Student Workshop on Integrability

Monday 16 June 2025 - Friday 20 June 2025

Book of Abstracts

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Quantum integrability and Gromov-Witten theory of elliptic curves

Author: Ishan Jaztar Singh[None]

Co-authors: Paolo Rossi [1]; Sergey Shadrin [2]

[1] *University of Padova*

[2] *University of Amsterdam*

The double ramification (DR) hierarchy, introduced by Buryak, is a Hamiltonian integrable hierarchy associated with Gromov-Witten (GW) theories and, more broadly, cohomological field theories. Building on Buryak-Rossi's quantization framework, which extends Kontsevich's deformation quantization, it is possible to construct a quantum DR hierarchy for GW theories. Notable examples include the quantum KdV and quantum Toda hierarchies, arising from the GW theories of a point and projective space, respectively.

In this work, we present our construction of the quantum DR hierarchy associated with the GW theory of elliptic curves, inspired by the foundational work of Okounkov and Pandharipande. Our approach leverages the holomorphic anomaly equation and quasimodularity techniques developed by Oberdieck and Pixton, extending them to address DR-type intersection numbers. Additionally, we incorporate recent advancements by Blot, Lewanski, and Shadrin on the DR/DZ equivalence conjecture to enrich our framework. This work provides new insights into the interplay between quasimodularity, quantum DR hierarchies, and elliptic curve GW theories.

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Exact quantum state preparation I

Author: Rafael Nepomechie[1]

[1] *University of Miami*

This course is an introduction to some approaches for exactly preparing multi-qubit states on a quantum computer. In Lecture 1, we begin with a brief review of quantum circuits; we then consider the GHZ state, and its preparation in constant depth. In Lecture 2, we introduce matrix product states and sequential state preparation; we consider the example of AKLT states, and their preparation in constant depth. In Lecture 3, we consider the preparation of Dicke states and Bethe states.

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Quantum non-equilibrium dynamics with classical determinist circuits I

Author: Katja Klobas[1]

[1] *University of Birmingham*

TBA

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Exact out-of-equilibrium dynamics with random unitary circuits I

Author: Andrea De Luca[1]

[1] *CY Cergy Paris Universite*

TBA

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Squeezed Ensembles and Anomalous Dynamic Roughening in Interacting Integrable Chains

Authors: Enej Ilievski[1]; Jacopo De Nardis[2]; Mario Guillaume Cecile[3]

[1] *University of Ljubljana*

[2] *CY Cergy Paris University*

[3] *University of Hamburg*

It is widely accepted that local subsystems in isolated integrable quantum systems equilibrate to generalized Gibbs ensembles. Here, we identify a particular class of initial states in interacting integrable models that evade canonical generalized thermalization. Particularly, we demonstrate that in the easy-axis regime of the quantum XXZ chain, pure nonequilibrium initial states that lack magnetic fluctuations instead locally relax to squeezed generalized Gibbs ensembles governed by nonlocal equilibrium Hamiltonians, representing exotic equilibrium states with subextensive charge fluctuations that violate the self-affine scaling. At the isotropic point, we find exceptional behavior and explicit dependence on the initial state. Particularly, we find that relaxation from the Néel state is governed by extensive fluctuations and a superdiffusive dynamical exponent compatible with the Kardar-Parisi-Zhang universality. On the other hand, there are other nonfluctuating initial states that display diffusive scaling, e.g., a product state of spin singlets. Our predictions provide examples of anomalous quantum transport and fluctuations in strictly quantum states which can be directly tested in state-of-the-art cold atomic experimental settings.

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Non-equilibrium dynamics in a periodically driven transverse field Ising chain

Author: Xiao Wang[1]

Co-authors: Jianda Wu [1]; Marton Kormos [2]; Masaki Oshikawa [3]

[1] *Tsung-Dao Lee Institute, Shanghai Jiao Tong University*

[2] *Budapest University of Technology and Economics*

[3] *The University of Tokyo*

In this talk, I will discuss the nonequilibrium dynamics in a quantum Ising chain where the transverse field slowly rotates. The corresponding magnetization oscillations are found to be non-thermalized and can be explained by contributions from different particle excitations in the quantum E_8 integrable model. For the details of the talk, firstly, I will provide a brief introduction to the quantum E_8 integrable model. Then, I will delve into the detailed composition of the time-dependent magnetizations based on quantum E_8 physics. Specifically, in the frequency domain, the magnetization spectrum reveals a series of singular peaks for the z (Ising) component. These singular peaks split

into two sets for the magnetization along the x and y directions, with frequency shifts determined by the rotational-field frequency. Finally, I will propose a Rydberg qubit array for potential experimental investigation.

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Integrable deformations of sigma models

Author: Eggon Viana Teixeira Galvão[None]

Integrability is a key property of certain field theories, typically characterized by an infinite number of conserved currents. It is a remarkable feature, since it allows us to explicitly compute exact solutions and observables. In general, integrability is a phenomenon that is confined to one or two-dimensional models. An example is the class of the 2D integrable sigma models. These are amongst a small class of interacting field theories that can potentially be solved exactly both classically and at the quantum level.

The canonical example is the Principal Chiral Model (PCM) defined on a group G. In a PCM, the fields are maps from a two-dimensional space Σ to a group G. One can also add a topological term to the PCM in order to construct another type of integrable sigma model, called Wess-Zumino-Witten (WZW). The integrability of the PCM and the WZW model is immediate, as in these cases one can follow a general procedure to construct an object called Lax connection, which can be used for constructing an infinite set of conserved charges.

It turns out that new integrable models can be derived by deforming the PCM and the WZW model in a systematic manner. These deformations allow us to investigate different portions of the space of integrable models.

In this presentation, I will provide an overview of integrable deformations of sigma models, with a particular focus on a specific class of deformations known as Yang-Baxter deformations. These are deformations of the PCM and are characterized by the presence of a Drinfeld-Jimbo R-matrix. The R-matrix satisfies the Classical Yang-Baxter (CYB) equation, which ensures the classical integrability of the model.

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New integrable deformations of principal chiral sigma models

Author: Eggon Viana Teixeira Galvão[None]

Integrability is a key property of certain field theories, often characterized by an infinite number of conserved currents. This feature enables the exact computation of solutions and observables. Typically, integrability is found in one- or two-dimensional models, such as 2D integrable sigma models. These models, among a small class of interacting field theories, can be solved exactly both classically and quantum mechanically. A canonical example is the Principal Chiral Model (PCM), a two-dimensional field theory where fields map from a two-dimensional space Σ to a group G. The PCM is integrable because it admits a Lax connection, leading to an infinite set of conserved charges.

Constructing deformations of PCM that preserve integrability allows us to explore different regions of integrable models. A notable deformation is the Yang-Baxter (YB) deformation, particularly the η-deformation—an inhomogeneous YB deformation of the PCM.

In this poster, I will outline the key features of η-deformations, including their integrability structure and applications. Moreover, I also discuss the eta-deformations of the PCM in the presence of spectators, which are eta-deformations when only a subgroup H of G is deformed, rather than the entire

group G. In this context, the fields taking values in the coset space G/H will not be affected by the deformation, playing the role of spectators. However, the dynamics of these spectator fields mix with those of fields involved in the deformation, resulting in a non-trivial, new integrable deformation of the PCM.

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Trans-series Solutions in the Lieb-Liniger Model

Author: Dennis le Plat[1]

[1] *Wigner Research Centre for Physics*

The Lieb-Liniger model is a fundamental example of an interacting integrable system, describing bosons in one dimension with point-like interactions. A key challenge in its study is solving the linear integral equations that govern the rapidity density and its moments. In this talk, I will present a trans-series approach to solving these equations, which systematically encodes both perturbative and non-perturbative effects. I will describe how to construct the trans-series from a perturbative basis obtained via ordinary differential equations and demonstrate its consistency with high-precision numerical results.

