

# **A Universal Field Equation for Dispersion: Turbulence, Porous Media, Nano-films and Microbial Dynamics**

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## Abstract

Nearly fifty years ago Zwanzig posited that a wave-vector and frequency dependent 2<sup>nd</sup>-order diffusion tensor, tensor-producted with the Fourier-mode of the gradient of concentration, was the appropriate constitutive law for diffusion when the space-time scales are pre-asymptotic. Here we present a generalization of his pioneering idea, along with the appropriate background analysis, and apply the concept to four disparate topics on disparate scales. MD and MC simulations are employed with the theory to examine phase transitions and stick-slip phenomena in confined nano-films, 3d-PTV experiments are employed with the theory to look at pre-asymptotic dispersion in porous media, a Levy-velocity process is used to study Richardson and related atmospheric super-diffusions, and renormalized Levy-trajectories are used to model microbe motility. Each of these, as well as many other dispersive processes, obeys the same form of a field equation.