Critical phenomena and their microscopic origin in the current fluctuations of driven diffusive systems

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The discovery of dynamical phase transitions (DPTs) in the fluctuations of non-equilibrium systems has attracted much attention in recent years. In contrast with standard critical phenomena, which occur at the configurational level when varying a control parameter such as the temperature, DPTs appear in trajectory space when conditioning the system to sustain an unlikely value of dynamical observables such as the time-integrated current. DPTs thus manifest as a change in the trajectories in order to enhance the probability of such large fluctuations, making them far more probable than anticipated due to the emergence of ordered structures such as travelling waves, condensates or hyperuniform states.

Particularly interesting is that driven diffusive systems may undergo DPTs in order to sustain atypical values of the current. This leads in some cases to intriguing symmetry-breaking phenomena at the level of trajectories which increase the probability of such rare events. In this talk we will shed light on both the macroscopic properties and the microscopic origin of such spontaneous symmetry breaking in a paradigmatic diffusive model, the so-called weakly asymmetric exclusion process. By defining a collective order parameter and making use of large deviation theory we will uncover, for any boundary driving, the full dynamical phase diagram. We will additionally show that the optimal profiles in the symmetry-broken phase correspond to the extreme metastable states stemming from the gapless region of the generator of the dynamics. We will finally provide the first direct observation of this phenomenon through extensive numerical simulations generating rare trajectories by means of population dynamics techniques.

These results thus represent a step forward in the connection of current fluctuations in driven diffusive systems with metastability and standard critical phenomena.