Z109a A Differentiable Cosmological Emulator for Halo Assembly Bias Studies

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Galaxies form in dark matter haloes. The spatial distribution of dark matter haloes, and the distribution and the number of galaxies within a dark matter halo, depend primarily on the halo mass. However, they are also known to depend on halo properties other than mass, such as halo formation history (Wechsler et al. 2006). This secondary dependence is called assembly bias. In this work, to construct a halo statistics emulator that also predicts the assembly bias, we focused on the concentration of haloes as a representative secondary parameter, and measured the cross-correlation function of various halo samples selected according to the mass and concentration using Dark Quest II simulation data. We then constructed an accurate power spectrum emulator for these statistics as inputs of halo mass and concentration using a feed-forward neural network. By taking partial derivatives of the emulator output with respect to halo mass, we demonstrate that the network successfully captures how variations in concentration modulate the power amplitude. In this talk, we will discuss the implementation of automatic differentiation (AD) for both emulator-based gradient evaluations and point-estimation workflows, highlighting the accuracy advantages of AD over simple finite-difference approximations when compared to simulated galaxy power spectra. Finally, we will outline prospects for integrating automatic-differentiation-compatible Hamiltonian Monte Carlo (HMC) methods into cosmological inference pipelines, exploiting the synergistic strengths of AD and HMC for efficient, high-dimensional parameter exploration.