Bayesian Inference of Galaxy Quenching Across Redshift in the Virgo Cluster

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Team SIGMA team (*Signal, Modèles et Applications*)

Duration Flexible depending on student availability, with a minimum of about four months

Keywords galaxy evolution, quenching mechanisms, hydrodynamical simulations, Bayesian inference

Scientific Context Galaxy quenching, the cessation of star formation, is a key process in galaxy evolution. Different physical mechanisms (ram-pressure stripping, starvation, AGN feedback) dominate depending on environment, mass, and cosmic epoch (e.g., Szpila et al., 2025).

The Virgo cluster, our nearest massive cluster, is an excellent laboratory to study quenching across cosmic time. Hydrodynamical CLONES simulations (Sorce et al., 2021) serve as *digital twins* of Virgo, including gas physics, star formation, and environmental effects. They allow us to investigate not just whether galaxies are quenched, but *how quickly* they transition and the physical conditions associated with this transition (cluster-centric distance, gas-to-stellar mass ratio, velocity, infall time, etc.).

This project is part of the UNIVERSITWINS project, funded by the University of Lille Initiative of Excellence. UNIVERSITWINS aims at bias-controlled interpretations of astronomical observations by building digital twins and leveraging AI to investigate mismatches between theory and data.

Internship Topic The student will study galaxy quenching in hydrodynamical CLONES simulations of Virgo. Specific tasks include: identifying galaxies undergoing quenching at different redshifts using specific star formation rate (sSFR) evolution and main sequence offsets ; measuring the transition timescale and associate it with environmental and internal properties: cluster-centric distance, gas fraction, stellar mass, velocity, isolated vs. infalling status, etc. ; classifying quenching mechanisms probabilistically using Bayesian inference ; comparing simulation results with observational studies of Virgo and similar clusters (e.g. Bidaran et al., 2022, 2023, 2020).

The ultimate goal is to understand how quenching mechanisms evolve with cosmic time and environment, and how digital twins can reproduce observed galaxy transformations.

Objectives

- Analyze hydrodynamical simulation outputs to trace galaxy sSFR evolution across redshifts.
- Develop methods to classify quenching mechanisms and estimate transition timescales.
- Quantify how quenching depends on environment, mass, and infall history.
- Compare simulation predictions with observational catalogs of Virgo galaxies to validate models.

Missions

- Learn the CLONES hydrodynamical simulation outputs and relevant data formats.
- Implement algorithms to detect sSFR transitions and quantify quenching timescales.
- Apply Bayesian or AI-based inference to classify quenching channels probabilistically.
- Compare simulation predictions with observational datasets of Virgo.
- Explore correlations between transition properties and environment, mass, or infall status.

Required Skills

- Programming and data analysis skills (Python strongly preferred).
- Motivation to apply Bayesian inference and AI/data science techniques to simulations and observational comparisons.

References

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