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Accurate and computationally inexpensive 21 cm maps with diffusion models

Modeling the distribution of neutral hydrogen is essential for understanding the physics of structure formation and the nature of dark matter, but accurate numerical simulations are computationally expensive. We describe a novel Variational Diffusion Model (VDM), built on a 3D CNN attention U-Net architecture, which we use in concert with the CAMELS simulation suite to generate accurate 21 cm intensity maps from computationally inexpensive dark-matter-only N-body simulations. Our model delivers both halo mass density and neutral hydrogen maps in large cosmological boxes of 25 $(\mathrm{Mpc}/h)^3$, from which we derive highly accurate 21 cm power spectra up to scales as small as $k = 10\ h\ \mathrm{Mpc}^{-1}$. We discuss the strengths of this method compared to existing approaches (e.., its ease of training) and highlight potential applications in the upcoming SKA era for cosmological studies and for distinguishing between cold and warm dark matter models.

AI keywords

Diffusion models, emulation, conditional generation.

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Track Classification: Simulations & Generative Models