Anomalous relaxation and hyperuniform fluctuations in center-of-mass conserving systems with broken time-reversal symmetry

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Abstract: We study a paradigmatic model of absorbing-phase transition - the Oslo model - on a one-dimensional ring of L sites with a fixed global density $\bar{\rho}$; notably, microscopic dynamics conserve both mass and *center of mass (CoM), but lacks time-reversal symmetry*. We show that, despite having highly constrained dynamics due to CoM conservation, the system exhibits diffusive relaxation away from criticality and superdiffusive relaxation near criticality. Furthermore, the CoM conservation severely restricts particle movement, rendering the mobility - a transport coefficient analogous to the conductivity for charged particles - to vanish exactly. Indeed the temporal growth of current fluctuation is qualitatively different from that observed in diffusive systems with a single conservation law. Away from criticality, steady-state fluctuation $\langle \mathscr{Q}_i^2(T,\Delta)\rangle$ of current $\mathscr{Q}_i$ across ith bond up to time T *saturates* as $\langle \mathscr{Q}_i^2\rangle \simeq \Sigma_Q^2(\Delta) - \text{const.}T^{-1/2}$; near criticality, it grows subdiffusively as $\langle \mathscr{Q}_i^2\rangle \sim T^{\alpha}$, with $0 < \alpha < 1/2$, and eventually *saturates* to $\Sigma_Q^2(\Delta)$. The asymptotic current fluctuation $\Sigma_Q^2(\Delta)$ is a *nonmonotonic* function of Δ: It diverges as $\Sigma_Q^2(\Delta) \sim \Delta^2$ for $\Delta \gg \rho_c$ and $\Sigma_Q^2(\Delta) \sim \Delta^{-\delta}$, with $\delta > 0$, for $\Delta \to 0^+$. By using a mass-conservation principle, we exactly determine the exponents $\delta = 2(1-1/\nu_\perp)/\nu_\perp$ and $\alpha = \delta/z\nu_\perp$ via the correlation-length and dynamic exponents, $\nu_\perp$ and z, respectively. Finally, we show that, in the steady state, the self-diffusion coefficient $\mathscr{D}_s(\bar{\rho})$ of tagged particles is connected to activity by $\mathscr{D}_s(\bar{\rho}) = a(\bar{\rho})/\bar{\rho}$.

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