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Mini-Conference on
“Non-ergodicity & integrability”
of the programme “Quantum Paths”
May 28 – June 1, 2018
Abstracts

- **Monday, May 28, 2018**

  Kareljan Schoutens
  Many-body strategies for multi-qubit gates

  The standard method for implementing algorithms for quantum computation is through quantum circuits. Such circuits typically contain quantum gates involving more than a single or two qubits. Multi-qubit gates can be decomposed into 1- and 2-qubit gates, but this is not necessarily the most efficient strategy. We present a framework for quantum control directly at the level of multiple qubits. A key ingredient is what we call an eigengate: a simple quantum circuit that maps computational basis states to eigenstates of a many-body hamiltonian. We show how to make it all work for a Krawtchouk qubit chain, and for operators associated to a spin chain with inverse square exchange, first introduced by Polychronakos. Based on arXiv:1707.05144, Phys Rev A97.04232, with Koen Groenland

  Gabor Takacs
  Correlation functions of the quantum sine-Gordon model in and out of equilibrium

  Recent progress in cold-atom experiments simulating QFT models led to direct measurement of higher order correlations. I present a numerical approach to correlation functions of the quantum sine-Gordon model, building upon the so-called Truncated Conformal Space Approach, allowing to construct higher order correlations in a system of finite size in various physical states of experimental relevance, both in and out of equilibrium. Deviations from Gaussianity due to the presence of interaction are measured and their dependence on temperature is analysed, exhibiting the experimentally observed crossover between Gaussian and non-Gaussian regimes. We also studied dynamics after a quench, observing the effects of the interaction on the time evolution of correlation functions, their spatial dependence and their non-Gaussianity as measured by the kurtosis.

  Austen Lamacraft
  Operator Moments of Noisy Coupled Qubits and the Fredrickson–Andersen Model

  Random noise cooks a system of coupled qubits to infinite temperature. The dynamics of noise averages of operators displays diffusive behaviour or fast relaxation, depending on whether the drive conserves one of the spin components or not. However, this tells us nothing about the dynamics of entanglement or quantum chaos, which require at least the second moment of operators. We show that these are described by the Fredrickson–Andersen model, originally introduced as a model of cooperative relaxation near the glass transition, and discuss the consequences for operator spreading and impurity decay.

Maksym Serbyn

Probing ergodicity breaking with matrix elements

In many-body localized (MBL) phase strong disorder allows quantum systems to escape thermalization via emergence of extensive number of conserved quantities. Delocalization transition between MBL and ergodic phase which occurs upon decreasing disorder can provide a useful insights into workings of thermalization. In this talk I will use the matrix elements to probe the ergodicity breaking. Using statistics of matrix elements of local operators, I will show how one can locate the delocalization transition. In addition, energy structure of matrix elements will be used to reveal a wide critical region within the ergodic phase. In this region matrix elements show critical dependence on the energy difference and exhibit strong multifractality. Finally, by relating the properties of matrix elements to level statistics, I will present two-parameter level spacing distribution that governs the crossover between Wigner-Dyson and Poisson level statistics. Finally, I will discuss possible generalization of this picture to other examples of ergodicity breaking.

Neil Robinson

Nonthermal states in theories with confinement

Nicolo Defenu

Quantum anomaly and scaling dynamics in the 2D Fermi gas

A scale invariant system looks similar on different length scales. Usually this is realized only after some fine tuning, for instance near a phase transition or a scattering resonance. Remarkably, a classical gas in two dimensions is scale invariant for an arbitrary strength of contact interaction. This has striking consequences for its nonequilibrium scaling dynamics, in particular the breathing motion in a harmonic trapping potential.
For a two-dimensional fermionic quantum gas, instead, quantum fluctuations violate the classical scaling symmetry and give rise to a quantum anomaly. I will discuss the consequences of this scale anomaly and how it can be observed in the equation of state, the pairing properties, and the nonequilibrium scaling dynamics.

- **Tuesday, May 29, 2018**

Anna Minguzzi

Damping of Josephson oscillations in strongly correlated one-dimensional atomic gases

We study the Josephson oscillations of two strongly correlated one-dimensional bosonic clouds separated by a localized barrier. Using a quantum-Langevin approach and the exact Tonks-Girardeau solution in the impenetrable-boson limit, we determine the dynamical evolution of the particle-number imbalance, displaying an effective damping of the Josephson oscillations which depends on barrier height, interaction strength and temperature. We show that the damping originates from the quantum and thermal fluctuations intrinsically present in the strongly correlated gas. Thanks to the density-phase duality of the model, the same results apply to particle-current oscillations in a one-dimensional ring where a weak barrier couples different angular momentum states.

