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Merging Physical Models with Deep Learning for Cosmology

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With an upcoming generation of wide-field cosmological surveys, cosmologists are facing new and outstanding challenges at all levels of scientific analysis, from pixel-level data reduction to cosmological inference. As powerful as Deep Learning (DL) has proven to be in recent years, in most cases a DL approach alone proves to be insufficient to meet these challenges, and is typically plagued by issues including robustness to covariate shifts, interpretability, and proper uncertainty quantification, impeding their exploitation in scientific analysis.
In this talk, I will instead advocate for a unified approach merging the robustness and interpretability of physical models, the proper uncertainty quantification provided by a Bayesian framework, and the inference methodologies and computational frameworks brought about by the Deep Learning revolution.
In particular, we will see how deep generative models can be embedded within principled physical Bayesian modeling to solve a number of high-dimensional astronomical ill-posed inverse problems. I will also illustrate how the same generative modeling techniques can alleviate the need for analytic likelihoods in cosmological inference, enabling instead Simulation-Based Inference approaches. And finally, I will highlight the power of the computational frameworks initially developed for Deep Learning when applied to physical modeling, making codes from analytical likelihoods to large-scale cosmological simulators automatically differentiable.

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