Fast and Accurate Non-Linear Predictions of Universes with Deep Learning

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Motivation

✓ NN can indeed learn from fast approximation methods the evolution of dark matter particles outperforming analytical methods.

Goal

✓ Improvement of this methodology by using high resolution and full N-body simulations for universes with different cosmological parameters.

Types of cosmological simulations

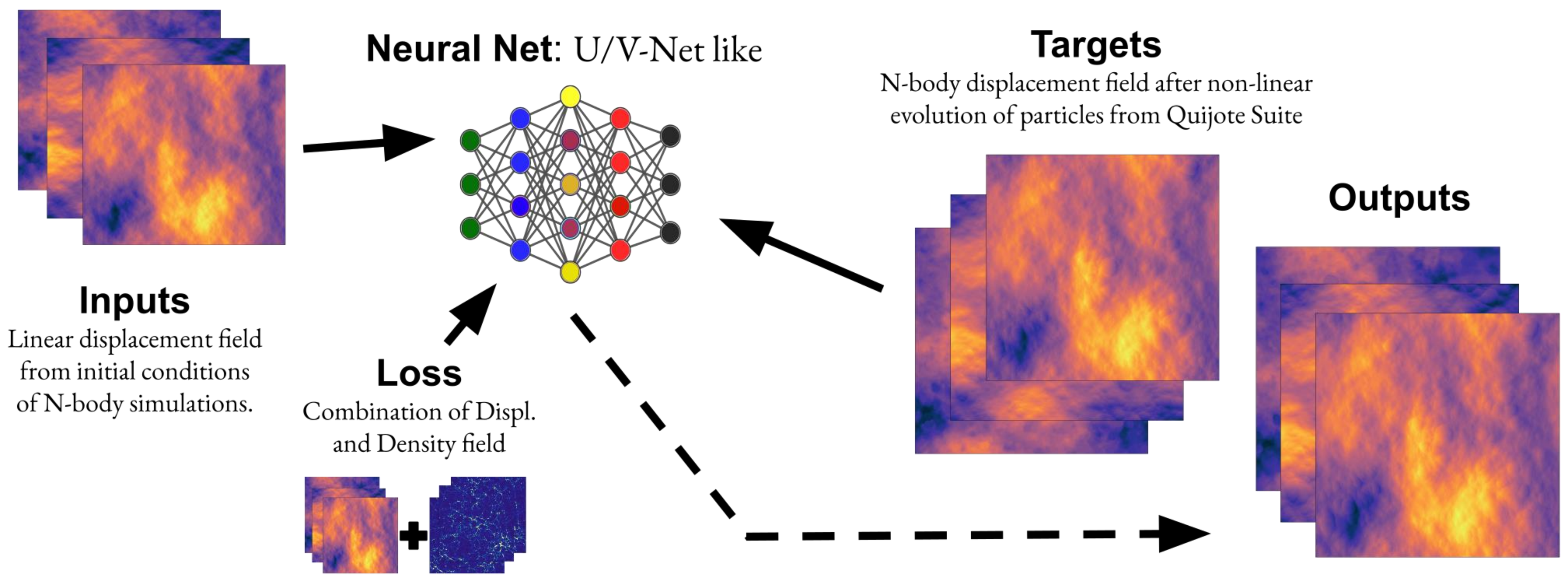
✓ **N-body**
- Brute force method;
- Computationally expensive.

✓ **Linear Theory**
- ZA, 2LPT;
- Ideal for large-scales, small matter density.

✓ **Fast Approximations**
- Resolves well small-scale issues;
- COLA, L-PICOLA.

✓ **Neural Networks**
- Outperform Linear Theory and Fast Approximations;
- Need a dataset for training.

