Jellyfish Galaxies as Probes of Galaxy Evolution: A Simulation-Driven, AI-Informed Study

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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, hydrodynamical simulations, jellyfish galaxies, ram-pressure stripping, AI/data science

Scientific Context Jellyfish galaxies are striking objects showing disturbed gas morphologies and asymmetric tails, produced as galaxies undergo *ram-pressure stripping* while moving through the hot intracluster medium. They are excellent tracers of environmental processes in clusters.

The Virgo cluster, our nearest massive cluster, hosts several observed jellyfish candidates (e.g. Boselli et al., 2022), making it an ideal laboratory to test theories of environmental quenching.

CLONES (Sorce et al., 2021) are hydrodynamical simulations of Virgo, including gas physics, that serve as *digital twins* of the real cluster. This internship will combine analysis of these simulations with AI and data science techniques to identify jellyfish galaxies, quantify their properties, and compare with observations.

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 identify and characterize jellyfish galaxies in the hydrodynamical CLONE simulations of the Virgo cluster. Tasks include: developing automated selection criteria (gas morphology, stripped tails), quantifying their incidence and properties, and comparing with observational samples (e.g. Boselli et al., 2022; Poggianti et al., 2017).

The ultimate goal is to understand how jellyfish galaxies trace environmental effects and the dynamical history of Virgo.

Objectives

- Learn to analyze hydrodynamical simulation outputs with a focus on environmental processes.
- Develop and apply AI/data-driven methods to identify jellyfish galaxies in the simulations.
- Study their frequency, spatial distribution, and dependence on orbital histories.
- Compare simulations with observed jellyfish galaxies to constrain Virgo's dynamical state.

Missions

- Get familiar with the CLONES hydrodynamical simulations and data analysis tools.
- Implement algorithms for jellyfish identification using morphology, gas asymmetry, and kinematic signatures.
- Quantify the properties of simulated jellyfish galaxies and analyze trends with cluster-centric distance and infall times.
- Compare simulation results with observational catalogs of Virgo and other clusters.
- Explore AI or machine-learning methods to automate identification and characterization.

Required Skills

- Programming and data analysis skills (Python strongly preferred).
- Interest in connecting simulations with observational data and using AI/data science methods.

References

Boselli, A., Fossati, M., & Sun, M. 2022, A&AR, 30, 3
Poggianti, B. M., Moretti, A., Gullieuszik, M., et al. 2017, ApJ, 844, 48
Sorce, J. G., Dubois, Y., Blaizot, J., et al. 2021, MNRAS, 504, 2998