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Overcoming limitations to parameter inference using Neural Ratio Estimation

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In the hunt for new physics phenomena, such as dark matter, it is crucial to compare experimental data to theoretical models. During this step, the most likely values of the model's parameters —such as particle masses and cross sections —are inferred. However, a rigorous statistical treatment of such an inference is oftentimes not practically feasible without making significant simplifying assumptions. In many cases, this may dramatically decrease the sensitivity and reliability of the inference analysis. Recently, new inference techniques based on machine learning have emerged to help overcome these limitations. In particular, "Neural Ratio Estimation"(NRE) stands out with its reported accuracy and efficiency. NRE achieves such success by avoiding explicit integration or optimization over large parameter spaces, which are typical in traditional inference techniques. Instead, in NRE, a neural network is trained to distinguish between the likely and the unlikely parameter values of any given observation. The training set consists of model simulations, which implicitly contain the necessary information for an inference. In this contribution, I will discuss how NRE, and some of its variants, can be applied to problems in gamma-ray astroparticle physics. Its applications in forward-folding problems and the inclusion of nuisance parameters will also be addressed. In particular, I will apply NRE to the search for Axion-like particles (ALPs) with the upcoming Cherenkov Telescope Array (CTA). This analysis is particularly relevant, because ALPs are popular dark matter candidates, whose detection (or exclusion) in gamma-ray observations is especially difficult using conventional inference techniques.

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