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Reconstructing the density and velocity fields using a V-Net

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The standard model of cosmology, LambdaCDM, predicts a velocity field generated by, and coupled to, the distribution of matter density perturbations. This coupling, β, can be directly predicted from the theory of gravity, and when it is measured, can be used to test the cosmological model. However, correctly modelling the predicted velocity field, beyond linear theory, can be challenging. Machine learning offers the possibility of a complete representation from incomplete data, and can be used to reconstruct the underlying density and velocity fields from the discrete tracer galaxies. We use a convolutional neural network, a V-net, trained on numerical simulations of structure formation to reconstruct the density and velocity fields. We find that, with detailed tuning of the loss function, the V-net could produce better fits to the density field in the high-density and low-density regions, and improved predictions for the probability distribution of the amplitudes of the velocities. However, the weights also reduce the precision of the estimated β parameter. We estimate the velocity field β parameter by comparing the peculiar velocities of halo catalogues to the reconstructed velocity fields, and find the estimated β values agree with the fiducial value at the 68\% confidence level.

Author: PARKINSON, David (Korea Astronomy and Space Science Institute)

Presenter: PARKINSON, David (Korea Astronomy and Space Science Institute)

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