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Emergent Integrability: Quantum Quenches of Integrable Systems Beyond the Euler Scaling Limit

Authors: Evgeny Polyakov[1]; Khristina Albitskya[1]

[1] *Russian Quantum Center*

Novel approach to integrable one-dimensional many-body systems with or without interactions is Generalized Hydrodynamics (GHD). According to GHD, excitations in the system can be described by quasi particles. The key postulate of the GHD is the assumption of a mesoscopic scale for time and space (fluid cells) which state maximizes local entropy. GHD provides evolution of the system over large temporal and spatial scales (Euler scaling limit), gives local observables within this regime.
However, the theory currently lacks a comprehensive explanation of the thermalization process and does not show the power law of relaxation of local observables in integrable systems.
We propose a method to address these gaps using our concept of emerging integrals of motion.

To demonstrate this, we consider a two-part model ("bipartitioning protocol"). Each part consists of a one-dimensional, semi-infinite Hubbard chain without interaction ($U = 0$). It is a reservoir (Fermi sea) filled with non-interacting fermions. The difference in the Fermi levels between the two parts represents the voltage before a quantum quench.
We focus on the system's evolution after the hopping interaction between the two parts is activated (quantum quench).

At the junction between the two parts, we investigate the local degree of freedom. Due to the interaction with the electrodes, the local observable of the quantum contact is "dressed" by excitations from the electrodes - by several degrees of freedom with which they significant interact - analogous to fluid cells in our framework. Occasionally, we observe the emergence of decoupled quasi-particles, that do not interact with the local observable of the quantum contact. These quasi-particles concern to conserving quantum numbers, which we term "emerging integrals of motion".

Our primary interest lies in determining the regime in which the density matrix of dressed local observables undergoes thermalization, thereby maximizing local entropy.
This insight could provide a microscopic

proof of the relaxation mechanism - the key postulates of the GHD.
Furthermore, we provide phase-space picture of since GHD is also formulated in phase space, we also plan to calculate the Wigner functions to demonstrate the evolution of the system.

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Exploring 9x9 Integrable Hermitian Hamiltonians via the Boost Operator Method

Author: Ysla França Adans[1]

Co-author: ANA RETORE

[1] *Institute of Theoretical Physics —IFT/UNESP - Brazil*

Quantum integrable models possess a sufficiently large number of conserved quantities in involution. As a result, these models often admit mathematical methods that enable the construction of exact solutions, even in the presence of complex physical properties such as nonlinearity and dispersion. Consequently, they are of great interest across various areas of theoretical and mathematical physics. In this context, the discovery and classification of new integrable models constitute a significant and active research field.

Among the various approaches, the Boost Operator Method is a novel technique used to identify integrable spin chain models. The core of this method lies in finding the R-matrix, the mathematical entity that characterizes integrable models, associated with a given Hamiltonian. This is achieved by employing an operator capable of generating the hierarchy of conserved charges starting from the Hamiltonian.

In this work, we discuss this method and present results concerning the classification of 9×9 Hermitian Hamiltonian models. These models can be physically interpreted as a system with two-site interactions, where each site can occupy three distinct states. Considering the basis $\mathcal{V} = \{|0>, |->, |+>\}$, the states $|\pm>$ represent the presence of a particle at a site, while $|0>$ denotes an empty site, leading to a 9×9 Hamiltonian matrix. The imposed Hermitian condition ensures a real energy spectrum.

Specifically, we analyze a model that allows for the creation and annihilation of $|->$ particles at the sites, in addition to particle swapping, resulting in a 29-vertex Hermitian Hamiltonian model. Through this classification, we identify a new family of integrable models.

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Bethe Ansatz, Quantum Circuits, and the F-basis

Authors: Roberto Ruiz[1]; Alejandro Sopena[2]; Balázs Pozsgay[3]; Esperanza López[1]; Germán Sierra[4]

[1] *Instituto de Física Teórica*

[2] *Quantum Research Centre, Technology Innovation Institute*

[3] *Eötvös Loránd University*

[4] *Instituto de Fisica Teorica, UAM/CSIC*

We present a systematic approach to unitarise the Bethe Ansatz, enabling the construction of quantum circuits that exactly prepare eigenstates of a class of integrable models. The key step is a change of basis in the auxiliary space of the algebraic Bethe Ansatz to the 'F-basis', known from the theory of integrable models. The F-basis, which ensures symmetry under exchange of auxiliary qubits, connects the algebraic and coordinate Bethe Ansatz and renders the plane-wave superpositions of the latter explicit. The exchange symmetry is central to both the exact computation of the circuit unitaries

and the rigorous elimination of post-selection. We illustrate the framework with new quantum circuits for the inhomogeneous spin-1/2 XXZ model. This work is based on [arXiv:2411.02519].

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Confinement and false vacuum decay on the Potts quantum spin chain

Author: Anna Krasznai[1]

Co-author: Gábor Takács [1]

[1] *Budapest University of Technology and Economics*

Confinement is a central concept in the theory of strong interactions, which leads to the absence of quarks (and gluons) from the spectrum of experimentally observed particles. The underlying mechanism is based on a linear potential, which can also be realised in condensed matter systems. A one-dimensional example with a great analogy to quantum chromodynamics is the mixed-field three-state Potts quantum spin chain in the ferromagnetic regime. Compared to the analogous setting for the Ising spin chain, the Potts model has a much richer phenomenology and non-equilibrium dynamics, which originates partly from baryonic excitations in the spectrum and partly from the various possible relative alignments of the initial magnetisation and the longitudinal field in a global quantum quench. In my presentation, I will discuss how we obtain the low-lying excitation spectrum by combining semi-classical approximation and exact diagonalisation, and how the results can be applied to explain the various dynamical behaviours we observe in numerical simulations. Besides recovering dynamical confinement, as well as Wannier-Stark localisation due to Bloch oscillations similar to the Ising chain, a novel feature is the presence of baryonic excitations in the quench spectroscopy. In addition, when the initial magnetisation and the longitudinal field are misaligned, both confinement and Bloch oscillations only result in partial localisation, with some correlations retaining an unsuppressed light-cone behaviour together with a corresponding growth of entanglement entropy.

Reference:

[1] O. Pomponio, A. Krasznai and G. Takács, "Confinement and false vacuum decay on the Potts quantum spin chain,"Scipost Phys. 18 (2025) 082

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Quench dynamics of entanglement from crosscap states

Authors: Colin Rylands[1]; Konstantinos Chalas[2]; Pasquale Calabrese[1]

[1] *SISSA*

[2] *SISSA, Trieste*

The linear growth of entanglement after a quench from a state with short-range correlations is a universal feature of many body dynamics.
It has been shown to occur in integrable and chaotic systems undergoing either Hamiltonian, Floquet or circuit dynamics and has also been observed in experiments.
The entanglement dynamics emerging from long-range correlated states is far less studied, although no less viable using modern quantum simulation experiments.
In this talk, I will present the dynamics of the bipartite entanglement entropy and mutual information in quenches starting from \textit{crosscap states}, a class of states constructed by entangling antipodal points of a finite and periodic system.

We consider the evolution of these initial states, in integrable and chaotic systems for both brickwork quantum circuits and Hamiltonian dynamics.
Specifically, I will show the different patterns of behaviors that we observe in dual unitary and random unitary quantum circuits, as well as free and interacting fermion Hamiltonians, which are explained by a modified membrane picture for the former case and a quasiparticle picture that can be derived explicitly for the latter.
For chaotic systems we have constant maximal entanglement entropy, whereas for integrable systems after an initial time delay we have a linear decrease followed by a series of revivals.
Mutual information is linearly decreasing from its initial maximal value in both cases, vanishing for chaotic, while exhibiting revivals for integrable systems.

