

Augmenting Galaxy Catalogues in FLAMINGO using Machine Learning

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Robust hydrodynamic simulations are necessary for placing strong constraints on cosmological parameters through the analysis pipelines of observations of statistics such as galaxy clustering. However, for these purposes, the simulations need both large box size and high resolution, which is computationally prohibitive. In this work we use the connection between galaxies and their host dark matter halos to populate dark-matter-only simulations, using data from the FLAMINGO simulations suite. We employ the Extremely Randomized Trees algorithm to model the connection between the mass profile, history and environment of dark matter halos and the probability distribution of the stellar mass of the galaxy contained in the halo. However, we also demonstrate that dark matter properties which probe the centre of the dark matter profile are highly predictive when applied to data from hydrodynamic simulations but are also sensitive to the baryonic feedback missing from dark-matter-only simulations. We use a Gaussian Processes emulator that simultaneously optimises the hyperparameters of our model and selects for the dark matter features which are predictive of the stellar mass while being insensitive to the differences between the hydrodynamic and dark-matter-only simulations. Using this combination of features, we produce novel catalogues from large box dark-matter-only simulations in FLAMINGO. Our catalogue from the FLAMINGO-10k simulation reproduces the galaxy stellar mass function in the hydrodynamic simulations to within 0.1 dex in the range of stellar masses to which the FLAMINGO stellar mass function was calibrated. We also reproduce the mean and scatter of the stellar mass-halo mass relation to within 0.2 dex over a large range of halo masses. Furthermore we find agreement in the two-point correlation function within several stellar mass ranges to match to within 0.1 dex over a large range of length scales.

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