Jožef Stefan Institute

University *of Ljubljana*
Faculty *of Mathematics and Physics*

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Book of Abstracts

Organization committee:

Antonello Scardicchio, Piotr Sierant, Lev Vidmar, Jakub Zakrzewski

Local organizer: Lev Vidmar

Fabien Alet: Two topics on disordered many-body quantum systems

I will introduce two sets of results on the impact of symmetries in disordered quantum many-body systems. First, I will present numerical results based on large-scale exact diagonalization for spin chains with extended non-abelian SU(N) symmetries, where we expect that no many-body localization can occur. If time allows, I will also present in the second part results for understanding gap ratio statistics, a standard tool in the numerical study of disordered systems, when discrete symmetries are present and not resolved in the spectra.

Piotr Sierant: Exact diagonalization studies of many-body localization

The status of many-body localization (MBL) as a stable non-ergodic phase of matter has been recently debated. In this talk, I will briefly discuss exact diagonalization (ED) approaches employed in studies of MBL, mentioning, in particular, polynomially filtered exact diagonalization method (POLFED) [1]. I will describe a simple method of analysis of the ergodic-MBL crossover observed in ED results. The method relies on introducing two system size dependent disorder strengths: the first one demarcates departure from ergodic behavior at given system size L; the second one is the crossing point which estimates, at a given L, the position of the putative ergodic-MBL transition. I will present results of this method for 1D disordered systems: Heisenberg spin chain [1], constrained spin chains [2], and Floquet models [3]. I will compare the observed finite size drifts at the ergodic-MBL crossover in the interacting many-body systems with finite size effects at Anderson localization transition on random regular graphs [4].

[1] Phys. Rev. Lett. 125, 156601 (2020), P. Sierant, M. Lewenstein, J. Zakrzewski
[2] Phys. Rev. Lett. 127, 126603 (2021), P. Sierant, E. Lazo, M. Dalmonte, A. Scardicchio, J. Zakrzewski
[3] Phys. Rev. B 107, 115132 (2023), P. Sierant, M. Lewenstein, A. Scardicchio, J. Zakrzewski
[4] arXiv:2205.14614, P. Sierant, M. Lewenstein, A. Scardicchio

Marcin Mierzejewski: Restoring ergodicity in a strongly disordered interacting chain

I will review our recent studies concerning a chain of interacting fermions with random disorder that was intensively studied in the context of many-body localization. We have shown that only a small fraction of the density-density interaction represents a true local perturbation to the noninteracting Anderson insulator [1]. While this true perturbation is nonzero at any finite disorder strength *W*, it decreases with increasing *W*. This establishes a view that strongly disordered systems with density-density interaction should be viewed as a weakly perturbed integrable models, i.e., weakly perturbed Anderson insulators. Consequently, the latter models can hardly be distinguished from strictly integrable noninteracting systems in finite-size calculations at large *W*. We then studied several other models in which the true perturbation is of the same order of magnitude as the other terms of the Hamiltonian, and showed that the system remains ergodic at arbitrary large disorder.

[1] B. Krajewski, L. Vidmar, J. Bonča, M. Mierzejewski, Phys. Rev. Lett. 129, 260601 (2022)

Pietro Brighi: Many-body localization proximity effect in two-species bosonic Hubbard model

The many-body localization (MBL) proximity effect is an intriguing phenomenon where a weak thermal bath localizes due to the interaction with a disordered system [R. Nandkishore, PRB (2015)]. The interplay of thermal and non-ergodic behavior in these systems gives rise to a rich phase diagram, whose exploration is an active field of research. In this talk, I will present recent work on the study of a bosonic Hubbard model featuring two particle species representing the bath and the disordered system. Using state of the art numerical techniques, we investigate the dynamics of the model in different regimes, based on which we obtain a tentative phase diagram as a function of coupling strength and bath size. When the bath is composed of a single particle, we observe clear signatures of a transition from an MBL proximity effect to a delocalized phase. Increasing the bath size, however, its thermalizing effect becomes stronger and eventually the whole system delocalizes in the range of moderate interaction strengths studied. In this regime, we characterize particle transport, revealing diffusive behavior of the originally localized bosons.

Antonello Scardicchio: Re-reading Basko, Aleiner, and Altshuler seventeen years later

I will go through the BAA 2006 paper and the papers directly related to it, in light of the last fifteen years of works and the recent controversies.

