INTEGRABLE AND CHAOTIC DYNAMICS (July 3rd to 8th 2022, Pokljuka)

Program

Monday ($9^{00} - 16^{45}$)

[9:00-10:00] Herbert Spohn: ***Generalized hydrodynamics for the Calogero*** $1/sinh^2$ ***fluid***
To be announced.

[10:00-11:00] Vincent Pasquier: ***Generalized hydrodynamics in Box-ball system***
To be announced.

[11:30-12:30] Marius de Leeuw: ***Yang-Baxter integrable open quantum systems***
In this talk I will discuss a constructive way to find Lindblad superoperators that are related to solutions of the Yang-Baxter equation. By using this method, we were able to fully classify a large set of integrable Lindbladians. I will discuss some of the new models that we found and their properties. Finally, I will focus on applications to quantum circuits and describe some general features that our models seem to exhibit.

[13:30-14:30] Vladislav Popkov: ***Phantom Bethe excitations and spin helices in integrable spin chains***
We demonstrate the existence of a special chiral "phantom" mode with some analogy to a Goldstone mode in the anisotropic quantum XXZ Heisenberg spin chain. The phantom excitations contribute zero energy to the eigenstate, but a finite fixed quantum of momentum. The mode exists not due to symmetry principles, but results from nontrivial scattering properties of magnons with momentum k given by the anisotropy via cos (k) = Jz/Jx. The mode originates from special string-type solutions of the Bethe ansatz equations with unbounded rapidities, the phantom Bethe roots. All such Bethe states are chiral (the simplest representative being factorized state with helicoidal magnetization profile) and exist in both periodic and open XXZ spin chain under fine-tuning. We show how phantom Bethe states can be generated dissipatively, by setting a polarization gradient via coupling the ends of the open spin chain to suitable dissipative baths.

[14:45-15:45] Bruno Bertini: ***Growth of Rényi Entropies in Interacting Integrable Models and the Breakdown of the Quasiparticle Picture***
Rényi entropies are conceptually valuable and experimentally relevant generalisations of the celebrated von Neumann entanglement entropy. After a quantum quench in a clean quantum many-body system they generically display a universal linear growth in time followed by saturation. While a finite subsystem is essentially at local equilibrium when the entanglement saturates, it is genuinely out-of-equilibrium in the growth phase. In particular, the slope of the growth carries vital information on the nature of the system's dynamics, and its characterisation is a key objective of current research. In the talk I will show that the slope of Rényi entropies can be determined by means of a spacetime duality transformation. I will argue that the slope coincides with the stationary density of entropy of the model obtained by exchanging the roles of space and time. Therefore, very surprisingly, the slope of the entanglement can be expressed as an equilibrium quantity. I will use this observation to find an explicit exact formula for the slope of Rényi entropies in all integrable models treatable by thermodynamic Bethe ansatz and evolving from integrable initial states. Interestingly, this formula can be understood in terms of a quasiparticle picture only in the von Neumann limit.

[15:45-16:45] Lev Vidmar: ***Ergodicity breaking transition in zero dimensions***
It is of great current interest to establish toy models of ergodicity breaking transitions in quantum many-body systems. Here we study a model that is expected to exhibit an ergodic to nonergodic transition in the thermodynamic limit upon tuning the coupling between an

ergodic quantum dot and distant particles with spin-1/2. The model is effectively zero dimensional, however, a variant of the model was proposed by De Roeck and Huveneers to describe the avalanche mechanism of ergodicity breaking transition in one-dimensional disordered spin chains. We show that exact numerical results based on the spectral form factor calculation accurately agree with theoretical predictions, and hence unambiguously confirm existence of the ergodicity breaking transition in this model. We benchmark specific properties that represent hallmarks of the ergodicity breaking transition in finite systems.

Tuesday ($9^{00} - 15^{45}$)

[9:00-10:00] Bernard Derrida: *Large deviations in non-equilibrium diffusive systems*

After a short review of the different approaches used to determine the large deviation functions of diffusive systems in their steady state, the talk will present a few recent results on the way these large deviations functions are modified by weak contacts with the boundaries and on the influence conditioning on the current on these large deviation functions.

