DY 17: Many-body Systems: Equilibration, Chaos, and Localization (joint session DY/TT)

Time: Tuesday 9:30–13:00 Location: A 151

DY 17.1 Tue 9:30 A 151

Non-equilibration, synchronization, and time crystals in isotropic Heisenberg models — •Jürgen Schnack, Patrick Vorndamme, and Peter Reimann — Bielefeld University

Isotropic, but otherwise largely arbitrary Heisenberg models in the presence of a homogeneous magnetic field are considered, including various integrable, non-integrable, as well as disordered examples, and not necessarily restricted to one dimension or short-range interactions. Taking for granted that the non-equilibrium initial condition and the spectrum of the field-free model satisfy some very weak requirements, expectation values of generic observables are analytically shown to exhibit permanent long-time oscillations, thus ruling out equilibration [1]. If the model (but not necessarily the initial condition) is translationally invariant, the long-time oscillations are moreover shown to exhibit synchronization in the long run, meaning that they are invariant under arbitrary translations of the observable [2]. Analogous long-time oscillations are also recovered for temporal correlation functions when the system is already at thermal equilibrium from the outset, thus realizing a so-called time crystal.

[1] P. Reimann, P. Vorndamme, J. Schnack, Phys. Rev. Research 5, 043040 (2023)
[2] P. Vorndamme, H.-J. Schmidt, Chr. Schröder, J. Schnack, New J. Phys. 23, 083038 (2021)

DY 17.2 Tue 9:45 A 151

Many-body localization in random exchange coupling Heisenberg chain — •Yilun Gao and Rudolf A. Römer — Department of Physics, University of Warwick, Coventry, CV4 7AL

Disordered quantum systems have become an important research topic in modern condensed matter physics ever since the discovery of Anderson localization. The investigation of many-body localization in quantum interacting systems has received much recent attention following the increase of computational power and improvement in numerical methods. We focus on a Heisenberg spin chain with full SU(2) symmetry where the exchange couplings between neighboring spins are taken to be disordered. Sparse matrix diagonalization method is applied when calculating eigenvalues and eigenvectors of the Hamiltonian matrix. By understanding the structure of eigenvalues and eigenvectors in terms of spin symmetry, we investigate the participation ratio and entanglement entropy as a function of disorder strength. We average over many disorder realizations and compare the results for different system sizes. We find, for small system sizes, a clear distinction between the SU(2)-invariant random exchange model and the more often studied random field model.

DY 17.3 Tue 10:00 A 151

Long-range spectral statistics of the Rosenzweig-Porter model — •Wouter Buijsman — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

The Rosenzweig-Porter model is a single-parameter random matrix ensemble that supports an ergodic, fractal, and localized phase. Introduced over sixty years ago, this model recently gained renewed interest as a toy model for the many-body localization transition. We construct a unitary (Floquet) equivalent of this model, for which we numerically study the long-range spectral statistics [1,2]. The construction is based on interpreting the Rosenzweig-Porter model as a Brownian quantum system [3]. Our main result is the observation that the transition between the ergodic and fractal phases can be probed through the spectral form factor. Complementing previous results on the level spacing distribution, this establishes that spectral statistics are sufficient to fully map out the phase diagram of the model. We quantitatively discuss the scaling of the Thouless time, and point out the possible universality of the spectral form factor at the transition between the fractal and the localized phases.

[1] W. Buijsman and Y. Bar Lev, *Circular Rosenzweig-Porter random matrix ensemble*, SciPost Phys. **12**, 082 (2022).
[2] W. Buijsman, *Long-range spectral statistics of the Rosenzweig-Porter model*, arXiv:2309.14043 (2023).
[3] W. Buijsman, *Efficient circular Dyson Brownian motion algorithm,* arXiv: 2309.07457 (2023).

DY 17.4 Tue 10:15 A 151

Interplay of many-body interactions and quasiperiodic disorder in the all-bands-flat diamond chain — •Aamna Ahmed[1], Nilanjan Roy[2], and Auditya Sharma[3] — [1]University of Augsburg, Germany — [2]Nanyang Technological University (NTU), Singapore — [3]Indian Institute of Science Education and Research (IISER) Bhopal, India

While the physics of flat band systems, quasiperiodic disorder and many-body interactions have been important fields of activity, the interplay of these features has only scantily been explored. This talk will discuss the effect of many-body interactions and quasiperiodic Aubry André (AA) disorder on the one-dimensional all-band-flat (ABF) diamond lattice[**1,2**].

We show that coupling the ABF diamond lattice with nearest-neighbour interactions yields a non-ergodic phase independent of the strength of interaction. Interestingly, the resulting phases in the interacting diamond lattice depend on the symmetry and the strength of the applied quasiperiodic disorder. An exciting finding is the emergence of non-equilibrium quantum caging behaviour for specially engineered many-body initial states. Our work provides an insight into the phase diagram of an interacting flat band system subjected to quasiperiodic disorder via a non-equilibrium dynamical study.

