



Threifold Quantum

Theory, Experiment, Computation
Out of equilibrium

11-13 March 2026, ENS
Salle Favard, 46 Rue d'Ulm. 75005 Paris

Programme Day 1

(11/03/26)

08:45-09:15 Registration and opening

09:15-10:00 **Mari Carmen Banuls** (MPQ, Munich)

Title: *Investigating spectral properties at finite energy density with tensor networks*

Abstract: Tensor networks are well known as efficient numerical tools for ground states of quantum many-body systems in low spatial dimensions. The ansatz is however not suitable to describe highly excited eigenstates, or out-of-equilibrium dynamics. Nevertheless, recently proposed TNS algorithms allow us to access spectral properties of the Hamiltonian over extensive energy ranges. They allow us to access spectral densities of many-body operators (e.g. densities of states) but also to probe the structure of physical operators in the energy eigenbasis, in particular the predictions of the eigenstate thermalization hypothesis, which particularizes the random matrix behaviour for the physical many-body setting.

10:00-10:30 Coffee break

10:30-11:15 **Maurizio Fagotti** (LPTMS, Paris)

Title: *Organizing Nonequilibrium Quantum Systems: Weakly Broken Charges and Thermodynamics*

Abstract: Weak integrability breaking in Rydberg spin chains provides a controlled route to quantify how constraints decay. In the first part, I show that fragile conservation laws leave sharp fingerprints in nonlocal and semilocal observables, already in chains of as few as 14 Rydberg atoms. In the second part, I introduce a state-space notion of constraints: a foliation into minimum-variance leaves, where the minimal achievable coherent energy variance over decompositions is fixed by the quantum Fisher information. This construction generalizes equilibrium thermodynamics to states with energy-basis

coherence and motivates leaf typicality as an ETH-like criterion for local observables beyond the commuting (stationary) leaf.

References:

- [1] Chen, Capizzi, Marché, Bornet, Emperauger, Lahaye, Browaeys, MF, Mazza, "Observing weakly broken conservation laws in a dipolar Rydberg quantum spin chain", arXiv:2602.02251 (2026);
[2] MF, "Quantum-Coherent Thermodynamics: Leaf Typicality via Minimum-Variance Foliation", arXiv:2602.12212 (2026).
-

11:15-11:45 **Andrea Pizzi** (Cambridge)

Title: *Unstable periodic orbits galore and quantum hyperscarring in highly frustrated magnets*

Abstract: Highly frustrated magnets, with their macroscopically-degenerate classical ground states and massively-entangled quantum spin liquid phases, have been pivotal to the development of modern condensed matter concepts such as emergent symmetries, topological order, and fractionalisation. The effects of frustration and massive degeneracies at high energy, where the many-body dynamics becomes chaotic, have hitherto been far less explored. Here, we identify a high-energy dynamical analog of highly-frustrated magnetism, in the form of an extensive manifold of classical “interaction-suppressing” configurations giving rise to unstable periodic orbits. These are in general neither protected by symmetry nor integrability, and emerge from a set of dynamical local constraints that effectively nullify the interactions while allowing extensively many local degrees of freedom. The proliferation of unstable periodic orbits corresponds in the quantum case to “hyperscarring”, that is, quantum scarring on exponentially many unstable periodic orbits. On the product states associated to the latter, the amplitudes of the mid-spectrum thermal eigenstates exhibit a power-law distribution, in stark contrast to the expected exponential Porter-Thomas distribution that holds for generic product states. Our results reveal a new constrained dynamical regime where many-body quantum chaos coexists with structured manifolds of coherent dynamics, and establishes a mechanism for hitherto elusive extensive scarring.

11:45-12:15 **Riccardo Senese** (SISSA, Trieste)

Title: *Dynamics of interacting quantum integrable models via Monte Carlo sampling of form factors*

Abstract: Despite the exact solvability of the spectrum in interacting quantum integrable models, the computation of (dynamical) correlation functions—both in equilibrium at generic temperatures and out-of-equilibrium at late times—remains a major open challenge analytically and numerically. A fundamental bottleneck is that the Lehmann representation for the correlators involves a summation over a number of form factors that scales exponentially with system size, rendering exact summations prohibitive for any classical computational resources. I will present recent progress based on Markov Chain Monte Carlo (MCMC) sampling of form factors that enables the accurate reconstruction of correlation functions in (generalized) Gibbs ensembles [1], as well as out-of-equilibrium following global quantum quenches [2], for generic energy densities, particle densities, and interaction strengths. To demonstrate the efficacy of the approach I will focus on the

transverse-field Ising chain and the repulsive Lieb-Liniger gas, where a few benchmarks are available. Finally, I will address the origin of the absence of a “sign problem” and discuss scenarios in which it persists.

