Contribution ID: **11** Type: **Poster**

Emergent Integrability: Quantum Quenches of Integrable Systems Beyond the Euler Scaling Limit

Novel approach to integrable one-dimensional many-body systems with or without interactions is Generalized Hydrodynamics (GHD). According to GHD, excitations in the system can be described by quasi particles. The key postulate of the GHD is the assumption of a mesoscopic scale for time and space (fluid cells) which state maximizes local entropy. GHD provides evolution of the system over large temporal and spatial scales (Euler scaling limit), gives local observables within this regime.
However, the theory currently lacks a comprehensive explanation of the thermalization process and does not show the power law of relaxation of local observables in integrable systems.
We propose a method to address these gaps using our concept of emerging integrals of motion.

To demonstrate this, we consider a two-part model ("bipartitioning protocol"). Each part consists of a one-dimensional, semi-infinite Hubbard chain without interaction ($U = 0$). It is a reservoir (Fermi sea) filled with non-interacting fermions. The difference in the Fermi levels between the two parts represents the voltage before a quantum quench.
We focus on the system's evolution after the hopping interaction between the two parts is activated (quantum quench).

At the junction between the two parts, we investigate the local degree of freedom. Due to the interaction with the electrodes, the local observable of the quantum contact is "dressed" by excitations from the electrodes - by several degrees of freedom with which they significant interact - analogous to fluid cells in our framework. Occasionally, we observe the emergence of decoupled quasi-particles, that do not interact with the local observable of the quantum contact. These quasi-particles concern to conserving quantum numbers, which we term "emerging integrals of motion".

Our primary interest lies in determining the regime in which the density matrix of dressed local observables undergoes thermalization, thereby maximizing local entropy.
This insight could provide a microscopic
proof of the relaxation mechanism - the key postulates of the GHD.
Furthermore, we provide phase-space picture of since GHD is also formulated in phase space, we also plan to calculate the Wigner functions to demonstrate the evolution of the system.

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Session Classification: Poster