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Transport in two-species fermionic system on a lattice with anticorrelated disorder

Authors: Lolita Knyazeva[1]; Vladimir Yudson[2]

[1] *Moscow Institute of Physics and Technology, Russian Quantum Center*

[2] *HSE University, Russian Quantum Center*

In our work, we consider a two-component fermionic system on a lattice with anticorrelated disorder. Due to the locality of interspecies attractive interaction, it turns out that the disorder for composite pairs is supressed. This makes the transport of pairs to be possible. Within our study, we investigate the temperature dependence of particle 'conductivity'.

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R-matrix valued Lax pair for elliptic Calogero systems and the associative Yang-Baxter equation

Author: Maria Matushko[1]

[1] *Steklov Mathematical Institute of RAS*

The rational Calogero-Sutherland-Moser model is originally a system of identical particles scattering on the line with inverse-square potential. There are also trigonometric, hyperbolic and elliptic version of this model. The integrability of the model follows from the presence of a Lax pair.

The Calogero system of type A admits the so-called R-matrix Lax pair presentation, the matrix elements are expressed in terms of the quantum GL_N Baxter-Belavin elliptic R-matrices. For $N = 1$ this construction reproduces the Krichever's Lax pair with spectral parameter. The equations of motion follow from the associative Yang-Baxter equation for the elliptic Baxter-Belavin R-matrix.

I will tell how to extend the Kirillov's B-type associative Yang-Baxter equations to the similar relations depending on the spectral parameters and to construct an R-matrix valued for the Calogero-Inozemtsev of BC_n type. General construction uses the elliptic Shibukawa-Ueno R-operator and the Komori-Hikami K-operators satisfying reflection equation. Then, using the Felder-Pasquier construction the answer for the Lax pair is also written in terms of the elliptic Baxter-Belavin R-matrix.

The talk is based on the joint work with Andrei Zotov and Artem Mostovskii arXiv:2503.22659

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Frustration, lattice gauge theories and order-by-disorder in quantum plaquette models with linear and nonlinear constraints

Author: Konstantinos Sfairopoulos[1]

[1] *University of Nottingham*

We present results from plaquette models with ground states coming from both linear and nonlinear constraint rules. For the linear case, we study the triangular plaquette spin model, which we also study in the presence of an external longitudinal magnetic field. For the latter case, we study spin models whose ground state constraints come from nonlinear elementary cellular automaton rules. We present evidence that indicates that these quantum models, when in the presence of a transverse field term, show first-order quantum phase transitions. We discuss implications of their phase diagram regarding effects of frustration, magnetization plateaus, order-by-disorder, lattice gauge theories, Rydberg models and quantum trimers.

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Form factor bootstrap in the thermally perturbed tricritical Ising model

Authors: Bence Fitos[1]; Gábor Takács[1]

[1] *Budapest University of Technology and Economics*

We derive a systematic construction for form factors of relevant fields in the thermal perturbation of the tricritical Ising model, an integrable model with scattering amplitudes described by the E_7 bootstrap. We find a new type of recursive structure encoding the information in the bound state fusion structure, which fully determines the form factors of the perturbing field and the order/disorder fields. Knowledge of these form factors enables the systematic computation of correlation functions and dynamical structure factors in systems whose dynamics is governed by the vicinity of a fixed point in the tricritical Ising universality class.

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Probing Large Deviations in Accelerated TASEP: Bethe Ansatz, Cassini Ovals, and Spectral Gaps

Author: Anastasiia Trofimova[1]

Co-author: Lu Xu [1]

[1] *Grand Sasso Science Institute*

In this talk, I will discuss how to study the probabilities of observing unusually large or small particle currents in the context of the totally asymmetric simple exclusion process (TASEP) on a ring. To do this, we will revisit the large deviation function derived in a seminal paper by Derrida and Lebowitz (Phys.Rev.Lett.80,209(1998). We adapt their approach for the TASEP with accelerated rates.

In this scenario, we discover that the matrix operator governing the evolution of a particle current can also be diagonalized by Bethe ansatz techniques. We find the fascinating structure of Bethe solutions, lying on Cassini ovals, and use it to determine the largest eigenvalue, the spectral gap of the evolution matrix and, therefore characterise convergence properties at large times.

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The Hidden Symmetries of Yang-Mills Theory in (3 + 1)-dimensions

Authors: Henrique Malavazzi[None]; Luiz Agostinho Ferreira[1]

[1] *University of Sao Paulo*

This work explores novel hidden symmetries within (3+1)-dimensional Yang-Mills theories, uncovering structures that parallel the integrable systems typically seen in lower dimensions. By formulating the classical Yang-Mills equations as integral equations over generalized loop spaces, we reveal a flat connection and an infinite set of conserved, gauge-invariant charges. These charges, unlike energy and momentum, live in the space of non-abelian electric and magnetic charges and exhibit a fundamental Poisson bracket structure with an associated R-matrix. The theory exhibits a hidden, non-Lie infinite-dimensional symmetry group in loop spaces, hinting at a new framework for integrability in higher-dimensional field theories. Our results also consist in two classes of symmetries: one generated by conserved charges via Poisson brackets, and another as gauge-like transformations of the integral equations themselves. These findings suggest a profound hidden structure within Yang-Mills theories, possibly contributing to non-perturbative analysis in quantum chromodynamics and related models

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Subleading Regge trajectories in $\mathcal{N} = 4$ SYM

Author: Joseph Ventura Kieninger[1]

[1] *Humboldt Universität zu Berlin*

This poster presents a novel class of subleading Regge trajectories (with non-orthogonal intercepts) in $\mathcal{N} = 4$ SYM using the Quantum Spectral Curve (QSC), an integrability-based technique. I show how the standard application of the QSC, valid for leading trajectories, fails for the examined cases, and propose some crucial modifications to the method, which pass non-trivial consistency checks and are backed up by numerical data.
The studied trajectories appear in both twist-two and higher-twist operator families, and could be an important stepping stone for an identification of the Odderon intercept in $\mathcal{N} = 4$ SYM, which has not been done conclusively using resummation techniques.

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Entanglement dynamics and Page curves in random permutation circuits

Authors: David Szasz-Schagrin[1]; Michele Mazzoni[1]

Co-authors: Bruno Bertini [2]; Katja Klobas [2]; Lorenzo Piroli [1]

[1] *University of Bologna*

[2] *University of Birmingham*

The characterization of ensembles of random states over many qubits and their realization by quantum circuits are important tasks in quantum-information theory. In this work, we study ensembles of states generated by quantum circuits that randomly permute the computational basis, thus acting classically on the corresponding states. We focus on the averaged entanglement and present two

main results . First, we derive generically tight upper bounds on the entanglement that can be generated applying permutation circuits to arbitrary initial states. Notably, we show that the late-time "entanglement Page curves" are bounded in terms of the initial state participation entropies and its overlap with the "maximally antilocalized" state. Second, starting from simple N-qubit states, we compare the averaged Rényi-2 entropies generated by (i) an infinitely deep random circuit of two-qubit gates and (ii) global random permutations. Interestingly, we show that the two quantities are different for finite N, but the corresponding Page curves coincide in the thermodynamic limit. We also discuss how our conclusions are modified by additional random phases or considering circuits of k-local gates, with $k \geq 3$. Our results, which are based on analytic computations, expand the known phenomenology of random unitary circuits and highlight the implications of classical features on entanglement generation in many-body systems.

