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# From Initial Conditions to Peculiar Velocities: A Bayesian Field-Level Approach to the Nearby Universe

*Tuesday 4 February 2025 09:30 (30 minutes)*

The study of peculiar velocities provides a unique window into the dynamics of the nearby universe, allowing us to probe the non-linear regime of cosmic structure formation and test fundamental physics related to the Universe's expansion. As observational data quality and scale improve, modeling the nearby universe becomes more complex, requiring techniques that capture the non-linear dynamics and specificities of the matter and velocity distributions around us.

In this talk, I will present a physics-informed field-level inference framework that bridges early and late-time cosmology by reconstructing both density and velocity fields from observational data. Through Bayesian physical forward modeling, we jointly infer initial conditions and map non-linear density and velocity fields, providing dynamic structure formation histories of the nearby universe with rigorous uncertainty quantification.

I will highlight recent advances using the 2M++ galaxy compilation to reconstruct the universe's initial conditions and non-linear gravitational evolution. Our approach reproduces ΛCDM statistics, such as the power spectrum, bispectrum, and halo mass function, while resolving the detailed three-dimensional galaxy distribution, including precise mass estimates for individual galaxy clusters.

Additionally, I will present comparisons of our inferred velocity fields with state-of-the-art results, demonstrating consistent improvements in velocity inference. Finally, I will discuss extensions of our method to model highly non-linear systems, such as the Milky Way–Andromeda pair, leading to deeper insights into complex cosmic structure dynamics.

These advancements open new avenues for using peculiar velocities and galaxy clustering data to explore cosmic structure formation and the dynamic interplay of matter and gravity in the universe.

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