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The Cosmic Graph: Optimal Information Extraction from Large-Scale Structure using Catalogues

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The cosmic web, or Large-Scale Structure (LSS) is the massive spiderweb- like arrangement of galaxy clusters and the dark matter holding them together under gravity. The lumpy, spindly universe we see today evolved from a much smoother, infant universe. How this structure formed and the information embedded within is considered one of the "Holy Grails"of modern cosmology, and might hold the key to resolving existing "tensions"in cosmological theory. But how do we go about linking this data to theory? Cosmological surveys are comprised of millions of pixels, which can be difficult for samplers and analytic likelihood analysis. This also poses a problem for simulation- based inference: how can we best compare simulations to observed data? Information Maximising Neural Networks (IMNNs) offer a way to compress massive datasets down to (asymptotically) lossless summaries that contain the same cosmological information as a full sky survey, as well as quantify the information content of an unknown distribution. We will look at LSS assembled as a graph (or network) from discrete catalogue data, and use graph neural networks in the IMNN framework to optimally extract information about cosmological parameters (theory) from this representation. We will make use of the modular graph structure as a way to open the "black box"of simulation-based inference and neural network compression to show where cosmological information is stored.

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