Evidence of Kardar-Parisi-Zhang scaling on a digital quantum simulator

Nathan Keenan[1,2]
Niall F. Robertson[1], Tara Murphy[1], Sergiy Zhuk[1], John Goold[2]

[1]IBM Quantum, IBM Research Europe - Dublin, Mulhuddart, Dublin, Ireland
[2]Trinity College Dublin, Dublin, Ireland

nathan.keenan@ibm.com

Abstract
Understanding how hydrodynamic behaviour emerges from the unitary evolution of the many-particle Schrodinger equation is a central goal of non-equilibrium statistical mechanics. In this work we implement a digital simulation of the discrete time quantum dynamics of a spin-1/2 XXZ spin chain on a noisy near-term quantum device, and we extract the high temperature transport exponent at the isotropic point. We simulate the temporal decay of the relevant spin correlation function at high temperature using a pseudo-random state generated by a random circuit that is specifically tailored to the ibmq-montreal 27 qubit device. The resulting output is a spin excitation on a homogenous background 21 qubit chain on the device. From the subsequent discrete time dynamics on the device we are able to extract an anomalous super-diffusive exponent consistent with the conjectured Kardar-Parisi-Zhang (KPZ) scaling at the isotropic point. Furthermore we simulate the restoration of spin diffusion with the application of an integrability breaking potential. [1]

References

[1] N.Keenan, N.Robertson, T.Murphy, S.Zhuk, J.Goold, npj Quantum Information, 9 (2023) 72

Figures

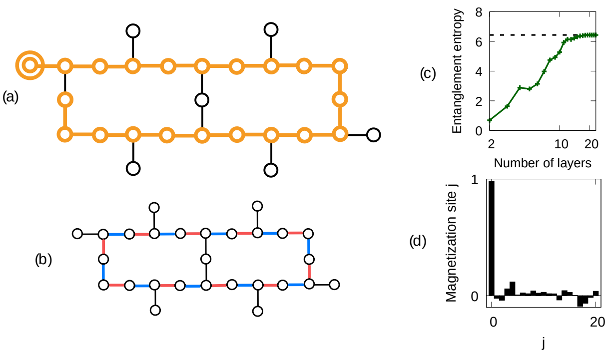

Figure 1: (a) The ibmq montreal qubit connectivity, with a 1-dimensional XXZ model (OBC) mapped onto a 21-qubit chain in the device. Site 0 is mapped to the encircled qubit, and is untouched by the randomisation procedure. (b) Red (blue) is CNOT pattern A (B) used in the random state preparation. These are alternated at each layer of the iterated random circuit. (c) The bipartite von Neumann entanglement entropy of the 20 qubit chain as a function of the number of layers in the random circuit. These results are from a clean simulation with connectivity matching that of ibmq montreal. The dashed line represents the maximum Page value (d) The spin density profile of the final state of one sampling of the random circuit.