Universal spin transfer dynamics in infinite temperature quantum spin chains

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Recently, there has been a growing interest in exploring the universal scaling behavior established in classical interface growth models within the dynamics of quantum many-body systems. In quantum spin chains, in the anomalous transport regime at infinite temperature, the spin dynamics follows the scaling functions of the Kardar-Parisi-Zhang (KPZ) universality class, with a characteristic dynamical exponent z = 3/2, despite lacking the distinguishing features of KPZ physics.
Indeed, such a conjecture that spin transfer falls within the KPZ universality class has been challenged by recent Google experiments on quantum simulators [1].
We propose a novel numerical approach to compute the quantum generating function (QGF) and extract the cumulants characterizing quantum observables dynamics [2]. It allows reaching size and time scales hitherto inaccessible with state-of-the-art classical or quantum simulations. Our numerical results confirm the experimental evidence, but also extend to times far beyond the coherence of experimental superconducting hardware, clearly demonstrating that spin dynamics is incompatible with KPZ universality [2].
Moreover, identifying spin fluctuations as the quantum analogue of interface roughness, we show that it exhibits a power law scaling as a function of time and subsystem size. By extracting roughness (α), growth (β), and dynamical exponent (z) independently, we verify that in all transport regimes they satisfy the Family-Vicsek self-similar scaling z = α/β.

References

[1] Google Quantum AI Collaboration, E. Rosenberg et al., Science **384**, 48-53 (2024)
[2] A. Valli et al., Phys. Rev. Lett. **135**, 100401 (2025)
[3] E. Rosenberg et al., Science **384**, 48-53 (2024)
[4] C. P. Moca et al., Phys. Rev. B **113**, L020405 (2026)

Figures

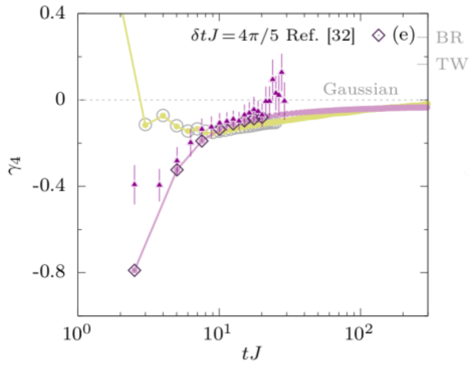

Figure 1: comparison of the numerical kurtosis to the experimental data: asymptotical dynamics is incompatible with values for KPZ distributions.

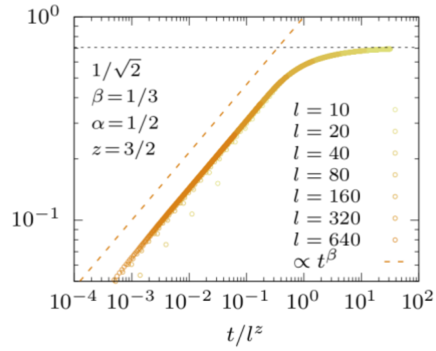

Figure 2: Family-Vicsek scaling collapse in the anomalous transport regime.