TT 9: Many-body Systems: Equilibration, Chaos and Localization I (joint session DY/TT)

Time: Monday 10:00–13:30 Location: HÜL 186

Invited Talk TT 9.1 Mon 10:00 HÜL 186

Dynamically probing winding numbers of Floquet toplogical insulators in optical lattices — •André Eckardt — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

The classification of topological Floquet systems with time-periodic Hamiltonians transcends that of static systems. For example, spinless fermions in periodically driven two-dimensional lattices are not completely characterized by the Chern numbers of the quasienergy bands, but rather by a set of winding numbers associated with the quasienergy gaps [Phys. Rev. X 3, 031005 (2013)]. I will present two schemes for probing these winding numbers in experiments with ultracold atoms in driven optical lattices. The first one relies on the quench-based tomography [PRL 113, 045303 (2014), Science 352, 1091 (2016)] of band-touching singularities occurring, when adiabatically connecting the driven system to a trivial high-frequency regime [PRL 122, 253601 (2019)]. The second one is based on observing the far-from equilibrium micromotion of the driven system within two driving periods after a sudden quench into the target Hamiltonian and relies on the identification of the winding numbers with an Hopf invariant characterizing the micromotion operator [Phys. Rev. Research 1, 022003(R) (2019)]. Together with the measurement of Chern numbers from the far-from equilibrium dynamics monitored in stroboscopic steps of the driving period [Nat. Comms. 10, 1728 (2019)], it provides a full characterization of the system.

TT 9.2 Mon 10:30 HÜL 186

Evaporative cooling and self-thermalization in an open system of interacting fermions — •Andrey Kolovsky[1,2] and Dima Shepelyansky[3] — [1]Kirensky Institute of Physics, 660036 Krasnoyarsk, Russia — [2]Siberian Federal University, 660041 Krasnoyarsk, Russia — [3]Université de Toulouse, CNRS, 31062 Toulouse, France

We study depletion dynamics of an open system of weakly interacting fermions with two-body random interactions. In this model fermions are escaping from the high-energy one-particle orbitals, that mimics the evaporation process used in laboratory experiments with neutral atoms to cool them to ultra-low temperatures. It is shown that due to self-thermalization the system instantaneously adjusts to the new chemical potential and temperature which decreases in course of time.

TT 9.3 Mon 10:45 HÜL 186

Entanglement entropy of fractal states — •Giuseppe De Tomasi[1] and Ivan Khaymovich[2] — [1]Department of Physics, T42, Technische Universität München, James-Franck-Straße 1, D-85748 Garching, Germany — [2]Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Straße 38, 01187-Dresden, Germany

In this talk we will discuss the relations between entanglement (and Renyi) entropies and fractal dimensions D_q of many-body wave-functions.

As a simple example we introduce a new class of *sparse* random pure states being fractal in the corresponding computational basis and show that their entropies grow linearly with for fractal dimension smaller than the subsystem size ($D_q < 0.5$ for equipartitioning) and reach the upper bound of Page value otherwise, far below the ergodic limit $D_q = 1$. The latter shows that Page value entanglement entropy does not guarantee ETH.

Moreover this D_q-dependence poses an upper bound for entanglement and Renyi entropies of any multifractal states and uncovers the relation between multifractality and entanglement properties of many-body wave-functions.

TT 9.4 Mon 11:00 HÜL 186

Tripartite information, scrambling, and the role of Hilbert space partitioning in quantum lattice models — Oskar Schnaack[1], •Niklas Bölter[1], Sebastian Paeckel[1], Salvatore R. Manmana[1], Stefan Kehrein[1], and Markus Schmitt[2,3,1] — [1]Institut für Theoretische Physik, Universität Göttingen — [2]Department of Physics, University of California, Berkeley — [3]Max-Planck-Institute for the Physics of Complex Systems, Dresden

For the characterization of the dynamics in quantum many-body systems the question how information spreads and becomes distributed over the constituent degrees of freedom is of fundamental interest. We investigate the time-evolution of tripartite information as a natural operator-independent measure of scrambling, which quantifies to which extent the initially localized information can only be recovered by global measurements. Studying the dynamics of quantum lattice models we demonstrate that in contrast to quadratic models generic interacting systems scramble information irrespective of the chosen partitioning of the Hilbert space, which justifies the characterization as scrambler.

