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Towards universal simulation-based inference with TMNRE

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The correct interpretation of detailed astrophysical and cosmological data requires the confrontation with equally detailed physical and detector simulations. From a statistical perspective, these simulations typically take the form of Bayes networks with an often very large number of uncertain or random parameters. These are often intractable to analyse using likelihood-based techniques. In these cases, specific scientific questions are answered through engineering dedicated data analysis techniques and/or simplified simulation models. Examples include point source detection algorithms, template regression, or methods based on one-point or two-point statistics. Importantly, these algorithms define the space of inference problems that can be solved and hence bound the information that we can extract from data. And they often introduce biases that can be difficult to control.
I will here argue that targeted simulation-based inference might provide a path towards providing precise and accurate answers for any possible inference problem using relatively few simulations from the complete simulation model only. I will demonstrate this in the context of models of the gamma-ray sky, using Truncated Marginal Neural Ratio Estimation (TMNRE) to perform inference for point sources, point-source populations and diffuse emission components. I will highlight the importance of selecting the right network architectures and validation of the results, and conclude with open problems and challenges.

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