# *Slow, non-diffusive dynamics in quantum many-body systems*

**Marcin Mierzejewski, Wrocław University of Science and Technology**
(http://www.if.pwr.edu.pl/˜mierzejewski/)

Dynamics of quantum systems is typically very fast as compared to the time-scales which are relevant for our everyday experience. In particular, the relaxation times in solids with strong electronic correlations may be of the order of a few tens of femtoseconds. At longer time, quantum systems approach their thermal equilibrium. And yet there are systems where the relaxation may be slowed down by many orders of magnitude or even completely eliminated. Approaching the thermal equilibrium unavoidably implies the loss of information concerning the initial quantum state. Therefore, methods of avoiding or slowing down the thermalization might be important for the future applications which will be based on processing of quantum information. However first of all, understanding such unusually slow dynamics represents an interesting challenge, that may be important for diverse branches of physics, e.g., for the condensed matter physics and the statistical physics.

In general, there are a few categories of quantum many-body systems relevant for the absence of thermalization or for a very slow thermalization: scarred models which don't thermalize for very rare but still physically relevant initial states; quantum time crystals where time-translation symmetry is broken for typical states; *disordered systems with many-body interactions* (DSMB) and *quantum integrable models* (IM). The research on the unconventional dynamics of quantum systems is by far dominated by the theoretical studies, hence it is important to focus on problems for which there exist experimental data. From among the systems listed above, the strongest experimental evidence has been established so far for the DSMB where the ultraslow dynamics or the absence of thermalization are generic and occur without fine-tuning of the model parameters. On the one hand, theoretical predictions suggest that absence of thermalization is possible only in 1D systems. On the other hand, the experiments show signatures of localization also in two-dimensional (2D) and three-dimensional (3D) systems. Thus, the dynamics of strongly disordered systems beyond 1D remains largely an open problem that is relevant for experimental studies. This problem is also the main motivation for the theoretical studies covered by the present project.

The present understanding of the DSMB is built upon rather straightforward numerical method. While these methods provided several milestone results concerning 1D DSMB, purely numerical methods may be insufficient for solving problems motivated by the existing experiments, in particular concerning transport in disordered 2D systems. In order to overcome this problem we will follow a twofold strategy based on a combination of a simplified approaches (to go beyond the limitations of the standard numerical methods) and investigations based on the *Eigenstate Thermalization Hypothesis, ETH*, (to get deeper understanding of the nonergodicity in strongly disordered DSMB). Within the former part, we will develop and study simplified approaches to transport in DSMB. In particular, we will use approximate methods (e.g., semiclassical rate equations) and study effective Hamiltonians. Such studies give reliable bounds on the transport properties in quasi-2D and 2D systems. One of the most general and universal view on thermalization is based on the Eigenstate Thermalization Hypothesis (ETH). The DSMB and IM may seem to be very different, however they share a common important property: they do not obey ETH. This raises a question about similarities and difference between IM and DSMB with respect to the violation of the ETH, which we will study within this project. This part of our proposal is higher-risk and higher-impact research which goes beyond problems specific for DSMB. A detailed understanding of the transition between regimes where ETH is fulfilled and where it is violated is missing. Such understanding is important not only from the perspective of DSMB but also IM.