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Long-range nonstabilizerness and phases of matter

Author: David Korbany[1]

Co-authors: Lorenzo Piroli [1]; Michael Gullans [2]

[1] *University of Bologna*

[2] *Joint Center for Quantum Information and Computer Science, University of Maryland and NIST*

In this talk, we will discuss [arxiv:2502.19504]: Long-range nonstabilizerness can be defined as the amount of nonstabilizerness which cannot be removed by shallow local quantum circuits (QCs). We study long-range nonstabilizerness in the context of many-body quantum physics, a task with possible implications for quantum-state preparation protocols and implementation of quantum-error correcting codes. After presenting a simple argument showing that long-range nonstabilizerness is a generic property of many-body states, we restrict to the class of ground states of gapped local Hamiltonians. We focus on one dimensional systems and present rigorous results in the context of translation-invariant matrix product states (MPSs). By analyzing the fixed points of the MPS renormalization-group flow, we provide a sufficient condition for long-range nonstabilizerness, which depends entirely on the local MPS tensors. Physically, our condition captures the fact that the mutual information between distant regions of stabilizer fixed points is quantized, and this fact is not changed after applying shallow quantum circuits. We also discuss possible ramifications in the classification of phases of matter and quantum error correction. An introduction to the mathematical tools, stabilizer states, MPS fixed points, shallow QCs and phases of matter, will be provided.

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Topological phases protected by $Z_N^{\otimes 3}$ symmetry

Author: Hrant Topchyan[1]

[1] *Yerevan Physics Institute (AANL)*

One of the more recent concepts in condensed matter theory are symmetry-protected topological (SPT) phases. Although the core of the theory exists, particular models as well as models outside the basic paradigm are not studied well yet. Here we study the topological modes protected by the $Z_N^{\otimes 3}$ symmetries in two-dimensional systems. A class of models with massless excitations emerges. By analyzing their properties, the objective is to determine the conformal field theory describing their thermodynamic limit. Further analysis shows signs of integrability. The emergent operator algebra produces the R-matrix resembling the 8-vertex model. Numerical analysis also supports the possibility of integrability.

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Dynamical quantum phase transitions on random networks

Author: Tomohiro Hashizume[1]

Co-authors: Felix Herbort [2]; Joseph Tindall [3]; Dieter Jaksch [2]

[1] *CUI and University of Hamburg*

[2] *University of Hamburg*

[3] *Flatiron Institute*

We investigate dynamical quantum phase transitions (DQPTs) in the transverse field Ising model on ensembles of random Erdős-Rényi networks of size N. We analytically show that dynamical critical points are independent of the edge generation probability p, and matches that of the integrable fully connected network ($p = 1$). This is due to the $O(N^{-1/2})$ bound on the overlap between the wave function after a quench and the wave function of the fully connected network after the same quench. For a DQPT defined by the rate function of the Loschmidt echo, we find that it deviates from the $p = 1$ limit near vanishing points of the echo. Our analysis suggests that this divergence arises from persistent non-trivial global many-body correlations absent in the $p = 1$ limit.

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Circuits as a simple platform for the emergence of hydrodynamics in deterministic chaotic many-body systems

Author: Sun Woo P. Kim[1]

Co-authors: Friedrich Hübner [1]; Juan P. Garrahan [2]; Benjamin Doyon [1]

[1] *King's College London*

[2] *University of Nottingham*

The emergence of hydrodynamics is one of the deepest phenomena in many-body systems. Arguably, the hydrodynamic equations are also the most important tools for predicting large-scale behaviour. Understanding how such equations emerge from microscopic deterministic dynamics is a century-old problem, despite recent progress in fine-tuned integrable systems. Due to the universality of hydrodynamics, the specific microscopic implementation should not matter. Here, we show that classical deterministic circuits provide a minimal, exact, and efficient platform that admits non-trivial hydrodynamic behaviour for deterministic but chaotic systems. By developing new techniques and focusing on 1D circuits as a proof of concept, we obtain the characteristic dynamics, including relaxation to Gibbs states, exact Euler equations, shocks, diffusion, and exact KPZ superdiffusion. Our methods can be easily generalised to higher dimensions or quantum circuits.

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Generalised BBGKY hierarchy for near-integrable dynamics

Author: Leonardo Biagetti[1]

Co-authors: Jacopo De Nardis [2]; Maciej Lebek [3]; Milosz Panfil [3]

[1] *CY Cergy paris University*

[2] *CY Cergy Paris University*

[3] *University of Warsaw*

We consider quantum or classical many-body Hamiltonian systems characterized by integrable contact interactions supplemented by a generic two-body potential, potentially long-range. We show how the hydrodynamics of local observables is given in terms of a generalised version of Bogoliubov–Born–Green–Kirkwood–Yvon
hierarchy, which we denote as gBBGKY, which is built for the
densities, and their correlations, of the quasiparticles of the underlying integrable model. Unlike the usual cases of perturbation theory from free gases, the presence of local interactions in the integrable
model "lifts"the so-called kinetic blocking, presenting thermalization time scales quadratic in the perturbing potential.
In particular, we check our results with exact molecular dynamics simulations for the perturbed Hard rod gas, finding convincing agreement.
Unlike previous approaches based on Fermi's golden rule and matrix elements, the
gBBGKY allows one to directly access the late time scattering integrals and the time evolution of multi-point
correlations in generic perturbed integrable models at hydrodynamic length and time scales.
It can be also applied to systems on a lattice such as long-range spin chains or fermionic systems as first experimentally driven examples.
Finally, we show how it can be straightforwardly extended to interacting multi-tubes systems, already implemented in cold-atoms experiments.

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Sine-Gordon model at finite temperature: the method of random surfaces

Author: Miklós Tóth[1]

Co-authors: Dávid Szász-Schagrin [2]; Gábor Takács [1]; Jedediah Pixley [3]; Márton Kormos [1]

[1] *Budapest University of Technology and Economics*

[2] *University of Bologna*

[3] *Rutgers University*

The sine-Gordon theory is a paradigmatic integrable field theory, relevant for the description of many 1D gapped systems. Despite its integrable nature, calculating finite temperature physical quantities, such as correlation functions, remains a challenge. The titular method of random surfaces is a Monte Carlo-based numerical algorithm that makes it possible to get non-perturbative results at finite temperature.

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The role of radiation in Toda chain hydrodynamics

Authors: Alberto Brollo[1]; Herbert Spohn[2]

[1] *Technical University Munich*

[2] *TUM Math departments*

From a many-body perspective, classical integrable systems fall into two broad categories: fluids and chains. The former are particle-based and their hydrodynamics closely mirrors that of quantum models. Chain systems, on the other hand, behave like integrable wave equations, with their long-time dynamics separating into solitons and dispersive radiation. While soliton gases are relatively well understood, they generally don't represent thermodynamic ensembles, and the role of radiation in GGEs remains an open question.

We focus on the Toda chain, whose inverse scattering spectrum includes both a solitonic mode and radiation. Using tools from random matrix theory, we compute average scattering data for random initial conditions. Radiation appears in generic GGEs, paving the way toward a coupled soliton–radiation hydrodynamic description.

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Complete Minimal Form Factors for Irrelevant Deformations of Integrable Quantum Field Theory

Author: Fabio Sailis[1]

[1] *City St George, University of London*

I will introduce a method to compute the minimal form factors of diagonal integrable field theories perturbed by generalized $T\bar{T}$-perturbations that is going to appear in the next few months in a new paper with O. Castro-Alvaredo and S. Negro. Building on our previous results, these MFFs are constructed in such a way as to not allow for any free parameters, an issue that plagued previous solutions. The MFFs are derived from a generalization of the standard integral representation which has been used since the birth of the form factor bootstrap program. Their asymptotics is characterized by exponential decay at large rapidities. By computing higher particle form factors we find that any natural higher particle solutions involve the cancellation of parts of the newly found MFF. We conclude that the assumption that the form factor equations, particularly the kinematic residue equation, remain unchanged in the presence of $T\bar{T}$-perturbations, is too strong. There is a tradeoff between having MFFs satisfying desirable analyticity and asymptotic properties and finding analytic solutions to the form factor equations, which is likely solved by non-trivial changes to the form factor equations, especially those where locality or semi-locality of fields are essential assumptions.

