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Emergent Hydrodynamics in the Symmetric Dyson Exclusion Process

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We study the \emph{symmetric Dyson exclusion process} (SDEP)—a lattice gas with exclusion and long-range, Coulomb-type interactions that emerge both as the maximal-activity limit of the symmetric exclusion process and as a discrete version of Dyson’s Brownian motion on the unitary group. Exploiting an exact ground-state (Doob) transform, we map the stochastic generator of the SDEP onto the spin- $\frac{1}{2}$ XX quantum chain, which in turn admits a free-fermion representation. This mapping yields closed, finite-size expressions for the time-dependent density and current in terms of modified lattice Bessel functions.

At macroscopic scales we conjecture that the SDEP displays \emph{ballistic}, non-local hydrodynamics governed by the continuity equation

$$\partial_t \rho + \partial_x j[\rho] = 0, \quad j[\rho](x) = \sin(\pi \rho(x)) \sinh(\pi \mathcal{H} \rho(x)),$$

where $(\mathcal{H})$ is the periodic Hilbert transform, making the current a genuinely non-local functional of the density. The local one-field description is equivalent to a local two-field “complex Hopf” system and implies ballistic scaling $(z = 1)$.

Closed evolution formulas allow us to solve the melting of single- and double-block initial states, producing limit shapes and arctic curves that agree with large-scale Monte-Carlo simulations. The model thus offers a tractable example of emergent non-local hydrodynamics driven by long-range interactions.

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