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Learning reionization history from high-redshift quasars

The damping wing signature of high-redshift quasars in the intergalactic medium (IGM) provides a unique way of probing the history of reionization. Next-generation surveys will collect a multitude of spectra that call for powerful statistical methods to constrain the underlying astrophysical parameters such as the global IGM neutral fraction as tightly as possible. Inferring these parameters from the observed spectra is challenging because non-Gaussian processes such as IGM transmission causing the damping wing imprint make it impossible to write down the correct likelihood of the spectra.

We will present a tractable Gaussian approximation of the likelihood that forms the basis of a fully differentiable Hamiltonian Monte-Carlo inference scheme. Our scheme can be readily applied to real observational data and is based on realistic forward-modelling of high-redshift quasar spectra including IGM transmission and heteroscedastic observational noise.

We improve upon our Gaussian likelihood approximation by learning the true likelihood with a likelihood-free version of the inference scheme. To this end, we train a normalizing flow as neural likelihood estimator as well as a binary classifier as likelihood ratio estimator and incorporate them into our inference pipeline.

We provide a full reionization forecast for Euclid by applying our procedure to a set of realistic mock observational spectra resembling the anticipated Euclid oberservations. By inferring the IGM neutral fraction as a function of redshift, we show that our method applied to upcoming observational data can significantly tighten present constraints on reionization history.

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