TT 9.5 Mon 11:15 HÜL 186

Moire Localization in Two Dimensional Quasi-Periodic Systems — •Biao Huang[1,2] and W Vincent Liu[1] — [1]University of Pittsburgh — [2]Max Planck Institute for the Physics of Complex Systems

Moire reconstructions of Bloch waves have led to exciting development recently, where bilayer systems with small twist angles produce new periodic structures including the flat-band induced superconductivity. Here, we point out that an incommensurate, large twist angle, realized in a recent bilayer graphene experiment, may imply a qualitatively new localized system. This includes a rapidly changing mobility edge with respect to energy distinguishing from quasi-periodic systems in 1D and 3D, and scaling exponents saturating the Harris bound formulated for a purely random system in the localization transition. Methods for engineering and signatures for detections in cold atom simulations are also discussed.

Ref: B. Huang and W. V. Liu, Phys. Rev. B 100, 144202 (2019).

TT 9.6 Mon 11:30 HÜL 186

Hierarchy of relaxation timescales in local random Liouvillians — Kevin Wang[1], •Francesco Piazza[2], and David Luitz[2] — [1]Department of Physics, Stanford University, Stanford, California 94305, USA — [2]Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, Dresden, Germany

To characterize the generic behavior of open quantum systems, we consider random, purely dissipative Liouvillians with a notion of locality. We find that the positivity of the map implies a sharp separation of the relaxation timescales according to the locality of observables. Specifically, we analyze a spin-1/2 system of size ℓ with up to n-body Lindblad operators, which are n-local in the complexity-theory sense. Without locality ($n = \ell$), the complex Liouvillian spectrum densely covers a "lemon"-shaped support, in agreement with recent findings [*Phys. Rev. Lett.* **123**, 140403;arXiv:1905.02155]. However, for *local Liouvillians* ($n < \ell$), we find that the spectrum is composed of several dense clusters with random matrix spacing statistics, each featuring a lemon-shaped support wherein all eigenvectors correspond to n-body decay modes. This implies a hierarchy of relaxation timescales of n-body observables, which we verify to be robust in the thermodynamic limit.

TT 9.7 Mon 11:45 HÜL 186

Decay of spin-spin correlations in disordered quantum and classical spin chains — •Dennis Schubert, Jonas Richter, and Robin Steinigeweg — University of Osnabrück, Germany

The real-time dynamics of equal-site correlation functions is studied for one-dimensional spin models with quenched disorder. Focusing on infinite temperature, we present a comparison between the dynamics of models with different quantum numbers $s = 1/2, 1, 3/2$, as well as of chains consisting of classical spins. Based on this comparison as well as by analysing the statistics of energy-level spacings, we show that the putative many-body localization transition is shifted to considerably stronger values of disorder for increasing s . In this context, we intro- duce an effective disorder strength, which provides a mapping between the dynamics for different spin quantum numbers. For small values of the effective disorder, we show that the real-time correlations become essentially independent of s , and are moreover very well captured by the dynamics of classical spins. Particularly for $s = 3/2$, the agreement between quantum and classical dynamics is remarkably observed even for very strong values of disorder. This behaviour also reflects itself in the appropriate spectral functions, which are obtained via a Fourier transform from the time to the frequency domain. As an aside, we also comment on the self-averaging properties of the correlation function at weak and strong disorder.

[1] arXiv:1911.09917

TT 9.8 Mon 12:00 HÜL 186

Statistics of correlations functions in the random Heisenberg chain — •Luis Colmenarez[1], David Luitz[1], Paul McClarty[1], and Masudul Haque[1,2] — [1]Max Planck Institute for the Physics of Complex Systems, Noethnitzer Str. 38, Dresden, Germany — [2]Department of Theoretical Physics, Maynooth University, Co. Kildare, Ireland

Ergodic quantum many-body systems satisfy the eigenstate thermalization hypothesis (ETH). However, strong disorder can destroy ergodicity through many-body localization (MBL) – at least in one dimensional systems – leading to a clear signal of the MBL transition in the probability distributions of energy eigenstate expectation values of local operators. We consider the full probability distribution of eigenstate correlation functions across the entire phase diagram. At intermediate disorder – in the thermal phase – we find further evidence for anomalous thermalization in the form of heavy tails of the distributions. In the MBL phase, we observe peculiar features of the correlator distributions: a strong asymmetry in $S_i^z S_{i+r}^z$ correlators skewed towards negative values; and a multimodal distribution for spin-flip correlators. A quantitative quasi-degenerate perturbation theory calculation of these correlators yields a surprising agreement of the full distribution with the exact results, revealing, in particular, the origin of the multiple peaks in the spin-flip correlator distribution as arising from the resonant and off-resonant admixture of spin configurations. The distribution of the $S_i^z S_{i+r}^z$ correlator exhibits striking differences between the MBL and Anderson insulator cases.

