodology

This study will utilize data from two cutting-edge surveys: the **MAUVE** and the **WALLABY**. These surveys offer a wealth of observational data that will be instrumental in addressing the research questions.

4.1 MAUVE Survey

The MAUVE survey, conducted with the VLT/MUSE instrument, observes 40 late-type galaxies in the Virgo Cluster. MAUVE is designed to track the influence of the environment on the gas-star formation cycle of cluster galaxies during their infall into the cluster. The survey aims to understand how and when star formation in these galaxies will cease by providing sub-kpc observations of the interstellar medium, particularly cold atomic and molecular gas, as well as stellar and star formation properties at different stages of galaxy infall.

The MAUVE data can provide the following information:

- **Star formation rates and past star formation histories:** The MAUVE data includes measurements of Hα and other optical emission lines, which can be used to determine the star formation rates and past star formation histories of the galaxies. This will allow us to reconstruct detailed star-formation histories for a representative sample of cluster galaxies for the first time.
- **Gas ionization states:** The MAUVE data includes emission line ratios, which can be used to infer the gas ionization states in the galaxies. These data will also provide metal enrichment maps at ~100-200 pc scale.
- **Gas and stellar kinematics:** The MAUVE data provides detailed information on the complex velocity structure and velocity dispersion of the warm ionized gas, revealing the dynamical state of the galaxies as they interact with the cluster environment. This includes the study of differential rotating discs, the presence of coherent rotational velocity structures within the galaxies, and the link between cold gas and star formation when environmental processes are at play.

In summary, the MAUVE survey builds upon the **VERTICO (THE VIRGO ENVIRONMENT TRACED IN CO SURVEY)** survey (Brown et al., 2021) with ALMA (Atacama Large Millimeter/submillimeter Array), mapping the full extent of the molecular gas disk of 40 late-type Virgo cluster galaxies and providing a rich multi-wavelength dataset with significant legacy value for studying the environmental impacts on galaxy evolution.

4.2 WALLABY Survey

The WALLABY survey, using the ASKAP (Australian Square Kilometre Array Pathfinder) radio telescope, is performing the most extensive survey of atomic hydrogen (HI) content in galaxies in the local Universe (Koribalski et al., 2020). This survey will contribute to:

- Understanding the atomic hydrogen content of galaxies at different stages of cluster infall.
- Investigating the relationship between HI content, gas accretion, and ongoing star formation in various environments.

By combining the datasets from these two surveys, this research will provide new insights into the environmental mechanisms that drive the quenching of star formation in galaxies.

5. Expected Outcomes

This research is expected to:

- Provide a deeper understanding of the environmental processes that contribute to star formation quenching in satellite galaxies within large clusters.
- Offer a detailed characterization of the roles of gas stripping and gas starvation in the quenching process.
- Shed light on the timescales of quenching and the stages of cluster infall where different mechanisms dominate.

6. Conclusion

This project aims to address key questions in galaxy evolution by investigating the quenching of star formation in large galaxy clusters. Through the exploitation of data from the MAUVE and WALLABY surveys, this research will enhance our understanding of how the cluster environment influences the evolution of galaxies, contributing to the broader field of astrophysics.

7. References

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