Weekly Seminar: Fall 2010

Date: Friday December 3rd

Time: 11:00 AM

Location: Maryland Hall 110

Speaker: Gregory Eyink (Johns Hopkins University)

Title: *"Spontaneous Stochasticity, Flux-Freezing and Magnetic Dynamo"*

Abstract

Spontaneous stochasticity of Lagrangian particle trajectories is a long-overlooked consequence of the explosive separation of particles undergoing turbulent Richardson diffusion. The effect implies a breakdown of Laplacian determinism for classical dynamics, with infinitely many (random) trajectories for the same initial particle position. We discuss both the theoretical basis and empirical evidence for the phenomenon. Spontaneous stochasticity implies that magnetic field-lines cannot be "frozen-in" to a turbulent MHD fluid (plasma or liquid metal) in the original sense of Alfven, even at infinite conductivity, if also the kinetic Reynolds number is large. We show that systems described by resistive MHD satisfy a stochastic Alfven Theorem and we use this result to argue that flux-conservation must remain stochastic at infinite Reynolds numbers. The predictions of standard flux-freezing are thus found to be wrong---by many orders of magnitude---in high-Reynolds-number MHD turbulence. Stochastic flux-freezing has fundamental consequences for many astrophysical problems, such as planetary and solar dynamos, star formation, solar flares, etc. As one example, we present numerical results on the kinematic, fluctuation dynamo in non-helical, incompressible turbulence at magnetic Prandtl number Pr=1, using a Lagrangian particle method with a hydrodynamic turbulence database at Re-λ=433. We find that Richardson diffusion and stochasticity of field-line motion play an essential role in magnetic energy growth. The Lagrangian mechanisms of small-scale dynamo are shown to be very similar to those in the soluble Kazantsev model at Pr=0.