Contribution ID: **51** Type: **20 Min Talk**

Diversity of integrable magnetization-conserving unitary qubit circuits

Integrable systems provide a rare opportunity to exactly understand the physics of complex systems, especially in the case of many-body quantum systems, where exponential complexity of simulation severely limits the effectiveness of brute-force approaches. With the recent rapid progress of quantum computers, integrable circuits have increasingly come into focus. While integrability is generally considered to hold only for fine-tuned systems, we have shown that this is not the case for magnetization-conserving qubit circuits. In these circuits, integrability is generic: any time-periodic qubit circuit in which a magnetization-conserving gate is applied to each pair of neighboring qubits exactly once per period is integrable.
We describe the key components of the algebraic Bethe ansatz for these circuits, particularly the R matrix for any magnetization-conserving gate and the transfer matrix for any geometry (i.e., arrangement of gates). Analysis of the R matrix structure reveals the existence of two distinct phases, analogous to the gapless and gapped phases in the Heisenberg XXZ circuits, each with different symmetries, conservation laws, transport properties, and zero edge modes. As another key aspect, the transfer matrix construction offers a systematic approach to identifying integrable geometries.
The work also examines how asymmetric geometry affects the spin transport by analyzing the dynamical structure factor on the ballistic hydrodynamic scale. While inducing nonzero higher odd moments, the first moment —corresponding to a drift in the spreading of correlations —remains zero.

The presentation is based on 2410.06760 (magnetization-conserving gates - Žnidarič, Duh, Zadnik) and 2503.04673 (geometries - Paletta, Duh, Pozsgay, Zadnik).

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Session Classification: Participants Talks