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Accounting for Selection Effects in Supernova Cosmology with Simulation-Based Inference and Hierarchical Bayesian Modelling

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Type Ia supernovae (SNe Ia) are thermonuclear exploding stars that can be used to put constraints on the nature of our universe. One challenge with population analyses of SNe Ia is Malmquist bias, where we preferentially observe the brighter SNe due to limitations of our telescopes. If untreated, this bias can propagate through to our posteriors on cosmological parameters. In this work, we develop a novel technique of using a normalising flow to learn the non-analytical likelihood of observing a SN Ia for a given survey from simulations, independently of any cosmological model. The learnt likelihood is then used in a hierarchical Bayesian model with Hamiltonian Monte Carlo sampling to put constraints on different sets of cosmological parameters conditioned on the observed data. Firstly, we verify this technique on toy model simulations finding excellent agreement with analytically-derived posteriors. We will conclude by demonstrating that this method recovers the true underlying cosmology when applied to realistic SNANA survey simulations where there is no analytical solution.

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