The Model



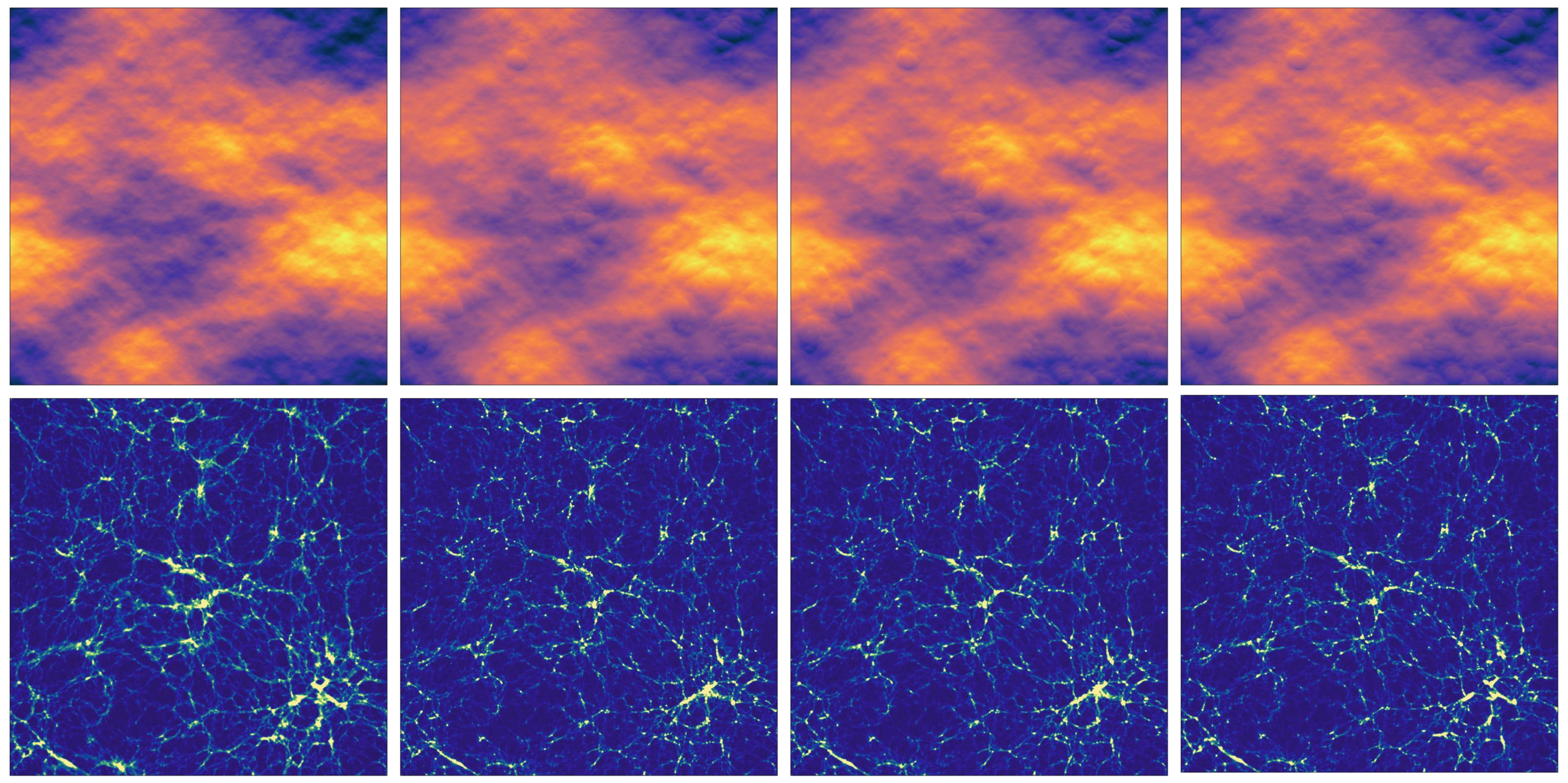


Fig. 2: The first line are slices of displacements of particles and in the second line we show density slices. **Can you spot any difference between these simulations by eye?** From left to right: Linear, N-Body (truth), Fast. Approx., and NN.

