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Gravitational Turbulence: the Small-Scale Limit of the Cold-Dark-Matter Power Spectrum

Monday 7 April 2025 11:50 (20 minutes)

The matter power spectrum, $P(k)$, is one of the fundamental quantities in the study of large-scale structure in cosmology. In this talk, I will study its small-scale asymptotic limit, and give a theoretical argument to the effect that, for cold dark matter in d spatial dimensions, $P(k)$ has a universal k^{-d} asymptotic scaling with the wave-number k, for $k \gg k_{\rm nl}$, where $k_{\rm nl}^{-1}$ denotes the length scale at which non-linearities in gravitational interactions become important. I will explain how gravitational collapse drives a turbulent phase-space flow of the quadratic Casimir invariant, where the linear and non-linear time scales are balanced, and this balance dictates the k dependence of the power spectrum. The k^{-d} scaling can also be derived by expressing $P(k)$ as a phase-space integral in the framework of kinetic field theory, analysing it by the saddle-point method; the dominant critical points of this integral are precisely those where the time scales are balanced. The coldness of the dark-matter distribution function - its non-vanishing only on a d-dimensional sub-manifold of phase-space - underpins both approaches. I will show Vlasov-Poisson simulations to support the theory.

Author: GINAT, Barry (University of Oxford)

Co-authors: NASTAC, Michael (University of Oxford); Dr EWART, Robert (Princeton University); Dr KONRAD, Sara (Heidelberg University); Prof. BARTELMANN, Matthias (Heidelberg University); Prof. SCHEKOCHIHIN, Alexander (University of Oxford)

Presenter: GINAT, Barry (University of Oxford)

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