MP 3: Quantum Dynamics

Time: Monday 15:00–18:30 Location: HL 001

Invited Talk MP 3.1 Mon 15:00 HL 001

Rigorous results on many-body localization — •Wojciech De Roeck — K.U. Leuven, Belgium

The concept of many-body localization was introduced around 2005. It is supposed to be a phase of matter in which thermalization is absent, as such violating basic laws of thermodynamics. Despite a lot of work, there is currently still a debate about the question whether this phase actually exists. In this talk I will present recent results that aim to shed light on this question. I will only consider mathematically rigorous results. Tentatively, these results support the view that many-body localization actually exists in one-dimensional quantum chains.

MP 3.2 Mon 15:30 HL 001

Unique Decompositions of Generators of Dynamical Semigroups — •Frederik vom Ende — Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Since the 1970s it is well known that every generator L of a completely positive, trace-preserving dynamical semigroup is of the form $L = -i[H,\cdot] + \Phi - \frac{1}{2}\{\Phi^*(\mathbf{1}),\cdot\}$ for some Hamiltonian H and some completely positive map Φ. We prove that every quantum state gives rise to a unique decomposition of L into its "building blocks" by means of vanishing expectation values: More precisely, for all states ω there exist unique H, Φ with $\mathrm{tr}(H\omega) = 0$ and $\mathrm{tr}(\Phi(\omega \cdot \omega)) = 0$ such that the above decomposition holds. As a special case, for $\omega = \frac{\mathbf{1}}{n}$ one recovers the uniqueness condition of Gorini, Kossakowski, and Sudarshan involving traceless Lindblad operators (which now has a physical interpretation by means of our result). Moreover, this insight allows for a generalization of such unique decompositions to arbitrary separable Hilbert spaces.

MP 3.3 Mon 15:50 HL 001

Quantum Chaos and Complexity in Triangular Billiard Systems — Vijay Balasubramanian[1,2], •Rathindra Nath Das[3], Johanna Erdmenger[3], and Zhuo-Yu Xian[3] — [1]David Rittenhouse Laboratory, University of Pennsylvania, 209 S. 33rd Street, Philadelphia PA 19104, USA. — [2]Theoretische Natuurkunde, Vrije Universiteit Brussel (VUB), and International Solvay Institutes, Pleinlaan 2, B-1050 Brussels, Belgium. — [3]Institute for Theoretical Physics and Astrophysics and Würzburg-Dresden Cluster of Excellence ct.qmat, Julius-Maximilians-Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

In view of quantifying quantum chaos in dynamical systems and motivated by the search for viable definitions of complexity in quantum field theory and holography, we revisit quantum billiards and examine the recently proposed measure of Krylov state complexity known as spread complexity. In particular, we investigate the growth of Krylov state complexity and spectral complexity in triangular billiard systems. While classically, these billiards exhibit a zero Lyapunov exponent, quantum mechanically they display spectral statistics intermediate between Poissonian and the Gaussian Orthogonal Ensemble (GOE), the exact form depending on the three angles. Using spectral complexity and statistics, we identify a hierarchy in the chaotic behaviour of different billiards. We find a direct correlation between Lanczos coefficients, a key ingredient of Krylov complexity, and the level repulsion present in the system. The effects of symmetry sectors on the system's dynamics are also explored.

MP 3.4 Mon 16:10 HL 001

Spread complexity for measurement-induced non-unitary dynamics and quantum Zeno effect — •Aranya Bhattacharya[1], Rathindra Nath Das[2], Bidyut Dey[3], and Johanna Erdmenger[2] — [1]Institute of Physics, Jagiellonian University, Łojasiewicza 11, 30-348 Kraków, Poland — [2]Institute for Theoretical Physics and Astrophysics and Würzburg-Dresden Cluster of Excellence ct.qmat Julius-Maximilians-Universität Würzburg
Am Hubland, 97074 Würzburg, Germany — [3]Indian Institute of Technology Kanpur, Kanpur 208016, Uttar Pradesh, India

We study the behaviour of spread complexity and spread entropy in quantum systems evolving under non-unitary dynamics. For non-hermitian Hamiltonians, we extend the bi-Lanczos construction of the Krylov basis to the Schrödinger picture. Also, a specialized algorithm is implemented for complex symmetric Hamiltonians, effectively reducing the computational memory requirements by half. We apply this construction to the one-dimensional tight-binding Hamiltonian subject to repeated measurements at fixed small time intervals. These result in effective non-unitary dynamics. In analogy to measurement-induced phase transitions, we consider a quench between hermitian and non-hermitian Hamiltonian evolution induced by turning on regular measurements at different frequencies. As a function of the measurement frequency, we find a transition that shifts the time at which the spread complexity starts growing, indicating the onset of the quantum Zeno effect.

MP 3.5 Mon 16:30 HL 001

Towards exact factorization of quantum dynamics via Lie algebras — •David Edward Bruschi[1], André Xuereb[2], and Robert Zeier[3] — [1]Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, Jülich, Germany — [2]Department of Physics, University of Malta, Malta — [3]Quantum Control (PGI-8), Forschungszentrum Jülich, Jülich, Germany

Determining exactly the dynamics of a physical system is the paramount goal of any branch of physics. Quantum dynamics are characterized by the non-commutativity of operators, which implies that the dynamics usually cannot be tackled analytically and require ad-hoc solutions or numerical approaches. A priori knowledge on the ability to obtain exact results would be of great advantage for many tasks of modern interest, such as quantum computing, quantum simulation and quantum annealing.