1. Interplay of many-body interactions and quasiperiodic disorder in the all-band-flat diamond chain, **PRB 107, 245110 (2023)**
2.Flat-band-based multifractality in the all-band-flat diamond chain, **PRB 106, 205119 (2022)**

DY 17.5 Tue 10:30 A 151

Prethermalization in an Interacting Flat Band System — •Mirko Daumann and Thomas Dahm — Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld

Studying the influence of a weakly perturbed flat band on transport of interacting particles reveals anomalous diffusion and prethermalization. For very weak perturbations transport is getting slower than regular diffusion because of repulsive particle-particle interaction. The effect can be understood by a canonical transformation of dispersive and flat band eigenstates into a basis of light and heavy quasiparticles which are trapping each other. They are subjected to orbital conservation laws what enables a treatment of the phenomenon in terms of the Born-Oppenheimer approximation and allows an illustration in a familiar physical picture analogous to electrons and nuclei. This approach furthermore sheds light on the thermalization process in such a system in general.

Methodology: Transport properties are calculated by simulating the broadening of initially localized wave packets of spinless fermions in a quasi one-dimensional Hubbard model with three-orbital diamond structure. Initial states are constructed in the framework of dynamical quantum typicality. Time evolution is performed by either the Lanczos algorithm or full diagonalization if possible.

DY 17.6 Tue 10:45 A 151

Hilbert space fragmentation in anyonic chains — •Ludwig Zweng, Nico Kirchner, and Frank Pollmann — Technical University of Munich (TUM)

Hilbert spaces of chains of non-Abelian anyons are constrained by their fusion rules. These constraints may restrict the dynamics and lead to nontrivial thermalization behavior for such systems. As an examplary anyonic model with restricted thermalization, we suggest a one dimensional Fibonacci anyonic chain where the topological charges can perform braid moves around each other. We identify subspaces in the fusion space of this model which are left invariant by certain braid moves and by fine-tuning an additional magnetic field, we find various dynamically disconnected sectors. These sectors stem from the destructive interference of different braid processes and we expect that this model displays weak Hilbert space fragmentation. Moreover, we show that in global quenches certain initial states do not evolve to thermal states but display fidelity revivals up to late times.

DY 17.7 Tue 11:00 A 151

Quantum dynamical phase transition in Erdos-Renyi graph — •Tomohiro Hashizume[1], Felix Herbort[1], Joseph Tindall[2], and Dieter Jaksch[1] — [1]CUI, institute of quantum physics, University of Hamburg, Hamburg, Germany — [2]Centre for Computational

Quantum Physics, Flatiron Institute, New York, USA

With the lack of the well-defined free energy, the dynamics of a closed quantum system reaching its equilibrium state is not constrained by the conventional statistical mechanical pricniples. In the light of expanding the temperature into the complex domain, the dynamical quantum phase transition manifests itself as non-analyticities in the logarithm of the survival probability of the initial state before the quench. Based on the duality between the equilibrium quantum phase of the transverse field Ising model and the same model on the probablistic random graph (Erdos-Rényi graph), we expand this duality to the non-equilibrium regime and study the dynamical phase transition in these models. We show that despite the consistency of the dynamical critical point for all probability of edge generalation, p, the anomality of the transition ceases to exist upon averaging the echo over all possible graphs for $p < 1$.

15 min. break

DY 17.8 Tue 11:30 A 151

Semiclassical eigenstate entanglement of bipartite Floquet systems — •Maximilian F.I. Kieler and Arnd Bäcker — TU Dresden, Institute of Theoretical Physics, Dresden, Germany

Strongly coupled quantum systems are expected to show the same amount of entanglement as random states. However, many body systems typically have an inherent multi-partite structure, and it is not clear, how this influences the entanglement. We show for the case of chaotic, bipartite quantum maps, that the eigenstate entanglement coincides up to leading order with the random matrix result. For this the eigenstate entanglement is transferred into a dynamical quantity and evaluated using semiclassical methods. The result is given in terms of periodic orbits of the subsystems. Interestingly, the coupling acts as synchronization between these orbits, only.

DY 17.9 Tue 11:45 A 151

Floquet-Anderson localization in the Thouless pump and how to avoid it — András Grabarits[1,2], Attila Takács[1,3], Ion Cosma Fulga[4,5], and •János K. Asbóth[1,6] — [1]Dept of Theor. Physics, Budapest University of Technology and Economics — [2]Dept of Physics and Materials Science, University of Luxembourg — [3]Universite de Lorraine, CNRS, Nancy, France — [4]Leibniz Institute for Solid State and Materials Research, IFW Dresden, — [5]Wurzburg-Dresden Cluster of Excellence ct.qmat, 01062 Dresden — [6]Wigner Research Centre for Physics, Budapest

We investigate numerically how onsite disorder affects conduction in the periodically driven Rice-Mele model, a prototypical realization of the Thouless pump, when run at finite period time T. We find that at any fixed period time and nonzero disorder, increasing the system size L to infinity always leads to a breakdown of the pump by Anderson localization of the Floquet states. In a properly defined thermodynamic limit, where L/T^θ is kept constant, Anderson localization can be avoided, and the charge pumped per cycle has a well-defined value (as long as the disorder is not too strong). The exponent θ is not universal, rather, depends on the disorder strength. Our findings are relevant for practical, experimental realizations of the Thouless pump, for studies investigating the nature of its current-carrying Floquet eigenstates, as well as the mechanism of the full breakdown of the pump, expected if the disorder exceeds a critical value.

