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JERALD: high-resolution dark matter and baryonic maps from cheap N-body simulations

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We present a newly developed code, JERALD - JAX Enhanced Resolution Approximate Lagrangian Dynamics -, that builds on the Lagrangian Deep Learning method (LDL) of Dai and Seljak (2021), improving on the time and the memory requirements of the original code. JERALD takes as input DM particle positions from a low-resolution, computationally inexpensive run of the approximate N-body simulator FastPM and, using a parametrization inspired by effective theories, reproduces 3D maps of both DM and baryonic properties such as stellar mass and neutral hydrogen number density of higher-resolution full hydrodynamical simulations.

We train the model using either the TNG Illustris simulation suite (specifically, TNG300-1) or various simulations from the Sherwood suite, which differs from TNG both in implementation and in sub-grid physics treatment. We investigate the robustness of the learnt mapping at various redshifts by training on one set of simulations and validating it on the other and, using the numerous different Sherwood simulations available, we explore the performance of the model against changes in cosmology and/or dark matter models.

We find that the model can reproduce higher resolution DM and baryonic maps with excellent agreement in the power spectra at large/intermediate scales up to $k \sim 5 \div 7h/\mathrm{Mpc}$ independently of the target simulation code and properties. We outline ongoing work aimed at integrating line of sight data, with a view of using our approach to produce fast, accurate and precise mock Ly-alpha data for use with upcoming surveys.

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