DY 31: Many-body Systems: Equilibration, Chaos and Localization II (joint session DY/TT)

Time: Wednesday 9:30–13:00 Location: HÜL 186

DY 31.1 Wed 9:30 HÜL 186

Many-body dynamical localization in the kicked Bose-Hubbard chain — Michele Fava[1], Rosario Fazio[2,3], and •Angelo Russomanno[4] — [1]Rudolf Peierls Centre for Theoretical Physics, Clarendon Laboratory, University of Oxford, Oxford OX1 3PU, UK — [2]Abdus Salam ICTP, Strada Costiera 11, I-34151 Trieste, Italy — [3]Dipartimento di Fisica, Universit\'a di Napoli "Federico II", Monte S. Angelo, I-80126 Napoli, Italy — [4]Max-Planck-Institut f\"ur Physik Komplexer Systeme, N\"othnitzer Strasse 38, D-01187, Dresden, Germany

We show that a clean kicked Bose-Hubbard model exhibits a many-body dynamically localized phase. This phase shows ergodicity breaking and we can argue that this property persists in the large-size limit: the Floquet states violate eigenstate thermalization and then the asymptotic value of local observables depends on the initial state and is not thermal. This implies that the system does not generically heat up to infinite temperature, for almost all the initial states. Differently from many-body localization here the entanglement entropy linearly increases in time. This increase corresponds to space-delocalized Floquet states which are nevertheless localized across specific subsectors of the Hilbert space: In this way the system is prevented from randomly exploring all the Hilbert space and does not thermalize.

DY 31.2 Wed 9:45 HÜL 186

Entanglement clusters in many-body localized systems — •Kevin Hemery, Adam Smith, and Frank Pollmann — Department of Physics, T42, Technische Universität München, James-Franck-Strasse 1, D-85748 Garching, Germany

A complete understanding of the many body localized (MBL)-ergodic transition is still missing. We investigate this phenomenon by analysing the entanglement structure of the eigenstates of the Heisenberg chain in presence of a disordered field. Our method is based on a combination of the two-site mutual information and a graph theory clustering algorithm.

First we test our approach by recovering the scaling behaviour of the number of entangled clusters across the phase transition, which has previously been extracted using the full density matrix. On the MBL side, we access large systems by using the so-called "DMRG-X" algorithm, a variational matrix-product-states based method. We compare our results to predictions drawn from renormalisation group based theories of the thermalisation avalanche.

DY 31.3 Wed 10:00 HÜL 186

Emergent localization in euclidean random matrices without small parameter — •Anton Kutlin and Ivan Khaymovich — Max Planck Institute for the Physics of Complex Systems, D-01187 Dresden, Germany

We study the wave functions localization properties for the isotropic euclidean random matrix (ERM) model in arbitrary dimension. Due to its generality, this model arises naturally in various physical contexts such as studies of vibrational modes [1,2], artificial atomic systems [3,4], liquids and glasses [5-7], ultracold gases and photon localization phenomena [8,9]. We generalize the known[10,11] renormalization group (RG) approach, formulate universal sufficient conditions for localization in ERM models and inspect a striking duality of the wave function spatial structure between ERMs and translation-invariant (TI) models with a diagonal disorder[12]. Finally, we discuss possible extensions of the approach to anisotropic models.

[1] B. Ash et al., PRE 98, 042134 (2018) [2] A. Amir et al., PRX 3, 021017 (2013) [3] A. de Paz et al., PRL 111, 185305 (2013) [4] P. I. Karpov et al., PRE 97, 062157 (2018) [6] J .Rehn et al., Phil. Trans. R. Soc. A 374: 20160093 (2016) [7] J. Rehn et al., PRB 92, 085144 (2015) [8] T. Scholak et al., PRA 90, 063415 (2014) [9] A. Gero et al., PRA 88, 023839 (2013) [10] A. L. Burin et al., Pis'ma Zh. Eksp. Teor. Piz. 50, No. 6, 304-306 (1989). [11] L. S. Levitov, PRL 64, 547 (1990). [12] X. Deng et al., PRL 120, 110602 (2018).

