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Modeling galaxy orientations on the SO(3) manifold with score-based generative models

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Upcoming cosmological weak lensing surveys are expected to constrain cosmological parameters with unprecedented precision. In preparation for these surveys, large simulations with realistic galaxy populations are required to test and validate analysis pipelines. However, these simulations are computationally very costly – and at the volumes and resolutions demanded by upcoming cosmological surveys, they are computationally infeasible.

Here, we propose a Deep Generative Modeling approach to address the specific problem of emulating realistic 3D galaxy orientations in synthetic catalogs. For this purpose, we develop a novel Score-Based Diffusion Model specifically for the SO(3) manifold. The model accurately learns and reproduces correlated orientations of galaxies and dark matter halos that are statistically consistent with those of a reference high-resolution hydrodynamical simulation.

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