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Statistical geometry of material loops in turbulence MICHAEL WILCZEK, LUKAS BENTKAMP, Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany, CRISTIAN C. LALESCU, Max Planck Computing and Data Facility, Garching, Germany, THEODORE D. DRIVAS, Princeton University, Princeton, USA — Turbulent mixing is often characterized by the statistics of one- or two-particle dispersion. An even more comprehensive characterization of the complexity of turbulent mixing can be achieved by capturing the evolution of extended material lines and surfaces. Here, we investigate the statistical geometry of material loops, i.e. closed material lines, by combining simulations, statistical turbulence theory, and dynamical systems theory. Tracking these structures in direct numerical simulations of homogeneous isotropic turbulence reveals that, while the loops develop convoluted shapes over time, their statistical geometry approaches a stationary state. In particular, their curvature distribution forms clear power-law tails, which we analytically determine in the framework of the Kraichnan model. Dynamically, we show that the high-curvature regime is dominated by the formation of isolated folds and that the power-law exponent can be related quantitatively to finite-time Lyapunov exponents. Thereby, the statistical geometry of material lines can be traced back to their dynamical evolution.

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