LyAl-Net: A high-efficiency Lyman-α forest simulation with neural network

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Abstract

We present a machine learning approach to emulate the numerical simulation of intergalactic medium physics for the Lyman-α forest. The inference of cosmological quantities requires accurate and large cosmological simulations. Unfortunately, their computational time can take millions of CPU hours for a modest coverage in cosmological scales (_~(100 Mpc/h)^3). Having the possibility to generate large quantities of mock Lyman-α observations will allow better control on covariance matrices for cosmological parameter estimation and the impact of systematics due to baryonic effects. This machine learning approach could have a decisive impact on the results derived from present experiments such as QSO surveys derived from SDSS3 and SDSS4 data, which has a resolution power R=1500 and R=2000 respectively. But it could be critical for exploitation in upcoming surveys like WEAVE-QSO, for which R=5000 in low-resolution and R=20000 in high-resolution mode.

In this work, we have used _~ 2% of the total volume from the Horizon-NoAGN simulation to train the U-net, a variant of convolutional neural networks, to predict the neutral hydrogen physical properties; density, temperature, and line-of-sight velocity fields. I will show results given by this emulator and quantitative assessment of their quality through analysis of the 1-point and 2-point statistics. The mean transmission calculated from the predicted quantities is *nearly identical* to the one derived from the raw fields of the original simulation with the resolution of R 30000. More generally, the computation of individual fields from the dark matter density agrees well within regular physical regimes of cosmological field. This approach provides extremely fast and robust numerical simulations not only for Lyman-α forest but also a tool for other applications in cosmology.

Keywords: Machine Learning, Neural Network, Large Scale Structure, Lyman alpha forest.

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