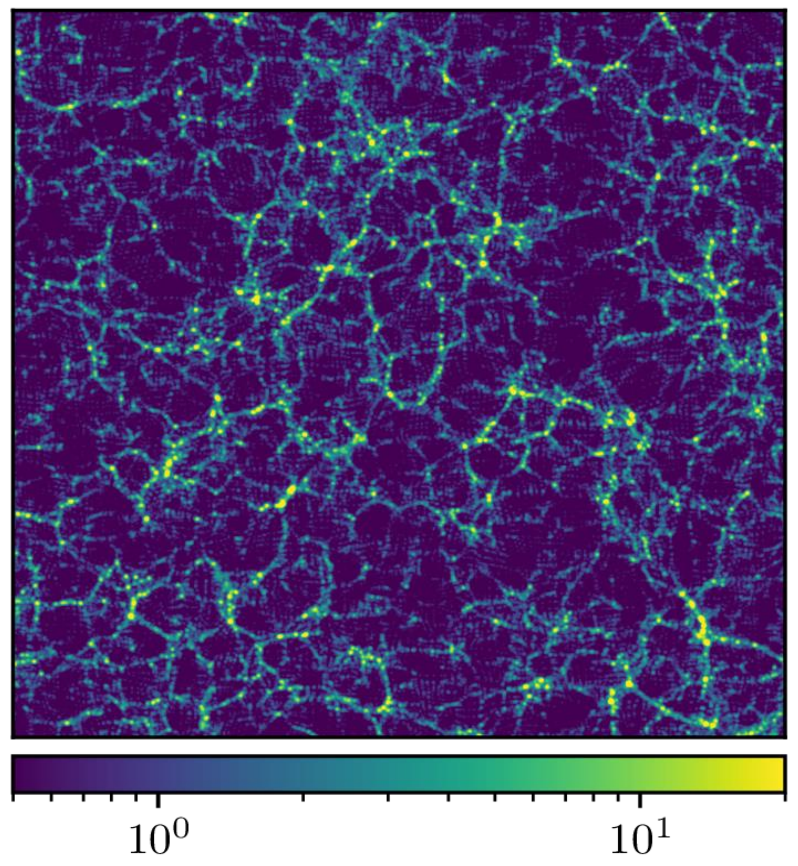


Fig. 1: Slice density δ distribution of dark matter particles in a box of 1 Gpc.

Metrics Used

✓ Power Spectrum P of Ψ and δ;

✓ Transfer function:

$$T(k) = \sqrt{\frac{P_{pred}(k)}{P_{true}(k)}}$$

✓ Cross-Correlation:

$$r(k) = \frac{P_{pred\times true}(k)}{\sqrt{P_{pred}(k)P_{true}(k)}}$$

Results

Fiducial Universes

✓ Same set of cosmological parameters: $\{\Omega_m, \Omega_b, \Omega_\Lambda, \sigma_8, h, n_s\}$

