Universal Transition to Turbulence in Shear Flows of Simple and Complex Fluids

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Abstract

Transition from laminar to turbulent flow drastically changes the mixing, transport, and drag properties of fluids, yet when and how turbulence emerges is elusive even for simple flow within pipes and rectangular channels. Unlike the onset of temporal disorder, which is identified as the universal route to chaos in confined flows, characterization of the onset of spatio-temporal disorder has been an outstanding challenge because turbulent domains irregularly decay or spread as they propagate downstream. Here, through extensive experimental investigation of channel flow, we identify a distinctive transition with critical behavior. Turbulent domains continuously injected from an inlet ultimately decayed, or in contrast, spread depending on flow rates. Near a transition point, critical behavior was observed. We investigate both spatial and temporal dynamics of turbulent clusters, measuring four critical exponents, a universal scaling function and a scaling relation, all in agreement with the (2+1) dimensional directed percolation universality class(1). We have tested this DP scenario to sheared liquid crystal. Although Reynolds number is much less than 1, implying totally different from Navier-Stokes turbulence, we found DP universality exist in sheared liquid crystal flows(2). The same scenario has been recently reported for the onset ot meso-scopic turbulence of active fluids(3).

Reference

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