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Data-driven reconstruction of Gravitational Lenses using Recurrent Inference Machine II

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Modeling strong gravitational lenses in order to quantify the distortions of the background sources and reconstruct the mass density in the foreground lens has traditionally been a major computational challenge. This requires solving a high dimensional inverse problem with an expensive, non-linear forward model: a ray-tracing simulation. As the quality of gravitational lens images increases with current and upcoming facilities like ALMA, JWST, and 30-meter-class ground-based telescopes, the task of fully exploiting the information they contain requires more flexible model parametrization, which in turns often renders the problem intractable. We propose to solve this inference problem using an automatically differentiable ray-tracer, combined with a neural network architecture based on the Recurrent Inference Machine, to learn the inference scheme and obtain the maximum-a-posteriori (MAP) estimate of both the pixelated image of the undistorted background source and a pixelated density map of the lensing galaxy. I will present the result of our method applied to the reconstruction of simulated lenses using IllustrisTNG mass density distributions and HST background galaxy images. I will also discuss how our method shows promise to produce MAP estimates for the Cosmic Horseshoe (SDSS J1148+1930), which has challenged traditional reconstructions methods for over 15 years. I will also discuss avenues for possible extensions of this framework to produce posterior samples in a high dimension space using simulation-based inference.

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