Fluctuating hydrodynamics, current fluctuations and hyperuniformity in boundary-driven open quantum chains

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We consider a class of either fermionic or bosonic open quantum chains driven by dissipative interactions at the boundaries and study the interplay of coherent transport and dissipative processes, such as bulk dephasing and diffusion. Starting from the microscopic formulation, we show that the dynamics on large scales can be described in terms of fluctuating hydrodynamics (FH). This is an important simplification as it allows to apply the methods of macroscopic fluctuation theory (MFT) to compute the large deviation (LD) statistics of time-integrated currents. In particular, fermionic open chains display a third-order dynamical phase transition in LD functions. We show that this transition is manifested in a singular change in the structure of trajectories: while typical trajectories are diffusive, rare trajectories associated to atypical currents are ballistic and hyperuniform in their spatial structure. We confirm these results by numerically simulating ensembles of rare trajectories, via the cloning method, including the computation of their structure factors.