[1] R. Senese, F.H.L. Essler; <https://arxiv.org/abs/2508.17908>

[2] R. Senese, F.H.L. Essler; in preparation

12:15-13:30 Lunch break

13:30-14:15 **Manuele Landini** (Innsbruck Univ., Innsbruck)

Title: *Probing ultracold 1D systems out of equilibrium*

Abstract: I will present the activities of our group, going under the broad topic of out of equilibrium phenomena in ultracold 1D gases. In our experiment, an ensemble of a few thousand effectively one dimensional ultracold Cs samples, each containing 10 to 30 atoms is prepared and investigated. Careful control over the trapping potential, temperature and interaction energy enables the investigation of collective quantum transport behavior of these systems and the preparation of out of equilibrium states with unusual statistical properties.

Starting from the stable repulsive regime, the control over interaction strength allows us to access the attractive regime. Here the system is metastable and characterized by the formation of aggregates called Bethe strings. We experimentally probe the formation of these states for different system parameters and measure their average binding energy in time of flight [1].

Furthermore, we perform topological pumping experiments by cycling the value of the coupling constant. In each cycle, the system is promoted to increasingly more energetic many-body states, stabilized by approximate integrability. These states are characterized by the presence of fractional Fermi seas (FFS) resulting from effective “hyperfermionic” statistics, where each particle occupies more than one quantum state. The creation of the FFS is inferred in the experiment by the direct observation of Friedel oscillations in the g_1 correlation function of the gas [2,3].

Introducing spin impurities with variable speed in the 1D gas, we were able to characterize their relaxation dynamics and infer the formation of a polaron, resulting in finite long-time velocity of the impurity, even though the system is not in a standard superfluid state [4]. By slowly accelerating the impurity across the polaronic dispersion, we could observe its momentum distribution, revealing a cross-over in the effective statistical behavior of the system from bosonic to fermionic, passing from the anyonic intermediate statistics as a function of the injected momentum [5].

[1] Observing Bethe strings in an attractive Bose gas far from equilibrium, M. Horvath, A. Bastianello, S. Dhar, R. Koch, Y. Guo, J.-S. Caux, M. Landini, H.-C. Nägerl, arXiv:2505.10550 (2025).

[2] Realization of fractional Fermi seas, Y. Zeng, A. Bastianello, S. Dhar, Z. Wang, X. Yu, M. Horvath, G. E. Astrakharchik, Y. Guo, H.C. Nägerl, M. Landini arXiv:2602.17657 (2026). [3] Exotic critical states as fractional Fermi seas in the one-dimensional Bose gas, A. Bastianello, Y. Zeng, S. Dhar, Z. Wang, X. Yu, M. Horvath, G. E. Astrakharchik, Y. Guo, H.-C. Nägerl, M. Landini, arXiv:2602.17656 (2026).

[4] Observing dissipationless flow of an impurity in a strongly repulsive quantum fluid, M. Horvath, S. Dhar, E. Wybo, D. Trypogeorgos, Y. Guo, M. B. Zvonarev, M. Knap, M. Landini, H.-C. Nägerl, arXiv:2602.12320 (2026).

[5] Observing anyonization of bosons in a quantum gas, S. Dhar, B. Wang, M. Horvath, A. Vashisht, Y. Zeng,

14:15-14:45 **Hansveer Singh** (Max Planck Inst. Dresden)

Title: *Extracting transport properties using zero noise extrapolations of noisy quantum dynamics*

Abstract: We examine extrapolating transport coefficients of quantum systems subjected to weak noise. Though noise generally breaks conservation laws of a quantum system, we show for weak noise strengths it is still possible to define an effective notion of transport. For chaotic diffusive quantum systems, we provide a protocol to extrapolate diffusion constants and argue that the effective diffusion constant in the weak noise limit can be decomposed into two parts: an analytic function of the noise strength and a function determined by non-linear corrections to diffusive hydrodynamics. We support our findings with tensor network simulations of a dissipative version of the staggered field spin-1/2 XXZ chain.

