TT 55: Dynamics and Chaos in Many-Body Systems I (joint session DY/TT)

Time: Thursday 15:00–17:30 Location: MOL 213

TT 55.1 Thu 15:00 MOL 213

Imperfect Many-Body Localization in Exchange-Disordered Isotropic Spin Chains — •Julian Siegl and John Schliemann — University of Regensburg

We study many-body localization in isotropic Heisenberg spin chains with the local exchange parameters being subject to quenched disorder. The Hamiltonian is invariant under global SU(2)- rotations and incorporates therefore a nonabelian symmetry. Systems of common spin length 1/2 and 1 are studied numerically using random matrix techniques. In both cases we find a transition from an ergodic phase at small disorder strength to an incompletely localized phase at stronger disorder. The transition is signaled by a maximum of the sample-to-sample variance of the averaged consecutive-gap ratio. The incompletely localized phase found here is distinguished from a fully localized system by the scaling behavior of the sample-to-sample variance.

TT 55.2 Thu 15:15 MOL 213

Magnetic Dipole Clusters - Resurrection of Catastrophe Machines — •Ingo Rehberg and Simeon Völkel — Experimental Physics, University of Bayreuth

Hysteretic transitions between stable configurations of a hexagonal magnetic dipole cluster [1] are set in a broader context by revealing the nature of the corresponding instabilities [2]. Following the animation of this bifurcation scenario [3], we present an experimental setup where the height of the centre dipole serves as the bifurcation parameter. This catastrophe machine demonstrates the two instabilities forming the hysteresis loop, and it might provide a hint to the unresolved puzzle of the slowing down of one of the eigenmodes [4].

[1] Andrew D.P. Smith et al., JMMM 549, 168991 (2022).
[2] Simeon Völkel et al., JMMM 559, 169520 (2022).
[3] https://doi.org/10.5281/zenodo.6380539 (18.5.2022).
[4] Peter T. Haugen et al., Chaos 32, 063108 (2022).

TT 55.3 Thu 15:30 MOL 213

Signatures of the interplay between chaos and local criticality on the dynamics of scrambling in many-body systems — Felix Meier[1], •Mathias Steinhuber[2], Juan Diego Urbina[2], Daniel Waltner[1], and Thomas Guhr[1] — [1]University of Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany — [2]University of Regensburg, Universitätsstr. 31, 93040 Regensburg, Germany

Fast scrambling, quantified by the exponential initial growth of Out-of-Time-Ordered-Correlators (OTOCs), is the ability to efficiently spread quantum correlations among the degrees of freedom of interacting systems, and constitutes a characteristic signature of local unstable dynamics. As such, it may equally manifest both in systems displaying chaos or even in integrable systems around criticality. We discuss the results from our recent publication [1], where we go beyond these two well-studied regimes with an exhaustive study of the interplay between local criticality and chaos. We address many-body systems with a well-defined classical (mean-field) limit, as coupled large spins and Bose-Hubbard chains, thus allowing for semiclassical analysis. Our aim is to investigate the dependence of the exponential growth of the OTOCs, defining the quantum Lyapunov exponent λ_{q} on quantities derived from the classical system with mixed phase space, specifically the local stability exponent of a fixed point λ_{loc} as well as the maximal Lyapunov exponent λ_{L} of the chaotic region around it.

[1] Meier, F., Steinhuber, M., Urbina, J. D., Waltner, D. & Guhr, T. arxiv:2211.12147

TT 55.4 Thu 15:45 MOL 213

Characterizing quantum chaoticity of kicked spin chains — •Tabea Herrmann, Maximilian F. I. Kieler, and Arnd Bäcker — TU Dresden, Institut für Theoretische Physik, Dresden, Germany

Quantum many body systems are commonly considered as quantum chaotic if their spectral statistics, such as the level spacing distribution, agree with those of random matrix theory. Using the example of the kicked Ising chain we demonstrate that even if both level spacing distribution and eigenvector statistics agree well with random matrix predictions, the entanglement entropy deviates from the expected Page curve. We propose a new measure of the effective spin interactions and obtain the corresponding random matrix result. By this the deviations of the entanglement entropy can be understood.

TT 55.5 Thu 16:00 MOL 213

Entanglement Characterization of Measurement-Induced Phase Transition in Fermionic Chains — •Jiangtian Yao[1,2], Sebastian Diehl[1], and Michael Buchhold[1] — [1]Institute for Theoretical Physics, University of Cologne, D-50937 Cologne, Germany — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany

We report characterization of measurement-induced phase transition in Gaussian fermionic chains. We use various entanglement measures to characterize the two phases as well as the nature of the transition. Through a numerical study on the entanglement spectra, we observe closure of the entanglement gap in the critical phase and relate the scaling of the closure to the effective central charge of the system. In addition, we numerically extract the effective Luttinger liquid parameter of the system and use it to characterize the critical phase. Lastly, we use the scaling behavior of the effective Luttinger liquid parameter as well as the Schmidt gap to estimate the critical point for the phase transition.

