Full counting statistics and Kardar-Parisi-Zhang scaling in infinite temperature quantum spin chains

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We investigate the spin-transfer statistics in one-dimensional anisotropic Heisenberg (XXZ) spin models. We introduce a novel tensor-network approach, with which we extract high-order cumulants directly from the generating function at unprecedented long times. We can validate our approach against quantum trajectory simulations - which give access to the full distribution but are limited to shorter times - allowing us to compare cumulant up to the sixth order for S=1/2 and S=1 spin chains [1]. S=1/2 spin chains are integrable, and at the isotropic point (Δ=1) the variance of the spin transfer is characterized by an algebraic growth in time with a superdiffusive z=3/2 exponent as for a Kardar-Parisi-Zhang (KPZ) universal scaling. Fluctuations are weakly non-Gaussian but incompatible with a Baik-Rains distribution, in agreement with recent Google experiments [2] and with theoretical predictions for classical magnets [3]. In the easy-plane regime (Δ<1) transport is ballistic with asymptotically Gaussian distribution. In the XX limit (i.e., Δ=0), our simulations are verified by fermionizing the spin chain. Remarkably, in the diffusive easy-axis regime (Δ>1), we find distinctively non-Gaussian fluctuations, and cumulants consistent with those obtained from Mainardi-Wright family distributions [3]. For non-integrable S=1 spin chains, we find a distinctively different scenario. Spin transfer is the easy-plane regime displays a ballistic-to-diffusive crossover for S=1, while at the isotropic point, a resilient KPZ scaling is observed, suggesting near-integrability. The dynamical exponent drifts possibly towards a diffusive regime with z=2 - although we cannot rule out a z=5/3 Fibonacci-ratio exponent [4].

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