In this work we lay the foundations for an approach to determine the dimensionality of a Hamiltonian Lie algebra by appropriately characterizing its generating terms. This requires us to develop a new tool to construct sequences of operators that determine the final dimension of the algebra itself. Our work is exact and fully general, therefore providing statements on the ultimate ability to exactly control the dynamics or simulate specific classes of physical systems. This work has important implications not only for theoretical physics, but it also aids our understanding of the structure of the Hilbert space, as well as Lie algebras.

20 min. break

MP 3.6 Mon 17:10 HL 001

Quantum Scattering upon Local Deformations in Configuration Space — •Benjamin Schwager, Lars Meschede, and Jamal Berakdar — MLU Halle-Wittenberg, Halle (Saale), Germany

When a quantum particle is subjected to spatial constraints, its dynamics have to be modelled based on a configuration space that is a more general Riemannian manifold than Euclidean space. The resulting effective quantum wave equations contain correction terms in dependence of the geometric properties of this space. We apply the confinement potential approach to the Schrödinger equation to obtain an effective wave equation in reduced dimensions, and show that position-dependent modulations of the geometric invariants and the metric tensor cause lower-dimensional scattering events. It is found that theire characteristics differ significantly from the case of more familiar potential scattering. Furthermore, we present consequences for transport properties.

MP 3.7 Mon 17:30 HL 001

Almost everything about the unitary almost Mathieu operator — •Christopher Cedzich[1], Jake Fillman[2], and Darren Ong[3] — [1]Heinrich Heine Universität Düsseldorf, Universitätsstr. 1, 40225 Düsseldorf, Germany — [2]Texas State University, San Marcos, TX 78666, USA — [3]Xiamen University Malaysia, Jalan Sunsuria, Bandar Sunsuria, 43900 Selangor, Malaysia

We introduce the unitary almost-Mathieu operator, which is obtained from a two-dimensional quantum walk in a uniform magnetic field. We exhibit a version of Aubry-André duality for this model, which partitions the parameter space into three regions: a supercritical region and a subcritical region that are dual to one another, and a critical regime that is self-dual. We exactly compute the Lyapunov exponent on the spectrum in terms of the given parameters. We also characterize the spectral type for each value of the coupling constant, almost every frequency, and almost every phase. Namely, we show that for almost every frequency and every phase the spectral type is purely absolutely continuous in the subcritical region, pure point in the supercritical region, and purely singular continuous in the critical region. In some parameter regions, we refine the almost-sure results.

MP 3.8 Mon 17:50 HL 001

Ergodicity breaking and deviation from Eigenstate Thermalisation in relativistic QFT — •Miha Srdinsek[1,2,3], Tomaz Prosen[4], and Spyros Sotiriadis[5,6] — [1]ISCD - Sorbonne Universite — [2]IMPMC - Sorbonne Universite — [3]PASTEUR - Ecole Normale Superieure, PSL — [4]Faculty of Mathematics and Physics, University of Ljubljana — [5]Institute of Theoretical and Computational Physics, Department of Physics, University of Crete — [6]Dahlem Center for Complex Quantum Systems, Freie Universita *t Berlin

The validity of the ergodic hypothesis in quantum systems can be rephrased in the form of the Eigenstate Thermalisation Hypothesis (ETH), a set of statistical properties for the matrix elements of local observables in energy eigenstates, which is expected to hold in any ergodic system. We test ETH in a nonintegrable model of relativistic Quantum Field Theory (QFT) using the numerical method of Hamiltonian Truncation in combination with analytical arguments based on Lorentz symmetry and Renormalisation Group theory. We find that there is an infinite sequence of eigenstates with the characteristics of Quantum Many Body Scars, that is, exceptional eigenstates with observable expectation values that lie far from thermal values, and we show that these states are one-quasiparticle states. We argue that in the thermodynamic limit the eigenstates cover the entire area between two diverging lines, the line of one-quasiparticle states, whose direction is dictated by relativistic kinematics, and the thermal average line. Our results suggest that the strong version of ETH is violated in any relativistic QFT whose spectrum admits a quasiparticle description.

MP 3.9 Mon 18:10 HL 001

Emergent Born's statistics via colored noise driven quantum state reduction models. — •Aritro Mukherjee and Jasper van Wezel — Institute of Physics, University of Amsterdam, Science Park 904, 1098XH

While quantum mechanics successfully predicts ensemble averaged observable expectation values, unitary evolution cannot yield dynamics corresponding to a single shot projective measurement which is irreversible, stochastic and leads to one steady-state outcome. While decoherence is inherently an ensemble averaged phenomena and quantum interpretations posit no changes to the Schrodinger's unitary evolution, a possible way out are objective collapse theories which modifies the quantum evolution such that for microscopic systems, superpositions are unaffected whilst, for macroscopic systems, the quantum state is reduced to a classical mixture.

Here, I shall present a dynamical objective collapse model which derives its motivation from spontaneous symmetry breaking and its corresponding irreversibility. In particular, I will discuss a recent class of spontaneous unitarity violating models, which are driven by colored (correlated) noise and demonstrate the emergence of Born*s rules given a fluctuation-dissipation relationship holds. In such a scenario, the ensemble averaged dynamics is shown to be a Gorini-Kossakowski-Sudarshan-Lindblad master equation which also guarantees no-superluminal signaling, and this is shown for any Hilbert space dimension.