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Exploring universal scaling laws far from equilibrium with turbulent liquid crystal[1]

KAZUMASA A. TAKEUCHI, Department of Physics, The University of Tokyo

Recent theoretical progress has revealed a variety of universal scaling laws describing various scale-invariant phenomena out of equilibrium, but even the most basic and important of these developments had largely remained without complete experimental verification [1,2]. Here, I show that chaotic convection of electrically driven nematic liquid crystal is an ideal system to overcome past difficulties, which allows thorough experimental tests of theoretical predictions and beyond. First I present the route to turbulence in the electroconvection, focusing in particular on the transition between two regimes of spatiotemporal chaos, called the dynamic scattering modes (DSM) 1 and 2. This transition is characterized by spatiotemporal intermittency, where DSM2 patches randomly migrate, coalesce, and sometimes disappear. Measuring both static and dynamic critical behavior, we identified the directed percolation universality class [3], which is theoretically known as the most fundamental class for absorbing-state phase transitions [1]. We also studied the DSM2 regime under higher applied voltage, where DSM2 domains grow with fluctuating interfaces. Measuring how the interfaces roughen in the course of time, we found evidence for the scaling laws of the Kardar-Parisi-Zhang class [4], the prototypical class for stochastic growing interfaces [2]. Remarkably, fluctuations in the interface positions are found to exhibit the largest-eigenvalue distribution of Gaussian random matrices [4], indicating universality of recent rigorous results for solvable models [5]. The distribution is classified into a few universality subclasses according to the global shape of the interface, or to the initial condition. I also discuss some open problems raised by the experiment [4] on this universality beyond the scaling exponents.

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