Tracing the Formation History of the Virgo Cluster through its Substructure Analysis

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

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

Keywords cosmological simulations, galaxy clusters, statistical analysis, structure formation

Scientific Context Galaxy clusters are the largest gravitationally bound structures in the Universe. Their properties contain key information about how cosmic structures form and evolve. The Virgo cluster, our closest massive cluster, is an excellent laboratory to study these processes.

CLONES (Sorce et al., 2021) are *digital twins* of Virgo, simulated both with dark matter only and with dark matter + baryons. Comparing these two types of simulations allows us to disentangle the role of baryonic (gas-related) processes from the overall dark matter dynamics in shaping Virgo.

Internship Topic The student will carry out a statistical analysis of the substructures in the Virgo cluster (e.g., galaxy groups, satellite distributions) using the CLONES simulations. The work will involve: identifying substructures in the simulated clusters ; quantifying their properties (mass, number, distribution, etc.) ; comparing results between dark matter–only and dark matter+baryon runs ; confronting these results with observational data of Virgo to reconstruct its formation history (e.g. Lisker et al., 2018).

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.

Objectives
- Learn how to analyze cosmological simulation outputs.
- Study substructures in the Virgo cluster across different simulation types (dark matter–only vs. dark matter+baryons).
- Compare simulated substructure statistics with observations to better understand Virgo's assembly history.

Missions
- Get familiar with the CLONES simulations and their data format.
- Use statistical tools to detect and characterize substructures (number of satellites, masses, spatial distributions, etc.).
- Compare simulation outputs with observational catalogs of Virgo.
- Interpret the differences between dark matter–only and dark matter+baryon runs.

Required Skills
- Basic programming and data analysis skills (Python preferred).
- Interest in cosmology and galaxy formation.

References

Lisker, T., Vijayaraghavan, R., Janz, J., et al. 2018, ApJ, 865, 40
Sorce, J. G., Dubois, Y., Blaizot, J., et al. 2021, MNRAS, 504, 2998