DY 31.4 Wed 10:15 HÜL 186

Ergodization times and dynamical glass in classical Josephson junction chains — •Carlo Danieli[1], Mithun Thudiyangal[2], Yagmur Kati[3], and Sergej Flach[4] — [1]Max Planck Institute for the Physics of Complex Physics, Noethnitzer Str. 38, 01187 Dresden, Germany — [2]Department of Mathematics and Statistics, University of Massachusetts, Amherst MA 01003-4515, USA — [3]Center for Theoretical Physics of Complex Systems, Institute for Basic Science, Daejeon, Korea — [4]Center for Theoretical Physics of Complex Systems, Institute for Basic Science, Daejeon, Korea

Models of classical Josephson junction chains turn integrable in the limit of large energy densities or small Joseph- son coupling strength. Close to these limits, the Josephson coupling between superconducting grains induces a short range network. We compute distributions of finite-time averages of grain charges and extract the ergodization time TE which controls their convergence to ergodic delta distributions. We relate TE to the statistics of the fluctuations in time of the grain charges, which are dominated by fat tails. The ergodization time TE grows anomalously fast upon approaching the integrable limit as compared to the Lyapunov time TΛ - the inverse largest Lyapunov expo- nent. The microscopic reason for the observed behavior - which we labeled dynamical glass - is rooted in a growing number of grains evolving over long time in a regular fashion due to low probability of resonant interactions with the neighboring ones. We conjecture that the observed dynamical glass is Josephson junction networks irrespective of their dimensionality. Ref: Phys.Rev.Lett. 122 054102 (2019).

DY 31.5 Wed 10:30 HÜL 186

Real-time dynamics of string breaking in quantum spin chains — •Roberto Verdel[1], Fangli Liu[2], Seth Whitsitt[2], Alexey V. Gorshkov[2,3], and Markus Heyl[1] — [1]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187-Dresden, Germany — [2]Joint Quantum Institute, NIST/University of Maryland, College Park, MD 20742, USA — [3]Joint Center for Quantum Information and Computer Science, NIST/University of Maryland, College Park, MD 20742, USA

String breaking is a central dynamical process in theories featuring confinement, where a string connecting two charges decays at the expense of the creation of new particle-antiparticle pairs. In this talk, we show that this process can also be observed in quantum Ising chains [1], where domain walls get confined either by a symmetry-breaking field or by long-range interactions. Our main finding is that string breaking occurs, in general, as a two-stage process: First, the initial charges remain static and stable; yet, the connecting string can undergo complex dynamics. In the second stage, which can be severely delayed due to dynamical constraints happening in the previous phase, the string finally breaks. We analyse the constrained many-body dynamics of the first stage and its consequences for the final string breaking or the suppression of it.

References: [1] R. Verdel, F. Liu, S. Whitsitt, A. V. Gorshkov, and M. Heyl, (2019), arXiv:1911.11382 [cond-mat.stat-mech].

DY 31.6 Wed 10:45 HÜL 186

Dynamics of strongly interacting systems: From Fock-space fragmentation to Many-Body Localization — •Giuseppe De Tomasi[1], Daniel Hetterich[2], Pablo Sala[3], and Frank Pollmann[4] — [1]TUM Munich/Cambridge University — [2]TUM Munich — [3]TUM Munich — [4]TUM Munich

We study the t-V disordered spinless fermionic chain in the strong coupling regime, t/V –> 0. Strong interactions highly hinder the dynamics of the model, fragmenting its Hilbert space into exponentially many blocks in system size. Macroscopically, these blocks can be characterized by the number of new degrees of freedom, which we refer to as movers. We focus on two limiting cases: Blocks with only one mover and the ones with a finite density of movers. The former many-particle block can be exactly mapped to a single-particle Anderson model with correlated disorder in one dimension. As a result, these eigenstates are always localized for any finite amount of disorder. The blocks with a finite density of movers, on the other side, show an MBL transition that is tuned by the disorder strength. Moreover, we provide numerical evidence that its ergodic phase is diffusive at weak disorder. Approaching the MBL transition, we observe sub-diffusive dynamics at finite time scales and find indications that this might be only a transient behavior before crossing over to diffusion.

