FRI 3: Quantum Chaos

Time: Friday 10:45–12:00 Location: ZHG003

FRI 3.1 Fri 10:45 ZHG003

Chaos and integrability in partially distinguishable fermions on a lattice — •Caroline Stier, Edoardo Carnio, Gabriel Dufour, and Andreas Buchleitner — Albert-Ludwigs-Universität Freiburg

We study the fermionic many-body quantum dynamics generated by a Hubbard-like Hamiltonian with nearest neighbour interaction and a continuously tunable level of distinguishability of the particles. For not strictly indistinguishable fermions, distinct invariant symmetry sectors of the many-body Hilbert space are populated, with tangible impact on the many-body dynamics. For indistinguishable fermions, the dynamics is integrable; for partially distinguishable fermions, however, numerical results show the emergence of chaotic dynamics. We explain the breakdown of integrability with analytical arguments, in tandem with simulations of the dynamics within specific symmetry sectors.

FRI 3.2 Fri 11:00 ZHG003

High dimensional hyperbolic motion is maximally quantum chaotic — •Gerrit Caspari, Fabian Haneder, Juan Diego Urbina, and Klaus Richter — University of Regensburg

The Maldacena-Shenker-Stanford (MSS) bound is a condition on a system's quantum Lyanpunov exponent, defined as the growth rate of the regularized out-of-time-order correlator (OTOC) with respect to a thermal state. It states that the exponent is bounded by the system's temperature T, with maximally chaotic quantum systems, e.g. black holes, being defined by its saturation. Thus, it is expected that non-gravitational, maximally chaotic systems should have a gravitational dual.

In this contribution, we study the OTOC of a particle on a hyperbolic surface in arbitrary dimensions. Using the Wigner-Moyal formalism and a saddle-point approximation based on exact results for the mean level density given by the Selberg trace formula we show compliance to the MSS bound for low temperatures and finite dimensions and the asymptotic approach to a saturation formally obtained for infinite dimensions. To this end, a controlled asymptotic analysis of the interplay between dimensionality, temperature and quantum corrections is mandatory and nicely displays a transition from a sqrt(T) behavior into a T behavior of the quantum Lyapunov exponent. Together with the previous analysis of previous works, our results strongly indicate that high-dimensional hyperbolic motion admits an effective description in terms of emergent gravitational degrees of freedom.

FRI 3.3 Fri 11:15 ZHG003

Controlling Many-Body Quantum Chaos — •Lukas Beringer[1], Mathias Steinhuber[1], Juan Diego Urbina[1], Klaus Richter[1], and Steven Tomsovic[1,2] — [1]Institut für Theoretische Physik, Universität Regensburg, Regensburg, Germany — [2]Department of Physics and Astronomy, Washington State University, Pullman, WA USA

Controlling chaos is a well-established technique that leverages the exponential sensitivity of classical chaotic systems for efficient control. This concept has been generalized to single-particle quantum systems [1] and, more recently, extended to bosonic many-body quantum systems described by the Bose-Hubbard model [2]. In direct analogy to the classical paradigm, a localized quantum state can be transported along a specific trajectory to a desired target state. In the bosonic many-body case, this approach reduces to time-dependent control of the chemical potentials, making it suitable for rapid and customizable state preparation in optical lattice experiments. We discuss how this protocol can serve as a toolbox for studying many-body interference and present recent progress on preparation protocols for entangled states.

[1] S. Tomsovic, J. D. Urbina, and Klaus Richter, Controlling Quantum Chaos: Optimal Coherent Targeting, PRL 130.2 (2023): 020201.

[2] L. Beringer, M. Steinhuber, J. D. Urbina, K. Richter, S. Tomsovic, Controlling many-body quantum chaos: Bose-Hubbard systems, New J. Phys (2024): 26 073002.

FRI 3.4 Fri 11:30 ZHG003

Non-Markovianity in Chaotic Subsystem Evolution — •Zhuo-Yu Xian[1], Shao-Kai Jian[2], and Greg White[3,4,5] — [1]Department of Physics, Freie Universität Berlin, Arnimallee 14, DE-14195 Berlin, Germany — [2]Department of Physics and Engineering Physics, Tulane University, New Orleans, Louisiana, 70118, USA — [3]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [4]School of Physics and Astronomy, Monash University, Clayton, VIC 3800, Australia — [5]School of Physics, University of Melbourne, Parkville, VIC 3010, Australia

The process tensor captures how an environment influences a system across multiple time intervals, and its multi-time mutual information furnishes a measure of non-Markovianity. We examine the non-Markovianity of a subsystem's dynamics embedded in various unitary evolutions of the global system, described by random matrices, various Sachdev-Ye-Kitaev models, and holographic conformal field theories. This non-Markovianity arises from two distinct mechanisms: (i) interaction-induced temporal correlations, which appear already at early times, and (ii) entanglement phase transition, which appears at the Page time of a finite environment. We further show that the process-tensor mutual information coincides with the timeline pseudoentropy when the subsystem is depolarized and establishes its holographic correspondence in the dual black hole spacetime. Our results on non-Markovianity connect the fields of quantum chaos, many-body dynamics, and the black hole information problem.

FRI 3.5 Fri 11:45 ZHG003

Statistical Hadronization of Loosely Bound Nuclei — •Hjalmar Brunssen — Physikalisches Institut, Universität Heidelberg

It has been shown that the statistical hadronization model (SHM) yields an excellent description of hadron and light-nucleus yields in heavy-ion collisions at the LHC. While the yields of hadrons are in general well understood, the hadronization of nuclei is a very active research topic. In particular, the hypertriton, whose wavefunction is similar in size to the entire fireball, represents an ideal probe to test the production mechanism of nuclei.

This talk presents an approach for incorporating the size of loosely bound nuclei into the SHM calculation of production yields, focusing on hypertriton, deuteron and helium-3 nuclei. For this, the finite spatial extent of the wavefunction is considered, which leads to a significant correction relative to a point-like treatment, especially in small collision systems. We test the approach by comparing its predictions with data from ALICE and STAR.