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EMBER-2: towards implicit emulators to constrain astrophysics in FIRE-based simulations

Galaxy formation is a complex problem that links large-scale cosmology with small-scale astrophysics over cosmic timescales. The most principled method, full hydrodynamical simulations, come with high computational costs and thus, the development of faster models is essential. Modern field level emulation techniques leverage Convolutional Neural Networks (CNNs) to "paint" baryonic channels directly on top of dark matter simulations. These emulators are fast to train and reproduce relevant correlations at a fraction of the computational cost compared to traditional simulations.

I will introduce EMBER-2, an enhanced version of the EMBER (Emulating Baryonic EnRichment) framework, designed to emulate baryon channels including gas and HI density, velocity, and temperature over a broad redshift range, from z=6-0. EMBER-2 features a style-based network combined with implicit convolution kernels for fast and accurate emulations. EMBER-2 is capable of interpolating across the entire redshift range with a single CNN and small memory footprint.

EMBER-2 can accurately reconstruct HI-related metrics, such as the cosmic HI column densities, cross-correlations between dark matter, gas, and HI, as well as the correct HI fraction in gaseous halos.
In a different application, I will also present how EMBER-2 can be used to reconstruct the underlying dark matter distribution from HI surface densities.
I will outline how these advancements lay the groundwork for future analysis pipelines, such as those for the SKA, to constrain dark matter and galaxy formation models.

AI keywords

Generative Adversarial Networks, Distribution Learning, Physics-based Emulators

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Track Classification: Simulations & Generative Models