14:45-15:25

FLASH TALK SESSION

1) **Pavel Orlov** (Univ. of Ljubljana)

Title: *Circuits Built from Pairwise Difference Conserving Gates: From Loop Symmetries to Localization Transitions*

Abstract: We introduce a new class of models: circuits constructed from special local gates that we dubbed pairwise difference conserving (PDC) gates. These circuits can be defined on graphs of arbitrary dimension and for both quantum and classical spins. A key consequence of the PDC construction is the emergence of an extensive set of loop charges, associated with closed walks of even length on the graph. These charges exhibit a one-dimensional character reminiscent of 1-form symmetries and lead to strong Hilbert-space fragmentation: the dynamics decomposes into exponentially many disconnected sectors, each labeled by charge values. As a concrete realization, we analyze a classical cellular automaton belonging to this family, defined on the square lattice. In this model, we uncover a localization–delocalization phase transition in information spreading, controlled by loop charges. The transition is continuous and characterized by critical scaling of a Hamming-distance order parameter and a diverging correlation length, placing it in close analogy with equilibrium second-order phase transitions. Together, these results establish PDC circuits as a versatile platform for exploring symmetry-induced fragmentation, constrained dynamics, and emergent phase transitions across quantum and classical settings.

2) **Gianluca Morettini** (LPTMS, Paris)

Title: *Emergent integrable dynamics in a non-integrable Rydberg-atom chain*

Abstract: We investigate the dynamical consequences of weak integrability breaking in lattice systems and show that in recent Rydberg atomic experiments integrable and non-integrable dynamics can appear for different initial conditions.

In the limit of dominant nearest-neighbor couplings, the dynamics can be mapped onto an effective lattice Fermi gas that is integrable and exhibits ballistic transport.

The inclusion of long-range dipolar interactions, however, breaks the conservation laws associated to integrability, enabling a many-body effects to emerge and specifically a genuine diffusive transport.

We present a thorough numerical study that shows that for some initial conditions the model evolves as if those terms were not present, whereas for other ones their presence leaves clear measurable fingerprints.

We propose a theoretical mechanism that makes sense of these differences.

This work paves the way to a definition of the properties of weak integrability breaking in quantum many-body spin chains.

3) **Leonardo Biagetti** (CY Cergy-Paris)

Title: *Generalised BBGKY hierarchy for near-integrable dynamics*

Abstract: We consider quantum and classical many-body Hamiltonian systems that combine integrable contact interactions with generic two-body long-range potentials. We show that the time evolution of local observables can be formulated as a generalized Bogoliubov–Born–Green–Kirkwood–Yvon (gBBGKY) hierarchy, built on the quasiparticle densities of the underlying integrable model and their correlations. Starting from an ansatz for the state at time t , which we denote the correlated fluid cell ensemble, we derive this hierarchy and demonstrate that it exactly reproduces the dynamics of one- and multi-point correlation functions in perturbed integrable models at all times. These predictions are validated against microscopic molecular-dynamics simulations with perfect agreement. In the late-time regime, approach to the thermal distribution is mediated by a Boltzmann-style scattering integral featuring a complex interplay of contact integrable and long-range collision processes. In the specific case of dipolar gases, where the relevant matrix elements are known, we verify that our collision integral exactly recovers the Fermi's golden rule result and provide a full theoretical characterization of the experimental observations of [Tang et al. Phys. Rev. X 8, 021030 2018]. Our framework thus demonstrates how the BBGKY approach can be systematically extended to include strong local interactions, making it applicable to a broad class of experimentally relevant systems, from one-dimensional dipolar cold-atom gases to Lennard-Jones interacting molecules.

4) **Juan Pablo Bayona Pena** (Univ. of Bologna)

Title: *Generalized Hydrodynamics of Charge-Monitored Free Fermions*

Abstract: Generalized hydrodynamics (GHD) has emerged as a powerful framework for describing the out-of-equilibrium dynamics of integrable systems. Here we show that GHD can yield exact solutions for the evolution of local charges and currents in a free-fermion chain subject to continuous monitoring of the charge in a spatial subregion. The measurement backaction induces dephasing, generating non-Gaussian, long-range

correlations and driving the dynamics, in the thermodynamic limit, towards a long-lived non-equilibrium steady state. Surprisingly, the resulting charge and current profiles closely resemble those of a system with an effective impurity at the interface between two regions, leading to discontinuous jumps in local observables. Exploiting symmetries of the Lindbladian superoperator, we obtain exact results for a range of homogeneous and inhomogeneous initial states. Finally, we benchmark against numerical simulations and identify classes of initial conditions where non-Gaussian effects require further theoretical refinement.