Victor Galitski

Quantum Lyapunov Exponents

Classical chaotic systems exhibit exponential divergence of initially infinitesimally close trajectories, which is characterized by the Lyapunov exponent. This sensitivity to initial conditions is popularly known as the butterfly effect. Of great recent interest has been to understand how/if the butterfly effect and Lyapunov exponents generalize to quantum mechanics, where the notion of a trajectory does not exist.

In this talk, I will introduce the measure of quantum chaoticity so called out-of-time-ordered four-point correlator (whose semiclassical limit reproduces classical Lyapunov growth), and use it to describe quantum chaotic dynamics and its eventual disappearance in the standard models of classical and quantum chaos Bunimovich billiard and standard map or kicked rotor. I will also mention our recent results on quantum Lyapunov exponent in interacting disordered metals, which exhibit an interaction-induced transition from quantum chaotic to non-chaotic dynamics, which may manifest itself in a sharp change of the distribution of energy levels from Wigner-Dyson to Poisson statistics.

Jacopo de Nardis

Large scale dynamics of an interacting 1d Bose gas: hydrodynamics, particle-hole excitations and non-equilibrium steady states

I will start with a review of the generalized hydrodynamic approach to compute the non-equilibrium dynamics of an interacting integrable system. This is a large scale hydrodynamic description of the classical motion of particle-hole excitations thorough the system. We will then see how the single particle-hole excitations can be used also to compute exactly the dynamical correlations at small momentum on any equilibrium state. Finally as an application of the method, I will show how the non-equilibrium steady state that emerges at the junction between two interacting gases at different temperatures or density is a strongly correlated state with divergent response functions and long range correlations.

Mario Collura

Order-parameter statistics out-of-equilibrium in many-body quantum system

At the base of quantum mechanics is the statistical nature of measurements: the result of measurements is indeed described by a probability distribution function (PDF), and measuring the same observable in identical systems will give different outcomes in accordance with this distribution. The PDF carries very detailed information about the system, going much beyond the simple average. I will focus on the non-equilibrium dynamics of a fully polarised antiferromagnetic state under the unitary evolution induced by the XXZ Hamiltonian. It turns out that, depending on the quantum phase whereto the post-quench Hamiltonian belongs, the PDF of the subsystem staggered magnetisation may retain informations about the original order, thus acquiring a shape much different from a simple Gaussian distribution. This has a simple explanation in terms of the distribution of the overlaps between the initial state and the eigenstate of the post-quench Hamiltonian.

Alessio Chiocchetta

Fluctuation-induced quantum Zeno effect

An isolated quantum gas with a local dissipative defect features a non-monotonic behaviour of the particle loss rate, which decreases when the strength of the dissipation exceeds a critical value. This manifestation of this quantum-Zeno-like effect has been recently shown in experiments with cold atomic gases. We investigate the effect of a local dissipative defect on a interacting one-dimensional fermionic system. We found that the low-energy properties are dramatically affected by the interaction: the loss rate of long-wavelength modes vanishes for an arbitrary strength of the dissipation. Remarkably, transport properties are found to be similar to the Kane-Fisher coherent impurity problem. We substantiate these findings using both a RG-resummed perturbation theory and a low-energy Luttinger liquid description.

Stefan Groha

Full counting statistics in the transverse field Ising model in and out of equilibrium

One of the basic principles of quantum mechanics is the statistical nature of measurements of observables. The result of measurements is described by a probability distribution and measuring the same observable in identical systems will give different outcomes in accordance with this distribution. The full probability distribution carries very detailed information about the system and on top of expectation value encodes all fluctuations of the system. The talk will focus on full probability distributions in the transverse field Ising model in and out of equilibrium.

- **Wednesday, May 30, 2018**

Maurizio Fagotti
Time evolution of the bipartite entanglement in interacting integrable systems

We consider the dynamics of the entanglement entropies of bipartitions after global quantum quenches. We review the behavior of the entropies in noninteracting models and present a revised semiclassical theory, which turns out to be fully predictive. We discuss the generalizations to interacting systems and present new results, both in homogeneous and in inhomogeneous settings.