15 min. break

DY 31.7 Wed 11:15 HÜL 186

Impact of pertubations on expectation value dynamics — •Robin Heveling, Lars Knipschild, and Jochen Gemmer — University of Osnabrueck, Osnabrueck, Germany

Recently it was advocated by several groups that a variety of pertubations in condensed matter type systems may have "generic" effects on the dynamics of expectation values [1,2,3]. We investigate this approach numerically and to some extend analytically, scrutinizing various ways of modelling said generic effects.

[1] L. Dabelow, P. Reimann, Perturbed relaxation of quantum many-body systems, arXiv:1903.11881
[2] J. Richter et al., Exponential damping induced by random and realistic pertubations, arXiv:1906.09268
[3] L. Knipschild, J. Gemmer, Stability of quantum dynamics under constant Hamiltonian pertubations, arXiv:1811.00381

DY 31.8 Wed 11:30 HÜL 186

Influence of drive smoothness on the Floquet MBL transition — •Tobias Gulden[1,2], Asaf Diringer[2], and Netanel Lindner[2] — [1]IST Austria — [2]Technion - Israel Institute of Technology

We investigate how the critical driving amplitude at the Floquet MBL-to-ergodic phase transition changes between smooth and non-smooth driving over a large range of frequencies. To this end we study numerically a disordered spin-1/2 chain which is periodically driven by a sine or a square-wave drive, respectively. In both cases the critical driving amplitude increases monotonically with the frequency, and at large frequencies it is identical for the two drives. However, at low and intermediate frequencies the critical amplitude of the square-wave drive depends strongly on frequency, while the one of the cosine drive is almost constant in a wide frequency range. By analyzing the density of drive-induced resonances we conclude that this difference is due to resonances induced by higher harmonics in the Fourier spectrum which are present (absent) in the spectrum of the square-wave (sine) drive.

DY 31.9 Wed 11:45 HÜL 186

Periodic projections in quantum spin chains — •S. Harshini Tekur[1], Arnd Bäcker[2,1], and David J. Luitz[1] — [1]MPI für Physik komplexer Systeme, Dresden — [2]TU Dresden, Institut für Theoretische Physik

We investigate a new class of systems where a driven, disordered spin chain is opened by the addition of a periodic projection at one end of the chain, in analogy with classical or quantum maps with escape. The evolution operator over one period then becomes sub-unitary with a complex spectrum inside the unit circle. This class of systems exhibits several interesting properties, which we demonstrate by studying its level statistics, entanglement dynamics and spectral features like exceptional points which are unique to non-normal matrices. These may also be experimentally realized in a set-up where certain configurations of the spin chain are post-selected after a measurement.

DY 31.10 Wed 12:00 HÜL 186

Long-lived coherence in driven spin systems: from two- to infinite spatial dimensions — •Walter Hahn and V. V. Dobrovitski — QuTech, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

We study dipolar-coupled quantum many-spin systems with local disorder, subject to periodic pulse driving, in different spatial dimensions: from two-dimensional to (effectively) infinite-dimensional systems. Using direct numerical simulations, we show that these systems exhibit long-lived magnetization response for all dimensions, despite strong fluctuations in the spin-spin couplings, and corresponding strong singularities in the spin dynamics. We observe the long-lived magnetization response for the initial polarization being either along the driving pulses, or along the axis conserved by the internal Hamiltonian. For longer time delays, the magnetization echoes exhibit an even-odd asymmetry, i.e. the system's response is modulated at the period which is twice the period of the driving. The above results are corroborated by a Floquet-operator analysis.

