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On the origin of small-scale intermittency in turbulence[1]

CHARLES MENEVEAU, YI LI, Johns Hopkins University — Turbulent flows are notoriously difficult to describe, understand, and model based on first principles. One reason is that turbulence contains highly intermittent bursts of vorticity and strain-rate with highly non-Gaussian statistics. Quantitatively, intermittency is manifested in highly elongated tails in the probability density functions of the velocity increments between pairs of points. A long-standing open issue has been to predict the origin of intermittency and non-Gaussian statistics directly from the Navier-Stokes equations. Here we use a simplified version of the exact dynamics, namely the restricted Euler equations, to describe the generation of intermittency. By adopting a Lagrangian viewpoint, we derive a simple nonlinear dynamical system for the time evolution of longitudinal and transverse velocity increments. From this simple system (the "advected delta-vee" equations), we are able to show that the ubiquitous non-Gaussian tails in turbulence have their origin in the inherent self-amplification of longitudinal velocity increments, and cross amplification of the transverse velocity increments. Using direct numerical simulation filtered at various length-scales, we quantify and comment upon the dynamical effects of terms that are neglected in the advected delta-vee system, namely pressure Hessian, subgrid-scale stress tensor, and viscous forces.

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