[10:00-11:00] Juan Garrahan: *Stochastic strong zero modes*

In this talk I will describe how to extend the concept of strong zero modes (conserved operators localised at the edges of certain quantum spin chains which give rise to long coherence times) to classical stochastic systems. Being in general non-diagonal in the classical basis, SZMs have dynamical consequences which are very different from their quantum counterparts. I will show stochastic SZMs manifest through a large class of exact transient relations between time-correlation functions, absent in systems with apparently the same physics but without an SZM. Time permitting I will discuss further generalisations, e.g. to dissipative quantum systems.

[11:30-12:30] Kirone Mallick: *Macroscopic Integrability of the Exclusion Process*

The exclusion process, considered as a paradigm to describe classical transport in non-equilibrium statistical physics, is exactly solvable, microscopically. Many analytical results have been derived by using 'quantum integrability' techniques such as the Bethe Ansatz, Integrable Probabilities or the matrix Ansatz. At the macroscopic scale, the behaviour of this system follows a variational principle, proposed by G. Jona-Lasinio and his collaborators, known as the Macroscopic Fluctuation Theory (MFT). Optimal fluctuations far from equilibrium are determined by two coupled non-linear PDEs with mixed and non-local boundary conditions.

In this talk, we shall show that, for the exclusion process, the MFT system is classically integrable in the sense of Liouville and can be analyzed with the help of the inverse scattering method. By solving exactly the associated Riemann-Hilbert problem, we determine the large deviation function of the current and the optimal evolution that generates a required fluctuation, both at initial and final times.

[13:30-14:30] Patrik Ferrari: *Fluctuations of shocks in the asymmetric simple exclusion process*

In this talk we consider the totally asymmetric simple exclusion process with different types of initial conditions. We focus in particular to the shock, which microscopically is described by the second class particle, which can be seen as a microscopic perturbation of the system. We will discuss the large time limits of it. This talk is based on several papers with Peter Nejjar and a recent work with Alexey Bufetov.

[14:45-15:45] Žiga Krajnik: Anomalous flutuations and dynamical phase transitions in an integrable cellular automaton

We discuss fluctuations in a simple interacting cellular automaton in and out of equilibrium, where an analytical computation of the full counting statistics is feasible. Asymptotic analysis of the exact solution gives access to the current distribution on all scales and explicit cumulant asymptotics. Equilibrium typical fluctuations of the time-integrated spin current on sub-ballistic scales are non-Gaussian and the cumulants are found to grow with different algebraic exponents, signaling the onset of a dynamical phase transition, which we relate to the dynamics of complex zeros of the full counting statistics.

Wednesday ($9^{00} - 12^{30}$)

[9:00-10:00] Benjamin Doyon: ***Ballistic macroscopic fluctuation theory and long-range correlations***

I will overview a new theory which gives access to fluctuations and correlations at large scales of space and time in many-body systems (quantum and classical) out of equilibrium. The theory is concerned with the ballistic scale, and is entirely based on the data from the Euler hydrodynamic equations of the many-body system. It is an adaptation of the well-known macroscopic fluctuation theory, that has been very successful for purely diffusive systems. The "ballistic macroscopic fluctuation theory" (BMFT) gives predictions for the large-deviation theory of fluctuations and for the Euler scaling limits of correlation functions. A surprising new result is that generically, long-range spatial correlations develop over time if the initial state of the many-body system is spatially inhomogeneous; therefore the "fluid cells" of Euler hydrodynamics are in fact generically correlated amongst each other. I will describe the basic principles underlying the BMFT - including rigorous results about ergodicity in quantum systems - and some of its main consequences, in particular in integrable systems. This is work in collaboration with G. Perfetto, T. Sasamoto and T. Yoshimura.