15 min. break

TT 55.6 Thu 16:30 MOL 213

Dynamical characterization of the chaotic phase in the Bose-Hubbard model — David Peña Murillo and •Alberto Rodríguez — Departamento de Física Fundamental, Universidad de Salamanca, E-37008 Salamanca, Spain

We study the dynamical manifestation of the Bose-Hubbard model's chaotic phase [1] by analysing the temporal behaviour of connected two-point density correlations on experimentally accessible time scales up to a few hundred tunneling times. The time evolution of initial Mott states with unit density in systems including up to 17 bosons (Hilbert space dimension $\approx 10^9$) reveals that the chaotic phase can be unambiguously identified from the early time fluctuations of the considered observable around its equilibrium value [2]. The emergence of the chaotic phase is also seen to leave an imprint in the initial growth of the time signals. The possibility to discern specific features of this many-body chaotic phase, on top of the universal prediction of random-matrix theory, from these experimentally accessible measures is explored.

[1] L. Pausch *et al.*, Phys. Rev. Lett. 126, 150601 (2021)
[2] D. Peña Murillo, MSc Thesis, Universidad de Salamanca (2022)

TT 55.7 Thu 16:45 MOL 213

Universal Eigenvalue Distribution for Locally Interacting Quantum Systems — •Tobias Helbig, Tobias Hofmann, Ronny Thomale, and Martin Greiter — Institut für Theoretische Physik und Astrophysik, Universität Würzburg, D-97074 Würzburg, Germany

Wigner has shown [1] that the eigenvalue distribution of a Gaussian orthogonal or unitary ensemble of random matrices approaches a semicircle in the thermodynamic limit. Here, we show that the joint eigenvalue distribution of locally interacting quantum systems, that is, ensembles of finite dimensional subsystems with local interactions between them, approaches a Gaussian distribution as the number of subsystems is taken to infinity [2]. In the talk, we present our analytical results supported by numerical data and discuss possible implications of a Gaussian density of states for physical problems.

[1] E. P. Wigner. On the statistical distribution of the widths and spacings of nuclear resonance levels. Mathematical Proceedings of the Cambridge Philosophical Society, 47(4): 790-798 (1951).
[2] T. Hofmann, T. Helbig, R. Thomale, and M. Greiter. In preparation.

TT 55.8 Thu 17:00 MOL 213

Power-law decay of correlations after a global quench in the massive XXZ chain — •Flávia Braga Ramos[1], Andrew Urichuk[2,3], Imke Schneider[1], and Jesko Sirker[3] — [1]Fachbereich Physik und Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]University of Manitoba, Winnipeg, Canada — [3]Bergische Universität Wuppertal, Wuppertal, Germany

While there have been great advances in understanding the final equilibration of integrable systems after a quantum quench, relatively little is known about their precise relaxation towards the steady state. In this context, the XXZ chain provides a playground for the investigation of interaction effects in out-of-equilibrium properties of quantum many-body systems. We investigate the relaxation dynamics of equal-time correlations in the antiferromagnetic phase of the XXZ spin-1/2 chain following a global quantum quench of the anisotropy parameter. In particular, we focus on the relaxation dynamics starting from an initial Néel state. Using the exact solution of an effective free-fermion model, state-of-art density matrix renormalization group simulations, and the quench-action approach, we show that the late-time relaxation is characterized by a power-law decay $\sim t^{-3/2}$ independent of anisotropy. Overall, we find remarkable agreement in the results obtained from the distinct approaches.

TT 55.9 Thu 17:15 MOL 213

Universal correlations in chaotic many-body quantum states: lifting Berry's Random Wave Model into Fock space — Rémy Dubertrand[1], Juan-Diego Urbina[2], Klaus Richter[2], and •Florian Schöppl[2] — [1]Department of Mathematics, Physics and Electrical Engineering, Northumbria University, NE1 8ST Newcastle upon Tyne, United Kingdom — [2]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Using a semiclassical analysis based on Berry's ansatz [1] we investigate the universal statistical features of eigenstate correlations in chaotic mesoscopic many-body quantum systems, focusing on Bose-Hubbard lattices, where the existence of a classical (mean-field) limit allows for the use of many-body semiclassical methods [2]

For this, we first have to lift Berry's ansatz into the many-body space by expanding the microscopic correlations and the conjectured multivariant Gaussian distribution of expansion coefficients into the Fock space of quantum fields. Together with numerical evidence, which supports the extension to multi-point correlations of the known Gaussian distribution for a single expansion coefficient, the universality of eigenstate correlations can be extended well beyond random matrix theory, where these correlations are absent. Our results bring the correlation backbone of eigenfunctions into a precise signature of quantum chaos in many-body mesoscopic systems.

[1] M. V. Berry, Journal of Physics A: Mathematical and General **10**, 2083 (1977) [2] K.Richter, J.D. Urbina, and S. Tomsovic. "Semiclassical roots of universality in many-body quantum chaos," (2022)