Dynamics of inhomogeneous quantum systems with many–body interactions

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Thermalization is a very common process which characterizes evolution of generic macroscopic objects. Despite these objects posses huge number of the degrees of freedom, their physical properties (in the thermal state) are determined by a very few quantities, e.g. by the temperature, the number of particles or total magnetization. The other information encoded in the initial state is lost during the evolution. Since thermalization unavoidably implies the loss of information, there has recently been a significant interest in systems which do not thermalize. There are two basic categories of such systems, where the absence of thermalization is respectively either due to integrability (originating from additional conservation laws) or due to many-body localization (MBL). The recent development in understanding the dynamics of these systems has been very significant. However this development concerns mostly very simple models. In realistic systems, quantum particles are coupled to various degrees of freedom, such as e.g. spin or lattice excitations, which are absent in the simple studied models. Therefore it is by far not clear whether/which results obtained so far for these simple models remain valid also in more realistic systems with additional degrees of freedom. The main objective of our project is to answer this question. In particular, we will focus on the following tasks:

- **Task 1 (T1): Particle dynamics in disordered systems.** Within this task we will study localization in strongly disordered systems of particles interacting with additional degrees of freedom. Solving this problem is important for answering the fundamental question whether MBL may show up also in more realistic models including, e.g., the Hubbard model.
- **Task 2 (T2): Transport properties of strongly disordered systems.** In the presence of a strong disorder several studies predict subdiffusive transport. This property indicates on a possible violation of the Einstein relation that links the diffusion with the d.c. conductivity. As a result one may expect anomalous transport properties of systems driven by a non-zero fields. Within this task we will study particle and (possibly also energy) transport in disordered systems.
- **Task 3 (T3): Nonthermal steady states in interacting systems.** Relaxation towards the generalized Gibbs ensemble has beed fully explained so far for a single model of interacting particles, i.e. for the anisotropic spin-1/2 Heisenberg model. The main result which has been found within these studies concerns the presence of the new (quasilocal) conserved quantities which play essential role for the dynamics of physical quantities. However, it is not clear whether the same holds true for other non—thermalizing (nonergodic) systems with many-body interactions or this is an exclusive feature of the Heisenberg model. Within this task we will further develop our recent numerical approach and try to establish the conserved quantities also in other models of interacting fermions.

The significance of the systems which do not thermalize originates from the facts that they can be used to store quantum information. We will study models which are more realistic than previously studied toy models and will try to establish:

- which many-body interactions do not destroy the strict absence of thermalization ?
- what are the relaxation times which follow from the presence of other many–body interactions ?
- whether it will be possible to design solid state devices which do not thermalize or this phenomenon is inherently connected with the cold–atom systems ?

These questions should be answered before one will be able to assess the possible applications of the quantum system which do not show thermalization.