Andrea de Luca
Solution of a minimal model for many-body quantum chaos

I will present a minimal model for quantum chaos in a spatially extended many-body system. It consists of a chain of sites with nearest-neighbour coupling under Floquet time evolution. Quantum states at each site span a q-dimensional Hilbert space and the time evolution is specified as a random circuit, which is random in space but periodic in time (Floquet). Each site is coupled via a random matrix to its neighbour on one side during the first half of the evolution period, and to its neighbour on the other side during the second half of the period. I will introduce a diagrammatic formalism useful to average the many-body dynamics over realisations of the random matrices. This approach leads to exact expressions in the large-q limit and sheds light on the universality of random matrices in many-body quantum systems and the ubiquitous entanglement growth in out-of-equilibrium dynamics. I will also discuss universal behaviour which goes beyond random matrix theory and the role played by space dimensionality which emerges through a mapping into the classical Potts model, exact at large q.

Laurens Vanderstraeteni
Quasiparticle Excitations with Tensor Network States

In the last decade tensor networks have become one of the main variational methods for studying strongly-correlated quantum lattice systems in low dimensions. In particular, they provide an efficient parametrization for the ground state of these systems directly in the thermodynamic limit. We show that the tensor-network language can be extended to describe the quasiparticle excitations on top of these ground states as well. This method has proven to work extremely well for one-dimensional systems, and we show that it can be generalized to two dimensions as well. As such, our results provide the first simulation of dynamical properties using projected entangled-pair states.

Eric Vernier
Out-equilibrium dynamics of quantum integrable models: What can we compute exactly?

While quantum integrability has proved extremely successful as a tool to study the properties of many-body quantum systems, its application out of equlibrium has remained very challenging. In this talk I will discuss to which extent quantum integrability can be used to compute exactly the out-of-equilbrium dynamics of physical observables after a quantum quench. I will present the ”boundary quantum transfer matrixconstruction (developed in collaboration with Lorenzo Piroli and Balzs Pozgay), and its application to computing the dynamics of the Loschmidt echo and of local observables. This construction calls for a classification of ïntegrable initial states”, which I will also discuss.

Elena Tartaglia
Entanglement and diagonal entropies after a quench with no pair structure

In the study of quantum quenches, one generally considers initial states that produce a distribution of quasiparticle excitations with an opposite-momentum-pair structure. In this talk, we discuss the dynamical and stationary properties of the entanglement entropy after a quench from initial states which do not have such structure: instead of pairs of excitations, they generate ν-plets of correlated excitations with $\nu > 2$. Looking at a system of non-interacting fermions on the lattice, we show that the standard semiclassical formula does not apply when prepared in such an initial state. We then propose a generalised picture which correctly describes the entanglement entropy evolution and perfectly matches the numerical data.

Alessio Lerose

Quantum many-body Kapitza phases of periodically driven spin systems

As realised by Kapitza long ago, a rigid pendulum can be stabilised upside down by periodically driving its suspension point with tuned amplitude and frequency. While this dynamical stabilisation is feasible in a variety of instances in systems with few degrees of freedom, it is natural to search for generalizations to multi-particle systems. In particular, a fundamental question is whether, by periodically driving a single parameter in a many-body system, one can stabilise an otherwise unstable phase of matter against all possible fluctuations of its microscopic degrees of freedom. In this work we show that such stabilisation occurs in experimentally realisable quantum many-body systems: a periodic modulation of a transverse magnetic field can make ferromagnetic spin systems with long-range interactions stably trapped around unstable paramagnetic configurations as well as in other unconventional dynamical phases with no equilibrium counterparts. These quantum Kapitza phases, characterized by a long lifetime, are within reach of current experiments.

Luca Lepori

Long-range topological insulators and weakened bulk-boundary correspondence

I describe the appearance of new types of insulators and superconductors, not included in the famous“tenfold way classification”, in fermionic quantum systems with long-range couplings. This study is relevant for the physics of some set-ups realized by trapped ions, superconductors with impurities on the edges, ultracold lattices.

- **Friday, June 1, 2018**

Vladimir Gritsev

Integrability for dynamics, topology and disorder

Title: Integrability for dynamics, topology and disorder. I will make an overview of our recent results in the field of integrable models: I will discuss integrable Floquet systems, integrable interacting disordered model and novel class of integrable 1D and Richardson-Gaudin systems.