

Challenges and Opportunities in Astrophysics Software: Leveraging Differentiable Modeling for Cosmological Surveys

Abstract: The standard model of cosmology provides exciting prospects for exploring the fundamental physics underlying cosmic structures, cosmic expansion, and dark matter through advanced galaxy surveys. However, effectively bridging the gap between theory and observational data has become increasingly complex due to the sheer volume of data and intricate models involved. Progress in this field depends on the efficient use of computational resources and scalable methodologies. In this presentation, I will provide a high-level overview of the challenges faced in astrophysics software and demonstrate how differentiable programming can harness new opportunities for extracting knowledge from cosmological data. I will showcase the application of differentiable programming in cosmological parameter inference and the reconstruction of the initial conditions of our Universe, highlighting the SIBELIUS project, providing the most extensive data-constrained simulations featuring an analog of the Milky Way and Andromeda galaxy pair at its center.