Poster / **32**

Higher order tacnodes in a free fermionic model

Authors: Andrea Maroncelli[1]; Jean-Marie Stéphan[2]

[1] *INFN Firenze*

[2] *ENS de Lyon*

We investigate a free fermion model with nearest and next-nearest neighbor hopping, evolving in imaginary time from a product state with N consecutive fermions, and conditioned to go back to the same state after a given time. In the case of nearest neighbor hoppings, this model is known to give rise to limit shapes and arctic curves for large time and fermion number, with in particular two fluctuating regions which can be tuned to merge depending on ratio between time and N. Fluctuations near the merger are governed by a so-called tacnode kernel. In this paper we study the analogous picture in the presence of a next nearest interactions. In particular, we discuss the limit shapes, and compute analytically the corresponding density profile. We also study the behavior of correlations close to the merger point, and find a novel higher order tacnode kernel governing them.

Poster / **33**

Quench dynamics of entanglement from crosscap states

Authors: Colin Rylands[1]; Konstantinos Chalas[2]; Pasquale Calabrese[1]

[1] *SISSA*

[2] *SISSA, Trieste*

The linear growth of entanglement after a quench from a state with short-range correlations is a universal feature of many body dynamics.
It has been shown to occur in integrable and chaotic systems undergoing either Hamiltonian, Floquet or circuit dynamics and has also been observed in experiments.
The entanglement dynamics emerging from long-range correlated states is far less studied, although no less viable using modern quantum simulation experiments.
In this talk, I will present the dynamics of the bipartite entanglement entropy and mutual information in quenches starting from crosscap states, a class of states constructed by entangling antipodal points of a finite and periodic system.
We consider the evolution of these initial states, in integrable and chaotic systems for both brickwork quantum circuits and Hamiltonian dynamics.
Specifically, I will show the different patterns of behaviors that we observe in dual unitary and random unitary quantum circuits, as well as free and interacting fermion Hamiltonians, which are explained by a modified membrane picture for the former case and a quasiparticle picture that can be derived explicitly for the latter.
For chaotic systems we have constant maximal entanglement entropy, whereas for integrable systems after an initial time delay we have a linear decrease followed by a series of revivals.
Mutual information is linearly decreasing from its initial maximal value in both cases, vanishing for chaotic, while exhibiting revivals for integrable systems.

Poster / **34**

Generalised hydrodynamics of optical soliton gases: measurement of correlations

Author: Elias CHARNAY[1]

Co-authors: Adrien Escoubet ; Alvise Bastianello ; Thibault Bonnemain ; Benjamin Doyon ; Stéphane Randoux ; François Copie ; Pierre Suret

[1] *University of Lille*

Generalised Hydrodynamics (GHD) has proven successful to describe thermodynamics and hydrodynamics of integrable systems (See see Castro-Alvaredo, O. et al. Phys. Rev. X 6, 041065 (2016)). These systems present infinitely many constants of motion in involution and thus do not relax to a classical Gibbs Ensemble, but to a Generalised Gibbs Ensemble (GGE), taking into account all these constraints. GHD predicts the existence of ballistic two-point space-time correlations for the infinitely many conserved quantities of integrable systems. In particular, the mass $N = \int$
$lvert\psi(x,t)$
$rvert^2\,\mathrm{d}x$ in the focusing (attractive) Nonlinear Schrödinger Equation (fNLS) is conserved and its connected correlation at large scale takes the form:

```
\begin{equation}
t \,C(x, t) = t \, \langle\lvert\psi(x, t)\rvert^2\, \lvert\psi(0,0)\rvert^2\rangle_c = \int \,\textrm{d} \Re\eta\,\textrm{d}\Im\eta\
\delta(x/t - v^{\textrm{eff}}(\eta))\,\rho(\eta) \left(4\Im(\eta)^{\textrm{dr}}\right)^2
\end{equation}
```

where η refers to the complex eigenvalue of the Inverse Scattering Transform (or Bethe Ansatz) in fNLS, ρ is the density of state, v^{eff} the effective velocity of solitons, dr the dressing operator (see Koch, R. et al. Phys. A : Math. Theor. 55, 134001 (2022)). Solitons, as quasi-particles, propagate without changing their shape nor spectral parameters and with an effective velocity due to elastic collisions, giving these ballistic properties.

We present here our experimental results in a recirculating optical fibre loop (see Kraych A.E. et al. Phys. Rev. Lett. 122, 054101 (2019)) allowing measurements of these hydrodynamic correlations and of the density of state. The setup enables the propagation of arbitrary initial condition without much losses. At each roundtrip, the signal propagates inside \SI{5}{km} of standard optical fibre where losses are compensated globally by Raman amplification. We then extract 10% of this light to reconstruct the full field space-time dynamics through a heterodyne measurement system. Computing the intensity correlations naturally follows the reconstruction. We show that $C(x,t)$ does follow a polynomial law in $1/t$ with a coefficient that can be computed numerically from the previous formula.

With the same system, we explore other proofs that soliton gases relax to a GGE. In particular, it was predicted in [Bonnemain, T., Doyon, B. & El, G., J. Phys. A: Math. Theor.55 (2022)] that, because of the collisions, the gas undergoes an asymptotic change of metric: the solitons inside the gas perceives a different space than if they propagated freely. We show preliminary measurements of a soliton gas' asymptotic length.

Poster / 35

Long-time and large-distance asymptotics of Fredholm determinant representations of correlation functions at finite temperature

Author: Mikhail Minin[1]

[1] *Bergische Universität Wuppertal*

The study of correlation functions of integrable models at their free fermion points often leads to expressions involving Fredholm determinants of integrable integral operators. This occurs, for example, in dynamical two-point correlation functions of the impenetrable Bose gas, the XY and XX spin chains at finite temperature. In this talk, we address the problem of obtaining the long-time and large-distance asymptotics of Fredholm determinants of this type, using Riemann–Hilbert techniques. We present the asymptotic analysis in detail in a generalized setting and apply the resulting asymptotic expansion explicitly to the field–field correlation function of the impenetrable Bose gas. This talk is based on joint work with Frank Göhmann and Karol Kozlowski.

Poster / 36

Symmetry breaking in chaotic many-body quantum systems at finite temperature

Authors: Angelo Russotto[1]; Filiberto Ares[1]; Pasquale Calabrese[1]

[1] *SISSA*

Recent work [1] has shown that the entanglement of finite-temperature eigenstates in chaotic quantum many-body local Hamiltonians can be accurately described by an ensemble of random states with an internal U(1) symmetry. In this talk, I will discuss our recent work [2], where we develop this framework to investigate the universal symmetry-breaking properties of such eigenstates. As a probe of symmetry breaking, we employ the entanglement asymmetry, a quantum information observable that quantifies the extent to which symmetry is broken in a subsystem. This measure enables us to explore the finer structure of finite-temperature eigenstates in terms of the U(1)-symmetric random state ensemble. I will present the derivation of universal analytical predictions for the symmetric random states. These results show a remarkable agreement with exact numerical data across various locally interacting chaotic spin models.

[1] C. M. Langlett, C. Jonay, V. Khemani, and J. F. Rodriguez-Nieva, Quantum chaos at finite temperature in local spin Hamiltonians, arXiv:2501.13164.
[2] A. Russotto, F. Ares, and P. Calabrese, Symmetry breaking in chaotic many-body quantum systems at finite temperature, arXiv:2504.06146.

