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Simulation-Based Supernova Ia Cosmology

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Type Ia supernovae (SNae Ia) are instrumental in constraining cosmological parameters, particularly dark energy. State-of-the-art likelihood-based analyses scale poorly to future large datasets, are limited to simplified probabilistic descriptions of e.g. peculiar velocities, photometric redshift uncertainties, instrumental noise, and selection effects, and must explicitly sample a high-dimensional latent posterior to infer the few parameters of interest, which makes them inefficient.
I present a wholistic simulation-based approach to SN Ia cosmology that addresses these issues. I demonstrate cosmological inference from 100 000 mock SNae Ia, as expected from future surveys like LSST, using truncated marginal neural ratio estimation and a method that uses the approximate posteriors to construct regions with guaranteed frequentist coverage. Using an improved simulator and neural network, I also preform parameter estimation and principled Bayesian model comparison from real light curve data, examining the interplay of dust extinction and magnitude differences related to host stellar mass. Lastly, I discuss a simulation-based treatment of selection effects and non-Ia contamination, wherein the simulator produces varying-size data sets processed by a set-based neural network. In the future, these components will be combined in a grand unified cosmological analysis of type Ia supernovae.

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