[10:00-11:00] Balazs Pozsgay: ***On the integrability of the Rule54 model and other superintegrable cellular automata***

The Rule54 model is a cellular automaton which is one of the simplest interacting integrable models. Despite many results regarding its dynamical properties the actual algebraic understanding of its integrability was missing up to now. In this talk we give a partial explanation as to why this happened: We explain that there is no unique integrability structure associated to this model, instead it lies at the intersection of an (at least) one parameter family of integrable models. We also consider other models and show that a similar phenomenon appears.

[11:30-12:30] Jacopo De Nardis: ***Pushing the boundaries of generalised hydrodynamics: higher-order terms, integrability breaking and KPZ.***

I will present my work on some of the most recent developments in GHD, namely how to better understand diffusive and sub-diffusive transport in gapped XXZ, include higher order terms and possibly how to make sense of the KPZ scaling mystery.

Thursday ($9^{00} - 15^{45}$)

[9:00-10:00] Pedro Ribeiro: ***Random Matrix Models of Dissipative Quantum Dynamics***

Understanding the dissipative dynamics of complex quantum systems is essential to describe quantum matter at large time scales. However, even within a simplified Markovian description, studying the spectral and steady-state properties of Lindblad operators remains a challenging task. In this talk, we will discuss instances of ensemble averaging, using (non-Hermitian) random matrices, in order to access universal features of generic open quantum systems under Markovian dissipation. We will look at three representative cases: quadratic Liouvilians, the dissipative SYK model, and fully random Liouvilian operators. We shall use the recently proposed complex spacing ratios as a signature of dissipative quantum chaos.

[10:00-11:00] Berislav Buča: ***Non-stationary quantum many-body dynamics***

Non-stationary processes are special types of non-mixing dynamics characterised by long-time deterministic dynamics. They are ubiquitous in the real world around us - from biological to social phenomena. Likewise, on the quantum level, any successful long circuit depth calculation on a quantum computer is by definition non-stationary. Therefore, understanding how non-stationarity emerges from the microscopic quantum laws is of fundamental scientific and technological importance. I will discuss simple algebraic conditions that prevent a quantum many-body system from ever reaching a stationary state, not even a non-equilibrium one. I give several physically relevant examples in both closed and open quantum many-body systems, including an XXZ spin chain in a strong tilt field, a spin-1/2 Creutz ladder with oscillating out-of-time-order correlators, a spin-dephased Fermi-Hubbard model, and a two-component BEC in a lossy optical cavity which was recently experimentally studied.

References:

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[11:30-12:30] Lucas Sa: ***Many-body symmetry classes of non-Hermitian quantum matter***

We investigate the symmetry, spectral correlations, and universality of non-Hermitian quantum matter. We start by considering a non-Hermitian q-body Sachdev-Ye-Kitev (nHSYK) model with N Majorana fermions, and its chiral and complex-fermion extensions, relevant to the description of the short-time (or jump-free postselected) evolution of strongly-correlated quantum matter. Depending on q and N, we identify 19 out of the 38 non-Hermitian universality classes in the nHSYK model. For $q > 2$, the level statistics on several timescales are well described by random matrix theory, including for classes that involve universal bulk correlations of classes AI† and AII†, beyond the Ginibre ensembles. Imposing the physical constraint of Hermiticity- and trace-preservation through a Lindbladian evolution, the number of possible (superoperator) symmetry classes of the time-evolution generator is reduced. We show that simple (and experimentally realizable) examples of Lindbladians belong to a variety of non-Ginibre classes and discuss the universality of their correlations.

[13:30-14:30] Katja Klobas: ***Entanglement negativity and mutual information after a quantum quench: Exact link from space-time duality***

I will present recent results on the growth of entanglement between two adjacent regions in a tripartite, one-dimensional many-body system after a quantum quench. Combining a replica trick with a space-time duality transformation a universal relation between the entanglement negativity and Renyi-1/2 mutual information can be derived, which holds at times shorter than the sizes of all subsystems. The proof is directly applicable to any local quantum circuit, i.e. any lattice system in discrete time characterised by local interactions, irrespective of the nature of its dynamics. The derivation indicates that such a relation can be directly extended to any system where information spreads with a finite maximal velocity. The talk is based on a recent preprint arXiv:2203.17254.