Poster / **37**

Breaking local symmetries with locality-preserving operations

Authors: Michele Mazzoni[1]; Luca Capizzi[2]; Lorenzo Piroli[1]

[1] *University of Bologna*

[2] *Université Paris-Saclay, CNRS, LPTMS*

While in the general framework of quantum resource theories one typically only distinguishes between operations that can or cannot generate the resource of interest, in a many-body setting one can further characterize quantum operations based on underlying geometrical constraints. For instance, a natural question is to understand the power of resource-generating operations that preserve locality and causality. In this work, we address this question within the resource theory of asymmetry, which has recently found applications in the study of symmetry breaking phenomena in many-body physics. We focus on symmetries corresponding to a compact group G with a local action on the space of N qubits, and study the so-called G-asymmetry and its linearized version, ℓ_G. We present two main results. First, we derive a general bound on the asymmetry that can be generated by locality-preserving operations acting on symmetric product states, showing in particular that $\ell_G = O(\sqrt{N})$. Second, we show that locality-preserving operations can generate maximal asymmetry, $\ell_G \sim N$, when applied to symmetric states featuring long-range entanglement. Our results provide a unified perspective on recent studies of asymmetry in many-body physics, highlighting a non-trivial interplay between asymmetry, locality, and entanglement.

Poster / **38**

Entanglement Hamiltonian and orthogonal polynomials

Authors: Pierre-Antoine Bernard[1]; Riccarda Bonsignori[2]; Viktor Eisler[2]; Gilles Parez[3]; Luc Vinet[1]

[1] *Centre de Recherches Mathematiques (CRM), Universite de Montreal*

[2] *TU Graz*

[3] *LAPTh, Universite Savoie Mont Blanc, Annecy*

The entanglement Hamiltonian, defined as the logarithm of the reduced density matrix, is a central concept in many-body quantum physics, since it provides a full characterisation of the entanglement of a quantum state. In this seminar, I will present the results for the EH of free-fermion chains with a particular form of inhomogeneity, namely the hopping amplitudes and chemical potentials are chosen such that the single particle eigenstates are related to discrete orthogonal polynomials of the Askey scheme. The bispectral properties of these functions allow the construction of an operator which commutes exactly with the EH. We show that for these systems the commuting operators have the form of a spatial deformation of the physical Hamiltonian, with a deformation term identified as the local inverse temperature derived from a CFT treatment of the problem in the continuum limit. This result allows to obtain a very good approximation of the entanglement spectrum and entropy, using the properly rescaled eigenvalues of the commuting operator.

Participants Talks / **39**

Lie Symmetries and Bi-Hamiltonian structures of the Pais-Uhlenbeck Oscillator

Authors: Alexander Felski[1]; Andreas Fring[2]; Bethan Turner[2]; Takanoa Taira[3]

[1] *Max Planck Institute for the Science of Light*

[2] *City St Georges University of London*

[3] *Kyushu University*

The Lie symmetries of the Pais-Uhlenbeck Oscillator (PUO) are identified. They are then used to generate the Bi-Hamiltonian structure of this system. We then study how we might leverage this Bi-Hamiltonian
structure to mitigate the pathologies associated with theories where, as in the case of the PUO, the lagrangian admits time derivatives of order two or higher. Theories of this nature are usually thought to admit classical Hamiltonians that are unbounded from below, and either unbounded energy eigenvalue spectra or negative norm ”ghost”states at the quantum level. For this reason they are often generally referred to as ”ghost ridden”. However the appearance of a Bi-Hamiltonian structure can be shown to allow for the generation of positive definite Hamiltonians with appropriate symplectic structure in the case of the free theory. In addition, we leverage the Bi-Hamiltonian structure to construct families of transforms between the higher derivative Pais-Uhlenbeck oscillator and a two dimensional system where the dynamics and symplectic structure are preserved. We will also discuss the implications of including interactions, which provides an
important caveat to this argument. The results presented here are reported in [1,2].

References
[1] Fring A, Felski A, and Turner B. Equivalent representations and alternative formulations of higher time-derivative models. in preperation.
[2] Fring A, Taira T, and Turner B. Quantisations of exactly solvable ghostly models. 2025. arXiv: 2503.
21447 [quant-ph]. Submitted for publiction in J. Phys. A: Math. Theor.

Poster / 40

Exact ground state properties of the t-J model with U(1) symmetry breaking

Author: PEI SUN[None]

In this paper, we investigate the ground state energy of the one-dimensional supersymmetric t–J model with U(1) symmetry breaking. We study the distribution of the zero roots of the corresponding nested transfer matrix. We find that in the ground state, the zero roots form two string pairs, finite pure real roots, and pure imaginary roots. Based on the distribution of the zero roots, we obtain the ground state energy of the system in the thermodynamic limit.

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Oddities in the Entanglement Scaling of the Quantum Six-Vertex Model

Authors: SUNNY PRADHAN null[1]; Jesús Cobos[1]; Enrique Rico Ortega[2]; Germán Sierra[3]

[1] *University of the Basque Country*

[2] *CERN*

[3] *Instituto de Fisica Teorica, UAM/CSIC*

We investigate the entanglement properties of the Quantum Six-Vertex Model on a cylinder, focusing on the Shannon-Renyi entropy in the limit of Renyi order $n = \infty$.
This entropy, calculated from the ground state amplitudes of the equivalent XXZ spin-1/2 chain, allows us to determine the Renyi entanglement entropy of the corresponding Rokhsar-Kivelson wavefunctions, which describe the ground states of certain conformal quantum critical points.
Our analysis reveals a novel logarithmic correction to the expected entanglement scaling when the system size is odd.
This anomaly arises from the geometric frustration of spin configurations imposed by periodic boundary conditions on odd-sized chains.
We demonstrate that the scaling prefactor of this logarithmic term is directly related to the compactification radius of the low-energy bosonic field theory description, or equivalently, the Luttinger parameter.
Thus, this correction directly probes the underlying Conformal Field Theory (CFT) describing the critical point.
Our findings highlight the crucial role of system size parity in determining this model's entanglement properties and offer insights into the interplay between geometry, frustration, and criticality.

Poster / 42

Operatorial quasiparticle picture, from entanglement hamiltonians to projective measurements

Author: Riccardo Travaglino[1]

Co-authors: Colin Rylands [1]; pasquale Calabrese [1]

[1] *SISSA*

The quasiparticle picture provides simplest and yet most effective way to study the out-of-equilibrium evolution of entanglement measures following a quantum quench at the ballistic scale. It has found applications in the study of Renyi entropies and negativities in free and interacting systems, reproducing the main known features of entanglement evolution.
I will present a novel point of view for this rather dated subject, in which the quasiparticle picture for free theories is interpreted as an operatorial statement. Although very simple, this new perspective allows to access the hydrodynamic scale description of operatorial measures of entanglement, such as the entanglement hamiltonian, which provides the most complete possible characterization of bipartite entanglement, both in one dimension and in higher dimensions.
Also, I will show how this approach allows to shed light on the extension of the quasiparticle picture to different contexts in which its application is not yet well understood; in particular dissipative systems and systems undergoing quench evolution combined with localized projective measurements.

I will finally comment on the possibility to extend the approach to interacting systems, which would provide a novel way to bridge the quasiparticle picture to generalized hydrodynamics.

