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GalaxyFlow: Upsampling Hydrodynamical Simulations for Realistic Gaia Mock Catalogs

The Gaia DR3 catalog provides high-quality measurements of stars in the Milky Way, but the current N-body simulation-based mock Gaia catalogs have larger resolutions compared to those of the original Gaia dataset. Because of that, using the mock catalogs to aid statistical analyses on the Gaia dataset in a small position/velocity resolution scale is very limited.

To solve this issue, we introduce an unsupervised deep-learning method for upsampling the star particles representing clusters of stars in N-body simulations.

Our method is based on a density estimation technique called normalizing flows for smoothly modeling the coarse star particle distribution so that it can be used for generating a more smooth synthetic star distribution.

We demonstrate our upsampling algorithm on a sub-dataset of two simulated galaxies, h277 and Auriga 6, and we compare the upsampling performance of our approach to conventionally used kernel smoothing algorithms such as EnBiD.

Also, using a machine-learned likelihood-ratio-based test, we show that the distribution of our synthetic stars is not only smooth but also kinematically consistent with that of the original star particles.

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