

Predicting the Evolution of Dark Matter Halos Using Neural Networks

The earliest dark matter halos formed from the collapse of overdense regions in the matter density field. Since they formed by direct collapse, these halo populations contain information about the primordial density field of the universe. This can lead to a better understanding of processes such as inflation and the early matter-dominated era (EMDE).

GADGET-4 is a well-known N-body code used to simulate halo formation. One of the most useful simulation results is a merger tree that allows us to trace halo evolution back to formation time. Thus, we can determine which halos are the most massive progenitors (MMPs) that formed at large redshifts.

To improve the ability to predict halo progenitor status and bypass the computationally expensive simulation, I utilize machine learning techniques by training a convolutional neural network (CNN) to recognize patterns in existing simulation data. I train the CNN on a dataset of halo mass, as well as the mass and distance of its four nearest neighbors. I implement hyperparameter optimization to refine its ability to predict which halos at some early time are MMPs for the halos that exist at later times, to determine their ultimate fate.