Participants Talks / 43

Ergodic behaviors in 3 state cellular automata

Authors: Matija Koterle[1]; Rustem Sharipov[None]; Sašo Grozdanov[None]; Tomaž Prosen[None]

[1] *University of Ljubljana*

Classical cellular automata represent a class of explicit discrete spacetime lattice models in which complex large-scale phenomena emerge from simple deterministic rules. We discuss a classification of three-state cellular automata (with a stable 'vacuum'state and 'particles'with ± charges). The classification is aided by the automata's different transformation proper- ties under discrete symmetries: charge conjugation, spatial parity and time reversal. We distinguish models based on observed types and levels of ergodic behavior as quantified by the following observables: the mean return time, the number of conserved quantities, and the scaling of correlation functions. In each of the physically distinct classes, we present examples and discuss some of their phenomenology. This includes chaotic or ergodic dynamics, phase-space fragmentation, Ruelle-Pollicott resonances, existence of quasi-local charges, and anomalous transport with a variety of dynamical exponents.

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A Minimal Model for testing the Eigenstate Thermalization Hypothesis

Authors: Enej Ilievski[1]; Pavel Orlov[1]

[1] *University of Ljubljana*

The Eigenstate Thermalization Hypothesis (ETH) provides a foundational framework for understanding thermalization in quantum ergodic systems and, with appropriate generalizations, for characterizing equilibration in integrable models. However, numerical verification of ETH has traditionally relied on exact diagonalization (ED), which severely limits accessible system sizes.

In this work, we study an integrable model rooted in the integrability structure of Conformal Field Theories, where the matrix elements of a broad class of observables are known exactly. This allows us to verify ETH predictions both analytically and numerically for significantly larger system sizes than those attainable via ED.

Our primary result reveals that, in the thermodynamic limit, the structure of matrix elements nontrivially depends on the fluctuation scale of the ensemble from which the states are sampled. Crucially, agreement with the ETH is observed only for a specific regime of ensemble fluctuations, highlighting a subtle dependence of the ETH validity on the ensemble properties.

Our findings suggest a refined perspective on the ETH hypothesis and offer a new path for studying it beyond current numerical constraints.

Poster / 45

Integrable Models from Fusion Categories

Author: Luke Corcoran[1]

[1] *Trinity College Dublin*

Mathematical models of non-abelian anyons can be constructed using the data of fusion categories. In this context anyon species are labelled by objects in the category, and projectors can be constructed which describe the fusion of neighbouring anyons into a third anyon. The boost operator formalism provides a robust way to construct and classify integrable models based on fusion categories. Such models have several interesting features, including topological symmetries, non-factorisable spin-chain Hilbert spaces, and critical behaviour in the long-chain limit. In this talk I will give a pedagogical introduction to integrable models based on fusion category projectors, and survey recent results in the case of the Haagerup fusion category.

Participants Talks / **46**

Calogero-Moser and Ruijsenaars-Schneider models

Author: Apor Roth[1]

Co-author: Zoltan Bajnok [2]

[1] *Eötvös Loránd University*

[2] *W*

In the first part of the talk we will investigate the finite-volume spectra the nonrelativistic Calogero-Moser quantum systems, which can be solved analytically. We will compare the analytically calculated spectra from the finite-volume Calogero-Moser systems to the wavenumbers obtained from the corresponding Bethe ansatz equations. The eigenstates are also calculated numerically using the truncated Hilbert space method.
After that, the Ruijsenaars-Scheider models will be presented, which are the relativistic counterparts of the Calogero-Moser systems. The trigonometric Ruijsenaars-Schneider model can also be solved analytically. We will also present the numerical solutions of the trigonometric and elliptic models and compare the solutions to the corresponding Bethe ansatz equations.

Participants Talks / **47**

Transition between critical antiferromagnetic phases in the J_1-J_2 spin chain

Authors: Adam McRoberts[1]; Andrew Green[2]; Chris Hooley[3]

[1] *International Centre for Theoretical Physics*

[2] *London Centre for Nanotechnology, University College London*

[3] *Centre for Fluid and Complex Systems, Coventry University*

The J_1-J_2 spin chain is one of the canonical models of quantum magnetism, and has long been known to host a critical antiferromagnetic phase with power-law decay of spin correlations.

Using the matrix product state path integral to capture the effects of entanglement near the saddle points, we argue here that there are, in fact, two distinct critical phases: the 'Affleck-Haldane' phase, where the dimer field that parametrises local singlet order is part of a joint O(4) N\'eel-singlet order parameter; and the 'Zirnbauer' phase, where the dimer field is gapped out and the critical theory involves only an O(3) N\'eel order parameter. We describe a similar critical-to-critical transition in a model of three coupled spin chains.

The phases are so-named because each realises one of the competing pictures for how the O(3) non-linear sigma model with a topological theta term renormalises to the $\hat{\mathfrak{su}}(2)_1$ Wess-Zumino-Witten model.

Participants Talks / **48**

Exact dynamics with free fermions in disguise

Authors: Balázs Pozsgay[1]; Márton Mestyán[1]; Istvan Vona[2]

[1] *Eötvös Loránd University*

[2] *ELTE University, Wigner RCP*

A large class of free fermionic spin chain models have been found recently, that are not soluble by a Jordan-Wigner transformation, but by some more complex construction introduced in the original work of Fendley, that rather resembles the methods to solve integrable systems. In the present work we relied on these techniques to calculate the correlation functions of some local operators in Fendley's "free fermions in disguise" model and also established a scheme to measure them on a quantum computer. Thus, it is another example of a classically simulable quantum system, that may also be used for benchmarking these hardware in the future. In my talk, I will explain how to solve the dynamics of Fendley's original model, at least partially.

Participants Talks / 49

Hydrodynamics of nearly-integrable systems

Author: Maciej Łebek[1]

Co-author: Miłosz Panfil [1]

[1] *University of Warsaw*

Integrable systems feature an infinite number of conserved charges and on hydrodynamic scales are described by generalised hydrodynamics (GHD). This description breaks down when the integrability is weakly broken and sufficiently large space-time-scales are probed. The emergent hydrodynamics depends then on the charges conserved by the perturbation.

In my contribution I will focus on nearly-integrable Galilean-invariant systems with conserved particle number, momentum and energy. Basing on the Boltzmann approach to integrability-breaking we describe dynamics of the system with GHD equation supplemented with a collision term.

Employing Chapman-Enskog formalism and nonlinear fluctuating hydrodynamics I will show that depending on the length scales, one can distinguish three hydrodynamic regimes of the system: generalised hydrodynamics, Navier-Stokes (NS) regime and Kardar-Parisi-Zhang (KPZ) superdiffusion known to occur in generic 1d non-integrable fluids. Moreover, I will show how we can compute transport coefficients characterising the fluid in NS and KPZ regimes.

Based on: doi.org/10.1103/PhysRevLett.134.010405 and arXiv:2410.23209

Poster / 50

Finite-Temperature Correlation Functions and Nonanalytic Behavior in the Ising Field Theory

Authors: István Csépányi[1]; Márton Kormos[1]

[1] *Budapest University of Technology and Economics*

I present recent progress in computing finite-temperature dynamical correlation functions in the 1+1 dimensional Ising field theory, an integrable quantum field theory. Leveraging the fact that in the Ising model, the finite-temperature form factor expansion can be recast as a Fredholm determinant, I develop a numerical approach based on evaluating these determinants. This representation is especially powerful in the space-like regime, where only a few terms of the form factor series are sufficient to accurately compute the correlations. In contrast, the time-like regime requires an effective resummation of the entire series. I demonstrate that the Fredholm representation, combined with a suitable analytic continuation strategy, enables access to this regime as well, extending the reach of the method beyond previously tractable cases.

As a key application, I demonstrate that in the paramagnetic phase, the thermal correlation length displays an unexpected nonanalytic dependence on both the temperature and the space-time ray

parameter. This effect persists even at the lattice level, as supported by new, yet unpublished results from the finite-temperature dynamics of the Ising spin chain. These findings suggest that the interplay between integrability and thermal dynamics gives rise to richer analytic structures than previously understood.

