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Exact steady states and fragmentation-induced relaxation in the no-passing asymmetric simple exclusion process

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Abstract:
We introduce a multi-species generalization of the asymmetric simple exclusion process (ASEP) with a "no-passing" constraint, forbidding overtaking, on a one-dimensional open chain. This no-passing rule fragments the Hilbert space into an exponential number of disjoint sectors labeled by the particle sequence, leading to relaxation dynamics that depend sensitively on the initial ordering. We construct exact matrix-product steady states in every particle sequence sector and derive closed-form expressions for the particle-number distribution and two-point particle correlation functions. In the two-species case, we identify a parameter regime where some sectors relax in finite time while others exhibit metastable relaxation dynamics, revealing the coexistence of fast and slow dynamics and strong particle sequence sector dependence. Our results uncover a novel mechanism for non-equilibrium metastability arising from Hilbert space fragmentation in exclusion processes.

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