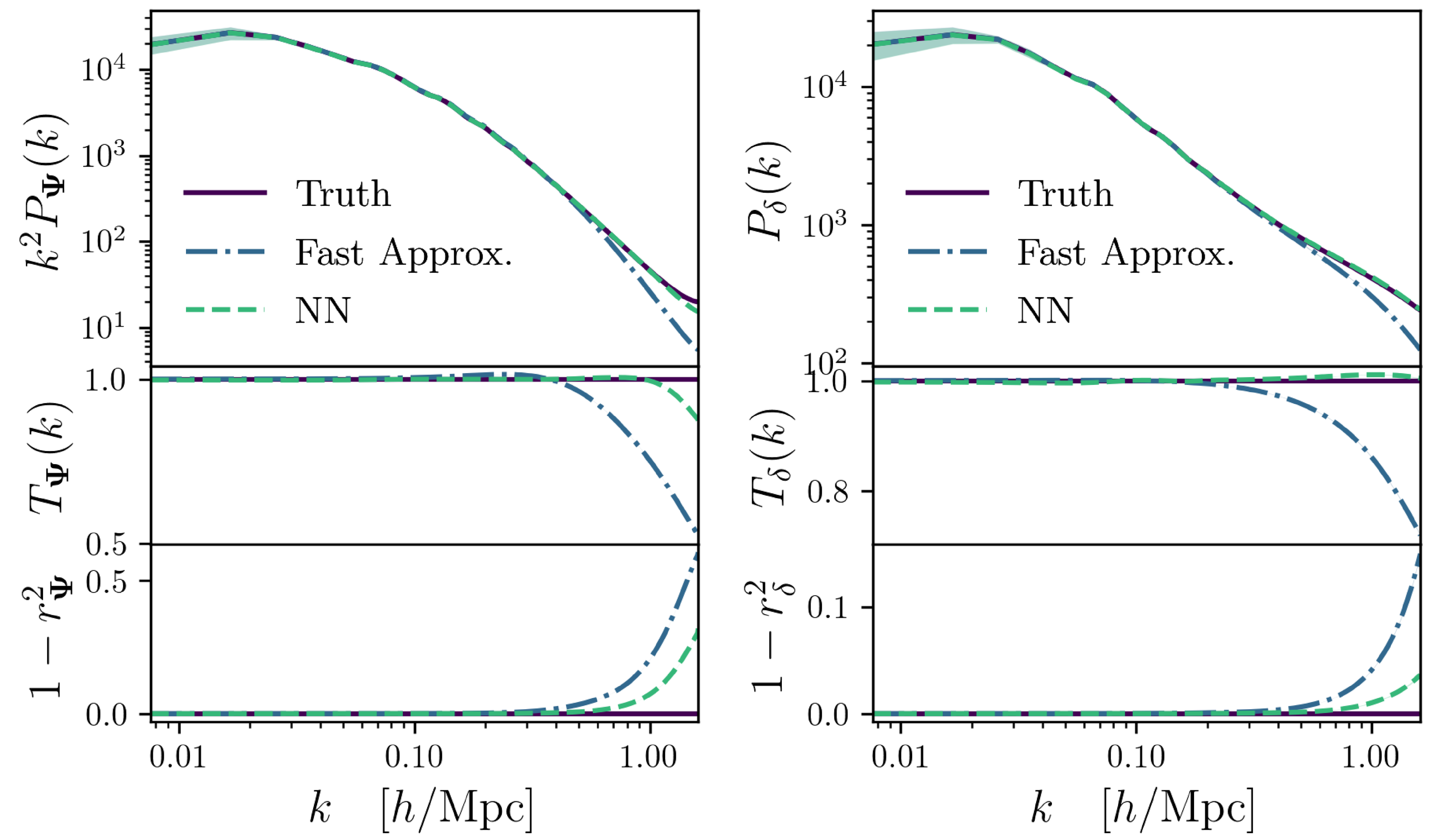


Fig. 3: Metrics for NN and fast approximator model compared with N-body sims.

Other Universes

✓ Tested on 2000 types of universes

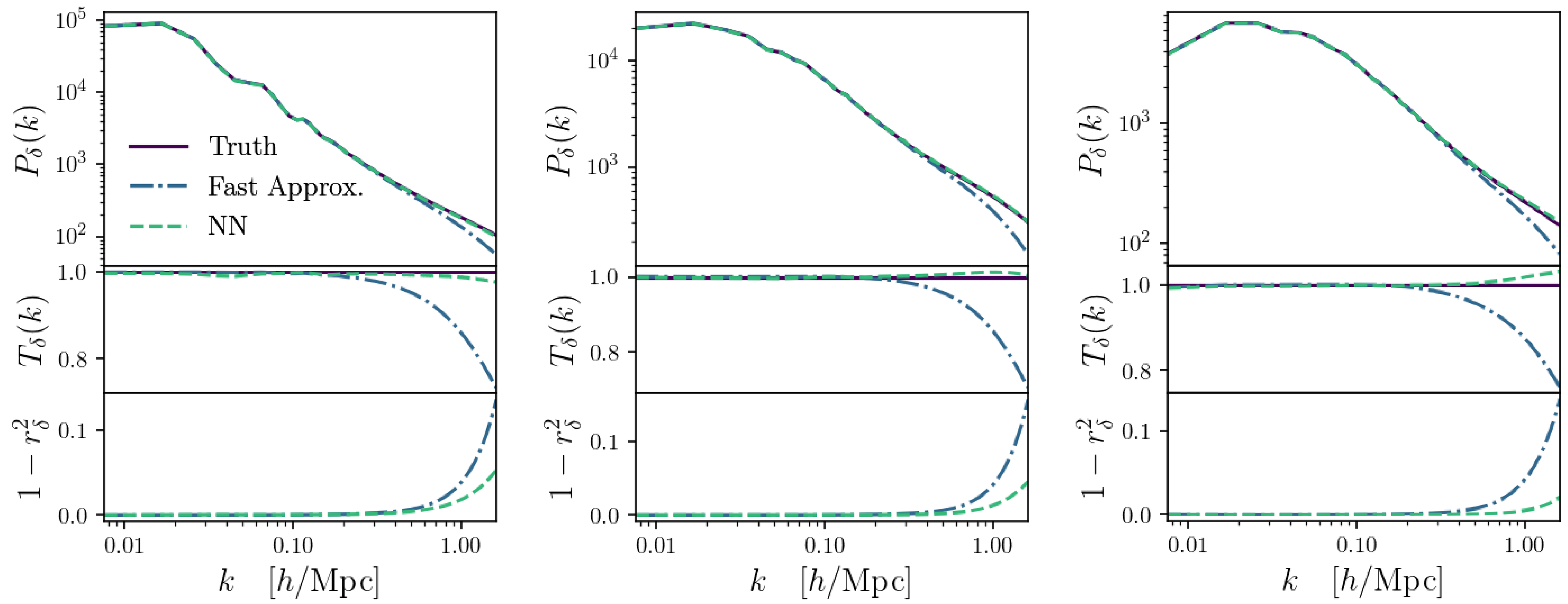


Fig. 4: Accuracy comparison between predictions by the fast approximator (blue dot-dashed) and our NN (green dashed) for universes with different cosmological parameters used in training.

References in hyperlinks | ✉ fisica.renan@gmail.com