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Diversity of integrable magnetization-conserving unitary qubit circuits

Authors: Balázs Pozsgay[1]; Chiara Paletta[2]; Lenart Zadnik[2]; Marko Žnidarič[2]; Urban Duh[2]

[1] *Eötvös Loránd University*

[2] *University of Ljubljana, Faculty of Mathematics and Physics*

Integrable systems provide a rare opportunity to exactly understand the physics of complex systems, especially in the case of many-body quantum systems, where exponential complexity of simulation severely limits the effectiveness of brute-force approaches. With the recent rapid progress of quantum computers, integrable circuits have increasingly come into focus. While integrability is generally considered to hold only for fine-tuned systems, we have shown that this is not the case for magnetization-conserving qubit circuits. In these circuits, integrability is generic: any time-periodic qubit circuit in which a magnetization-conserving gate is applied to each pair of neighboring qubits exactly once per period is integrable.
We describe the key components of the algebraic Bethe ansatz for these circuits, particularly the R matrix for any magnetization-conserving gate and the transfer matrix for any geometry (i.e., arrangement of gates). Analysis of the R matrix structure reveals the existence of two distinct phases, analogous to the gapless and gapped phases in the Heisenberg XXZ circuits, each with different symmetries, conservation laws, transport properties, and zero edge modes. As another key aspect, the transfer matrix construction offers a systematic approach to identifying integrable geometries.
The work also examines how asymmetric geometry affects the spin transport by analyzing the dynamical structure factor on the ballistic hydrodynamic scale. While inducing nonzero higher odd moments, the first moment —corresponding to a drift in the spreading of correlations —remains zero.

The presentation is based on 2410.06760 (magnetization-conserving gates - Žnidarič, Duh, Zadnik) and 2503.04673 (geometries - Paletta, Duh, Pozsgay, Zadnik).

Poster / 52

Entanglement and quench dynamics in the thermally perturbed tricritical fixed point

Authors: Csilla Király[1]; Máté Lencsés[1]

[1] *HUN-REN Wigner Reserch Centre of Physics*

The Blume-Capel model, a spin chain system exhibiting a tricritical point described by a conformal field theory with central charge $c = 7/10$, serves as a rich framework for studying its thermal perturbation, the E_7 integrable quantum field theory. In my work, I investigate both numerical and analytical aspects of the E_7 model, aiming to validate theoretical predictions and explore new phenomena relevant for experimental realization. The numerical component of the work utilizes the infinite Time Evolving Block Decimation (iTEBD) algorithm to simulate real-time dynamics, focusing on post-quench evolution. These simulations allowed identification of three out of four predicted even particles through spectral analysis. The analytical part centers on the form factor

bootstrap program, through which I compute one- and two-particle form factors of the twist field form factors incorporating nontrivial symmetry structures. These results were validated using the Δ-theorem. Further, I study the post-quench dynamics of the Blume–Capel model near the tricritical point, analyzing expectation values and entanglement entropies following E_7 mass quenches. The time evolution curves of local observables, the Neumann and the Rényi entropies exhibit strong agreement with theoretical predictions, thereby reinforcing the field-theoretical framework.

Participants Talks / 53

Structure of Local Conservation Laws in Quantum Integrable Systems

Author: Kohei Fukai[1]

[1] *The University of Tokyo*

In this talk, I explain the structure of the local consrvetaion law in several interacting integrable systems.

Quantum integrable systems are exactly solvable by the Bethe ansatz.
Behind their exact solvability, there is an infinite number of local conserved quantities $\{Q_k\}_{k=2,3,4,\ldots}$.
Although the existence of Q_k itself is guaranteed from the quantum inverse scattering method, obtaining their explicit expressions is challenging.
This difficulty lies not only in the expensive computational cost for higher order charges but also in finding a general pattern in the enormous amounts of data that emerge from this calculation.

I will review recent progress on this problem, including the derivation of general explicit expressions for the local conserved quantities in the spin-1/2 XYZ chain [Nozawa, Fukai, Phys. Rev. Lett., 2020] and the one-dimensional Hubbard model [Fukai, Phys. Rev. Lett., 2023].

In addition, I will explain how the complex structure of the local conserved quantities can be simplified using matrix product operator (MPO) representations, as demonstrated for the Heisenberg chain [Yamada, Fukai, SciPost Phys. Core, 2023].
In the case of the XYZ chain, we observe that a weighted-path generalization of the Catalan numbers emerges in the structure of the local conserved quantities—extending the Catalan tree pattern originally found by Grabowski and Mathieu in the Heisenberg chain [Grabowski, Mathieu, J. Math. Phys., 1995].

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Quantum non-equilibrium dynamics with classical determinist circuits II

Author: Katja Klobas[1]

[1] *University of Birmingham*

TBA

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Quantum non-equilibrium dynamics with classical determinist circuits III

Author: Katja Klobas[1]

[1] *University of Birmingham*

TBA

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Exact quantum state preparation II

Author: Rafael Nepomechie[1]

[1] *University of Miami*

This course is an introduction to some approaches for exactly preparing multi-qubit states on a quantum computer. In Lecture 1, we begin with a brief review of quantum circuits; we then consider the GHZ state, and its preparation in constant depth. In Lecture 2, we introduce matrix product states and sequential state preparation; we consider the example of AKLT states, and their preparation in constant depth. In Lecture 3, we consider the preparation of Dicke states and Bethe states.

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Exact quantum state preparation III

Author: Rafael Nepomechie[1]

[1] *University of Miami*

This course is an introduction to some approaches for exactly preparing multi-qubit states on a quantum computer. In Lecture 1, we begin with a brief review of quantum circuits; we then consider the GHZ state, and its preparation in constant depth. In Lecture 2, we introduce matrix product states and sequential state preparation; we consider the example of AKLT states, and their preparation in constant depth. In Lecture 3, we consider the preparation of Dicke states and Bethe states.

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Exact out-of-equilibrium dynamics with random unitary circuits II

Author: Andrea De Luca[1]

[1] *CY Cergy Paris Universite*

TBA

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Exact out-of-equilibrium dynamics with random unitary circuits III

Author: Andrea De Luca[1]

[1] *CY Cergy Paris Universite*

TBA

Poster / 60

Hydrodynamic projection in Lindblad equations with Bogoliubov decoupled hierarchy

Authors: Fabian H. L. Essler[1]; Patrik Penc[1]

[1] *University of Oxford*

We consider open fermionic models with different types of dephasing noise in the framework of Lindblad equations. There exists a particular class of models, for which the Bogoliubov–Born–Green–Kirkwood–Yvon (BBGKY) hierarchy decouples. This makes it possible to obtain exact results, even though the models are interacting and there is no Wick's theorem for multi-point correlations (initial Gaussian density matrices do not remain Gaussian under time evolution).
We show that the equations of motion for n-particle Green's functions can be mapped onto n-particle imaginarily time Schroedinger equations with non-Hermitian Hamiltonians. We fully solve the one and two-particle cases, which enables us to describe linear response functions out of equilibrium. Models with particle number conserving jump operators exhibit a global U(1) symmetry, which leads to hydrodynamic behaviour at late times. Interestingly, it is possible to exactly determine the hydrodynamic modes, as well as the hydrodynamic projections of local operators.

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Generalised hydrodynamics of optical soliton gases: measurement of correlations

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R-matrix valued Lax pair for elliptic Calogero systems and the associative Yang-Baxter equation

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Probing Large Deviations in Accelerated TASEP: Bethe Ansatz, Cassini Ovals, and Spectral Gaps

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Topological phases protected by $Z_N^{\otimes 3}$ symmetry

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Sine-Gordon model at finite temperature: the method of random surfaces

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