TT 9.9 Mon 12:15 HÜL 186

Quantum coherent dynamical extension to RKKY interaction — •Stephanie Matern and Bernd Braunecker — School of Physics and Astronomy, University of St Andrews, UK

We study the full time evolution of a pair of impurity spins coupled to a bath of itinerant electrons. Even if the spins do not interact directly they can be coupled through the bath. In its simplest form this corresponds to the RKKY interaction. However, the RKKY interaction is considered as instantaneous and disregards that the spins are not just affected by the response of the bath but have an influence on the bath itself. To capture this effect on the dynamics we take into account all temporal correlations, particularly the quantum coherent correlations building up between the spins and the bath. This immediately leads to non-Markovian dynamics and to a coupling between the spins induced by the coherent quantum excitations of the electron bath. This effective coupling can be considered as a dynamical quantum coherent extension to the RKKY interaction.

Our approach is based on a self-consistent projection operator calculation for generalised quantum master equations. This method allows us to keep track of the time evolution of both the spins and the electron bath, and therefore for the bath to go beyond the usual assumption that it is represented by a Gibbs equilibrium state.

TT 9.10 Mon 12:30 HÜL 186

Entanglement Negativity at Localization Transition — •Gergö Roosz[1], Robert Juhasz[2], and Zoltan Zimboras[2] — [1]TU Dresden — [2]Wigner RCP

We study the entanglement negativity and entanglement entropy asymptotic at the localization transition of the quasi-periodic Harper model. In the delocalized phase the scaling is identical with the scaling of the homogeneous system $S \sim \frac{1}{3}\ln l$ and $\mathcal{E} \sim \frac{1}{4}\ln l$. In the critical point the scaling is different, $S \sim \frac{\tilde{c}}{3}\ln L$ and $\mathcal{E} \sim \frac{\tilde{c}}{4}\ln L$, with $\tilde{c} \approx 0.78$ In the localized phase the length scale is set by the localization length l_{loc} and we find $S \sim \frac{\tilde{c}}{3}\ln l_{loc}$ and $\mathcal{E} \sim \frac{\tilde{c}}{4}\ln l_{loc}$. Unlike the random and aperiodic singlet phases, where the ratio of the entanglement entropy and negativity prefactor is 2, in the Harper model this ratio is identical with the homogeneous case, 3/4.

TT 9.11 Mon 12:45 HÜL 186

Signatures of excited-state quantum phase transitions in quench dynamics — •Michal Kloc — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

Excited-state quantum phase transitions manifest themselves as singularities in the level density of the excited states. In the case of integrable or weakly chaotic systems, we show that equilibration after a rapid quantum quench is affected by these singularities. The specific features of the equilibration process are analyzed using both purely quantum and quasiclassical approaches.

TT 9.12 Mon 13:00 HÜL 186

Density dynamics in the mass-imbalanced Hubbard model — •Tjark Heitmann, Jonas Richter, and Robin Steinigeweg — Physics Department, University of Osnabrück, Germany

We consider two mutually interacting particle species on a onedimensional lattice and study how the mass ratio between the two species affects the (equilibration) dynamics of the particles. While initial nonequilibrium density distributions are known to decay for equal masses (by diffusion [1]), the lighter particles localize in an effective disorder potential when the heavy particles become infinitely heavy and thus immobile. Knowing that, what behavior can we expect in the case of intermediate mass-imbalance ratios [2,3]? To investigate this question, we prepare pure initial states featuring a sharp nonequilibrium density profile and study their real-time dynamics which, by means of dynamical quantum typicality, can be related to equilibrium correlation functions. We observe that anomalous diffusion impedes localization as soon as the heavy particles become mobile.

[1] R. Steinigeweg et al., Phys. Rev. E 96, 020105(R) (2017).
[2] N. Y. Yao et al., Phys. Rev. Lett. 117, 240601 (2016).
[3] J. Sirker, Phys. Rev. B 99, 075162 (2019).

TT 9.13 Mon 13:15 HÜL 186

Thermalization properties of closed quantum systems in linear response — •Christian Bartsch — Fakultät für Physik, Universität Bielefeld, Universitätsstraße 25, D-33615 Bielefeld

Linear response theory provides a useful tool to describe nonequilibrium dynamics not too far away from equilibrium. We are able to identify different long time behavior for certain types of nonequilibrium initial conditions also with respect to the eigenstate thermalization hypothesis (ETH). Additionally, we investigate the stability of long time dynamics in driven quantum systems and its dependence on, e.g., the driving frequency. Along these lines we analyze the average energy input per driving period.