Wojciech De Roeck: An update on the avalanche model for many-body localization

The avalanche instability has been a useful view point on the MBL phase and its (in)-stability. In recent work, we have tried to put some of its phenomenology on more firm footing, both from a mathematical and a numerical point of view. One result is that we can now prove localization in a toy model where the avalanche instability is the only possible obstruction to localization: a chain of non-interacting spins coupled to a finite bath via an exponentially decaying coupling term.

Soumya Bera: Average internal clock for many-body delocalization

There is a growing consensus that generic disordered quantum wires, e.g. the XXZ-Heisenberg chain, do not exhibit many-body localization (MBL) - at least not in a strict sense within a reasonable window of disorder values. Specifically, computational studies of short wires exhibit an extremely slow but unmistakable flow of physical observables with increasing time and system size (`creep') that is consistently directed away from (strict) localization. Our work sheds fresh light on delocalization physics: Strong sample-to-sample fluctuations indicate the absence of a generic time scale, i.e., of a naive "clock rate"; however, the concept of an "internal clock" survives, at least in an ensemble sense. Specifically, we investigate the relaxation of the charge imbalance and the entanglement entropy in a 1D system of interacting disordered fermions. We observe that the average entropy appropriately models the ensemble-averaged internal clock and reduces fluctuations. We take the tendency for faster-than-logarithmic growth of entanglement and smooth dependency on the disorder of all our observables within the entire simulation window as support for the cross-over scenario, discouraging an MBL transition within the traditional parametric window of computational studies.

Tomaž Prosen: Some ideas on proving ergodicity in perturbed disordered dual-unitary circuits

I will discuss work in progress on approaching the problem of proving ergodicity and delocalizaiton in disordered Floquet circuits which can be treated as perturbation of dual-unitaries. I will motivate a conjecture on the universal bound of spectral Lyapunov exponents, yielding random matrix spectral statistics in the thermodynamic limit.

Dries Sels: tba

Thorsten Wahl: Tensor network approaches to many-body localization

I will give an overview over our results on the description of many-body localised (MBL) systems with quantum circuits - a specific type of tensor networks. I will illustrate how they can be used to quantitatively simulate the controversial two-dimensional MBL phase observed in optical lattice experiments. I will explain why this description captures experimentally relevant time scales, on which two-dimensional MBL is stable. I will also show that quantum circuits can be used to rigorously classify symmetry-protected topological MBL phases in one and two dimensions and to prove their robustness. Finally, I will demonstrate that the conventional notion of local integrals of motion has to be revised for topologically ordered MBL systems.

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Peter Prelovšek: Slow diffusion and Thouless localization criterion in modulated spin chains

In recent years the ergodicity of disordered spin chains has been investigated via extensive numerical studies of the level statistics or the transport properties. However, a clear relationship between these results has yet to be established. We present a relation between the diffusion constant and the energy-level structure, which leads to the Thouless localization criterion. The latter explains the drift of the crossover/transition to the localized regime with increasing system size. Moreover, we show that the Heisenberg spin chain in the presence of the quasiperiodic fields can be well approached via a sequence of simple periodic systems, where diffusion remains finite even at large fields.

Jakub Zakrzewski: Time dynamics in MBL crossover - what can we learn?

I will review recent efforts to obtain reliable information on MBL crossover from approximate time dynamics using tensor networks techniques. Time-evolving block decimation (TEBD) and time-dependent DMRG will be compared with the variational approach (TDVP) as well as Chebyshev propagation for smaller systems.

Miroslav Hopjan: Scale invariant survival probability at eigenstate transitions

Understanding quantum phase transitions in highly excited Hamiltonian eigenstates is currently far from being complete. It is particularly important to establish tools for their characterization in time domain. Here we argue that a scaled survival probability, where time is measured in units of a typical Heisenberg time, exhibits a scale invariant behavior at eigenstate transitions. We first demonstrate this property in two paradigmatic quadratic models, the one-dimensional Aubry-Andre model and three-dimensional Anderson model. Surprisingly, we then show that similar phenomenology emerges in the interacting avalanche model of ergodicity breaking phase transitions. This establishes an intriguing similarity between localization transition in quadratic systems and ergodicity breaking phase transition in interacting systems.