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The Essence of the Cosmos: how much cosmological information is trapped in large-scale structure, and can it be extracted ?

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How much cosmological information is embedded in large-scale structure, and can we extract it? Modern cosmological surveys aim to capture rich images or "fields" of evolving cosmic structure but are often too massive to be interrogated pixel-by-pixel at the field level. We demonstrate that simulation-based compression and inference can be equivalent to all-pixel field likelihoods. We compare simulation-based inference with maximally-informative summary statistics compressed via Information Maximising Neural Networks (IMNNs) to exact field likelihoods. We find that a) summaries obtained from convolutional neural network compression do not lose information and therefore saturate the known field information content, b) simulation-based inference using these maximally informative nonlinear summaries recovers nearly losslessly the exact posteriors of field-level inference, bypassing the need to determine or invert covariance matrices, or assume gaussian summary statistics, and c) even for this simple example, implicit, simulation-based likelihood incurs a much smaller computational cost than inference with an explicit likelihood. This work uses a new IMNNs implementation in ⊠⊠⊠ that can take advantage of fully-differentiable simulation and inference pipeline. We further highlight extensions of this pipeline to cases where the cosmological field information is not known a priori, such as in full N-body gravitational and hydrodynamical simulations.

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