DY 17.10 Tue 12:00 A 151

Deviations from random matrix entanglement statistics for kicked quantum chaotic spin-1/2 chains — •Tabea Herrmann, Roland Brandau, and Arnd Bäcker — TU Dresden, Institute of Theoretical Physics, Dresden, Germany

It is commonly expected that for quantum chaotic systems the statistical properties approach those of random matrices with increasing system size. We demonstrate for various kicked spin-1/2 chain models that the average eigenstate entanglement indeed approaches the random matrix result. However, the distribution of the eigenstate entanglement differs significantly. While for autonomous systems such deviations are expected, they are surprising for the more scrambling kicked systems. We attribute the origin of the deviations to the local 2×2 substructure. This is supported by similar deviations occurring in a local random matrix model with global diagonal coupling.

DY 17.11 Tue 12:15 A 151

The entanglement membrane in exactly solvable lattice models — •Michael A. Rampp, Suhail A. Rather, and Pieter W. Claeys — Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

Entanglement membrane theory is an effective coarse-grained description of entanglement and operator growth in non-integrable quantum many body systems. The central quantity containing information about the dynamics is the entanglement line tension. However, determining the entanglement line tension for microscopic models is difficult. We compute the entanglement line tension in a recently introduced class of exactly solvable unitary circuits, and show that it has a non-trivial form giving rise to a hierarchy of velocity scales, $v_E < v_B$. We find that these circuits saturate certain bounds on entanglement growth that are also saturated in holographic models. Furthermore, we relate the entanglement line tension to temporal entanglement and correlation functions. Our results shed light on entanglement membrane theory in microscopic Floquet lattice models and enable us to perform non-trivial checks on the validity of its predictions by comparison to exact calculations.

DY 17.12 Tue 12:30 A 151

Weak eigenstate thermalization hypothesis — Patrycja Łydzba[1], •Rafał Świetek[2,3], Marcin Mierzejewski[1], Marcos Rigol[4], and Lev Vidmar[2,3] — [1]Institute of Theoretical Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, 50-370 Wrocław, Poland — [2]Department of Physics, Faculty of Mathematics and Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia — [3]Department of Theoretical Physics, J. Stefan Institute, SI-1000 Ljubljana, Slovenia — [4]Department of Physics, The Pennsylvania State University, University Park, Pennsylvania 16802, USA

While the eigenstate thermalization hypothesis (ETH) is well established for quantum-chaotic interacting systems, its validity for other classes of systems remains a matter of intense debate. Focusing on quadratic fermionic Hamiltonians, we here argue that the weak ETH is satisfied for few-body observables in many-body eigenstates of quantum-chaotic quadratic (QCQ) Hamiltonians. In contrast, the weak ETH is violated for few-body observables in localized quadratic Hamiltonians. We argue that these properties can be traced back to the validity of single-particle eigenstate thermalization, and we highlight the subtle role of normalization of operators. Our results suggest that the difference between weak and no ETH in many-body eigenstates allows for a distinction between single-particle quantum chaos and localization. We test to which degree this phenomenology holds true for integrable systems such as the XYZ and XXZ models.

DY 17.13 Tue 12:45 A 151

Critical quantum dynamics of observables at eigenstate transitions — Simon Jiricek[1], •Miroslav Hopjan[2], Patrycja Łydzba[3], Fabian Heidrich-Meisner[1], and Lev Vidmar[2,4] — [1]Institut für Theoretische Physik, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany — [2]Department of Theoretical Physics, J. Stefan Institute, SI-1000 Ljubljana, Slovenia — [3]Department of Theoretical Physics, Wroclaw University of Science and Technology, 50-370 Wroclaw, Poland — [4]Department of Physics, Faculty of Mathematics and Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia

It is an outstanding goal to unveil the fingerprints of universal quantum dynamics at eigenstate transitions. Focusing on quadratic fermionic Hamiltonians, we identify physical observables that exhibit critical behavior at the transition. Our result is based on two ingredients: (a) A relationship between the observable time evolution in a many-body state and the transition probabilities in single-particle states, and (b) a scale invariance of transition probabilities, which generalizes the recent result for survival probabilities [1]. We then show that these properties give rise to a critical behavior in the quantum quench dynamics of observables, which share the common eigenbasis with the Hamiltonian before the quench. We numerically demonstrate this phenomenon at the localization transition in the three-dimensional Anderson model, for which the critical bahavior can be detected in experimentally relevant observables such as site occupations and particle imbalance. [1] M. Hopjan and L.Vidmar, Phys. Rev. Lett. 131, 060404 (2023)