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Automated Lens Parameter Estimation using Simulation-Based Inference

Modern cosmology surveys are producing data at rates that are soon to surpass our capacity for exhaustive analysis –in particular for the case of strong gravitational lenses. While the Dark Energy Survey may discover thousands of galaxy-scale strong lenses, the upcoming Legacy Survey of Space and Time (LSST) will find hundreds of thousands more. These large numbers of objects will make strong lensing a highly competitive and complementary cosmic probe of dark energy and dark matter. Unfortunately, the traditional analysis of a single lens is highly computationally expensive, requiring up to a day of human-intensive work. Being able to accurately estimate the lens parameters of a large sample of lenses will enable us to study the dark matter distribution across populations of lenses, as well as potentially constrain dark energy models. To leverage the increased statistical power from these surveys, we will need highly automated lens analysis techniques.

We present work in which we automate and accelerate parameter estimation of galaxy-galaxy lenses using Simulation-Based Inference (SBI). In particular, we demonstrate the successful application of Neural Posterior Estimators (NPE), based on masked autoregressive flows, to efficiently infer a 5-parameter lens mass model. We also present preliminary results on a 12-parameter model including lens mass, source light and external shear. We compare our NPE constraints to a Bayesian Neural Network (BNN) and find that it outperforms the BNN, often producing posterior distributions that are both more accurate and more precise. In some scenarios, the NPE method predicts constraints on lens parameters that are several times smaller than that from the BNN.

Significance

Neural posterior estimators in simulation-based inference methods are still quite new in many fields of astronomy and we present a novel application of it to astronomical data.

References

Presented at Fermilab's New Perspective conference: https://indico.fnal.gov/event/53945/contributions/243359/

Experiment context, if any

We used simulated Dark Energy Survey data, but did not use any proprietary data from that experiment..

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