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DY 31.11 Wed 12:15 HÜL 186

Disorder-free localization in an interacting two-dimensional lattice gauge theory — •Petr Karpov[1,2], Roberto Verdel[1], Yi-Ping Huang[1,3], Markus Schmitt[1,4], and Markus Heyl[1] — [1]Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, Dresden 01187, Germany — [2]National University of Science and Technology "MISiS", Moscow, Russia — [3]The Paul Scherrer Institute, Forschungsstrasse 111, 5232 Villigen, Switzerland — [4]University of California, Berkeley, California 94720, USA

Recently, disorder-free localization has been introduced as a new mechanism for ergodicity breaking in homogeneous systems caused by local constraints imposed by gauge invariance [1,2]. Here, we show that disorder-free localization can occur in genuinely interacting systems in two spatial dimensions. Specifically, we show that the quantum link model can become nonergodic by providing a strict bound on the localization-delocalization transition through an unconventional classical percolation problem. We investigate the quantum dynamics in this system by means of an improved classical network description [3] endowed with a time-dependent variational principle.

[1] A. Smith, J. Knolle, D.L. Kovrizhin, and R. Moessner, Phys. Rev. Lett. **118**, 266601 (2017).
[2] M. Brenes, M. Dalmonte, M. Heyl, and A. Scardicchio, Phys. Rev. Lett. **120**, 030601 (2018).
[3] M. Schmitt and M. Heyl, SciPost Phys. **4**, 013 (2018).

DY 31.12 Wed 12:30 HÜL 186

Learning many-body localization indicators directly from the Hamiltonian — •Alexander Gresch, Lennart Bittel, and Martin Kliesch — Heinrich-Heine University, Düsseldorf, Germany

Many-body localization (MBL) captures the phenomenon that the propagation of correlations in disordered quantum systems can be strongly suppressed due to interference effects. Quantum systems undergoing MBL do practically not equilibrate but instead preserve local signatures of their initial conditions for arbitrarily long times. This property makes such systems potential candidates for storage devices in quantum computation. However, a full analytical understanding has not been achieved and numerical approaches have to deal with the exponential growth of the Hilbert space dimension. Hence, approximate methods have been proposed. A recent approach uses artificial neural networks for distinguishing MBL states from non-localized ones, which allows to calculate the phase diagram of the transition. The already proposed deep learning schemes require an expensive preprocessing, e.g. the eigenstates of the Hamiltonian or their entanglement spectrum, as inputs.

In this work, we investigate the Heisenberg spin chain with random local magnetic field. We demonstrate that an MBL-prediction is possible from the given disorder parameters alone without any preprocessing. We guide the learning process via several different indicators for MBL that have previously served as a basis for numerical studies. Here, we provide new insights in their predictive capabilities from a machine learning perspective.

DY 31.13 Wed 12:45 HÜL 186

Anderson Localization in a Rydberg Composite — •Matthew Eiles, Alexander Eisfeld, and Jan-Michael Rost — Max Planck Institute for the Physics of Complex Systems, 38 Noethnitzer Str. Dresden 01187

We demonstrate the localization of a Rydberg electron in a Rydberg composite, a system containing a Rydberg atom coupled to a structured environment of neutral ground state atoms. This localization is caused by weak disorder in the arrangement of the atoms and increases with the number of atoms M and principal quantum number ν. We develop a mapping between the electronic Hamiltonian in the basis of degenerate Rydberg states and a tight-binding Hamiltonian in the so-called "trilobite" basis, and then use this concept to pursue a rigorous limiting procedure to reach the thermodynamic limit in this system, taken as both M and ν become infinite, in order to show that Anderson localization takes place. This system provides avenues to study aspects of Anderson localization under a variety of conditions, e.g. for a wide range of interactions or with correlated/uncorrelated disorder.