Breaking the Baryonic Degeneracy: Disentangling Cosmology from Galaxy Formation using CAMELS

Mr. Renier T. Hough*†
Prof. Amare Abebe

In modern cosmology, measuring the large-scale structure of the Universe is hindered by a major theoretical bottleneck known as the "baryonic degeneracy." On small cosmic scales, stellar feedback from SNe and AGN redistributes gas and dark matter in a way that perfectly mimics changes to fundamental cosmological parameters, such as the overall matter density (Ω_m).

This project utilises the CAMELS (Cosmology and Astrophysics with MachinE Learning Simulations) dataset, a massive suite of thousands of hydrodynamic simulations where both cosmological and astrophysical feedback parameters are systematically varied. By analysing the 1D power spectra $P(k)$ generated by these simulations, this study aims to use data science techniques to disentangle the signatures of cosmic expansion from the physics of galaxy formation.

1 Objectives

- Familiarisation with the CAMELS database, specifically extracting and plotting the pre-computed 1D matter power spectra.
- Visually and statistically quantify how varying stellar feedback suppresses the power spectrum at high wavenumbers compared to variations in Ω_m.
- Build and train a foundational Machine Learning model (e.g., a Random Forest Regressor via `scikit-learn`) to predict the true Ω_m of a simulation based solely on its $P(k)$ curve.
- Evaluate the model's success using standard *train/test splitting* on a single simulation suite (e.g., Simba).

2 Special requirements

The student should have experience programming in Python and basic Linux terminal usage. Prior Machine Learning experience is not strictly required.

This is an Honours level project that can be extended to a Master's level.

renierht@gmail.com
North-West University