[14:45-15:45] Marko Medenjak: TBA

To be announced.

Friday ($9^{00} - 15^{45}$)

[9:00-10:00] Marko Žnidarič: Non-Hermitian phantoms

Describing full unitary dynamics of a many-body system is difficult and also unpractical. Focusing on a coarse-grained dynamics, or few select smooth observables, often results in a more compact non-unitary evolution. Studying bipartite entanglement dynamics in random circuits one can derive a Markovian transfer matrix description that harbors rather intriguing many-body non-Hermitian physics. The speed of generating entanglement is not given by the 2nd largest eigenvalue of the transfer matrix, but rather by a phantom eigenvalue that is not in the spectrum of any finite transfer matrix. Resolution of this seeming paradox will involve a spectrum that is completely discontinuous in the thermodynamic limit. When dealing with finite non-Hermitian matrices it can turn out that being exact is actually wrong, while being slightly wrong is correct.

[10:00-11:00] Andrea De Luca: TBA

To be announced.

[11:30-12:30] Pieter Claeys: *Biunitary circuit dynamics and emergent quantum state designs*

Dual-unitary circuits have recently gained attention as a class of many-body models for which the dynamics is both chaotic and tractable. After a short introduction to dual-unitary circuit dynamics and the underlying space-time duality I will show how dual-unitary dynamics can be combined with specific measurement schemes without losing this underlying duality, leading to biunitary circuits encoding both classical and quantum information. As one application, I will discuss the emergence of quantum state designs, where following projective measurements on a bath an ensemble of states is obtained that becomes indistinguishable from the uniform Haar-random ensemble.

[13:30-14:30] Lenard Zadnik: *Semilocal Gibbs ensembles and nonequilibrium symmetry-protected topological order*

I will revisit the problem of nonequilibrium time evolution in 1D quantum systems after a global quench. Global symmetries such as the spin flip symmetry in spin-1/2 chains can invalidate the standard picture of local relaxation to a (generalised) Gibbs ensemble. This occurs in models whose Hamiltonians possess conservation laws that are not local but act as such in the symmetry-restricted space where time evolution occurs. Their effective locality is possible due to the occurence of a hidden symmetry breaking, which is related to the emergence of a symmetry-protected topological order. I will discuss the "semilocal (generalised) Gibbs ensembles" that describe the stationary states emerging after infinite time in such models. Their exceptional features include logarithmic scaling of the excess entropy of a spin block, triggered by a local perturbation in the initial state, and meltdown of the order, induced either by a weak symmetry breaking or by an increase of the temperature.

[14:45-15:45] Pavel Kos: *Thermalization dynamics and spectral statistics of extended systems with thermalizing boundaries*

In my talk, I will present the thermalization and spectral properties of extended systems connected, through their boundaries, to a thermalizing Markovian bath. Specifically, in our study we consider periodically driven systems modelled by brickwork quantum circuits where a finite section (block) of the circuit is constituted by arbitrary local unitary gates while its complement, which plays the role of the bath, is dual unitary. We show that the evolution of local observables and the spectral form factor are determined by the same quantum channel, which we use to characterize the system's dynamics and spectral properties. In particular, we identify a family of fine-tuned quantum circuits—which we call strongly nonergodic—that fails to thermalize. We provide a set of necessary conditions on the local quantum gates that lead to strong nonergodicity, and in the case of qubits, we provide a complete classification of strongly nonergodic circuits. We also study the opposite extreme case of circuits that are almost dual unitary, i.e., where thermalization occurs at the fastest possible rate. We show that, in these systems, local observables and spectral form factor approach, respectively, thermal values and random matrix theory prediction exponentially fast. We provide a perturbative characterization of the dynamics and, in particular, of the timescale for thermalization.