5) **Michele Coppola** (Jozef Stefan Inst. Ljubljana)

Title: *Learning the non-Markovian features of subsystem dynamics*

Abstract: The dynamics of local observables in a quantum many-body system can be formally described in the language of open systems. The problem is that the bath representing the complement of the local subsystem generally does not allow the common simplifications often crucial for such a framework. Leveraging tensor network calculations and optimization tools from machine learning, we extract and characterize the dynamical maps for single- and two-site subsystems embedded in an infinite quantum Ising chain after a global quench. We consider three paradigmatic regimes: integrable critical, integrable non-critical, and chaotic. For each we find the optimal time-local representation of the subsystem dynamics at different times. We explore the properties of the learned time-dependent Liouvillians and whether they can be used to forecast the long-time dynamics of local observables beyond the times accessible through direct quantum many-body numerical simulation. Our procedure naturally suggests a novel measure of non-Markovianity based on the distance between the quasi-exact dynamical map and the closest CP-divisible form and reveals that criticality leads to the closest Markovian representation at large times.

6) **Bilal Alilou** (LKB, Paris)

Title: *Phonon scattering from spatial relaxation of one-dimensional Bose gases*

Abstract: Probing the microscopic mechanisms that govern the thermalization of non-equilibrium, closed many-body systems is an active area of research, conveniently addressed in cold-atom platforms. In weakly interacting Bose gases at ultracold temperatures, thermalization is known to be induced by (phononic) quasiparticle interactions, typically characterized by a phonon decay rate. In one-dimensional (1D) Bose gases at equilibrium, this decay rate is known as the Landau damping rate, and has attracted particular attention due to its anomalous $k^{3/2}$ dependence on momentum. To measure it in practice, a natural strategy consists in probing the spatial relaxation of a density modulation initially imprinted on a 1D Bose gas. At sufficiently long times, this relaxation is expected to be governed by the Landau damping rate as the Bose gas approaches its final thermal state.

7) **Yi Zeng** (Univ. of Innsbruck)

Title: *Realization of Fractional Fermi Seas*

Abstract: The Pauli exclusion principle is a cornerstone of quantum physics: It governs the structure of matter. Generalizations of this principle, such as Haldane's generalized exclusion statistics, predict the existence of exotic quantum states characterized by fractional Fermi seas (FFS), i.e., momentum distributions with uniform but fractional occupancies. Here, we report the experimental realization of fractional Fermi seas in an excited one-dimensional Bose gas prepared through holonomy cycles in the interaction strength. The resulting excited yet stable Bose-gas states exhibit Friedel oscillations, smoking-gun signatures of the underlying FFS. The stabilization of these states offers an opportunity to deepen our understanding of quantum thermodynamics in the presence of exotic statistics and paves the way for applications in quantum information and sensing.

8) **Luka Paljk** (Univ. of Ljubljana)

Title: *Slow dynamics from a nested hierarchy of frozen states*

Abstract: We identify the mechanism of slow heterogeneous relaxation in quantum kinetically constrained models (KCMs) in which the potential energy strength is controlled by a coupling parameter. The regime of slow relaxation includes the large-coupling limit. By expanding around that limit, we reveal a nested hierarchy of states that remain frozen on time scales determined by powers of the coupling. The classification of such states, together with the evolution of their Krylov complexity, reveal that these time scales are related to the distance between the sites where facilitated dynamics is allowed by the kinetic constraint. While correlations within frozen states relax slowly and exhibit metastable plateaus that persist on time scales set by powers of the coupling parameter, the correlations in the rest of the states decay rapidly. We compute the plateau heights of correlations across all frozen states up to second-order corrections in the inverse coupling. Our results explain slow relaxation in quantum KCMs and elucidate dynamical heterogeneity by relating the relaxation times to the spatial separations between the active regions

15:25-15:45 Coffee break

15:45-16:30 **Manoj Joshi** (IQOQ, Innsbruck)

Title: *Characterization of Analog Quantum Simulators via Lindbladian Learning*

Abstract: Many-body quantum simulation is one of the most promising applications of quantum technologies. However, a central challenge remains: verifying the correctness of quantum simulation results in the presence of experimentally realized (and potentially unknown) Hamiltonians and unavoidable decoherence channels. Motivated by this challenge, we employ Hamiltonian and Liouvillian learning (Lindbladian learning) techniques to quantitatively validate experimentally implemented Hamiltonians in a trapped-ion system. A broad set of ansatz terms is incorporated into the analysis to identify the Hamiltonian that best captures the observed dynamics. Once the optimal candidate is determined, statistical noise and estimation bias are carefully analysed to

obtain reliable estimates of the Hamiltonian parameters. These studies are carried out on a trapped-ion quantum simulator consisting of ion strings with up to $N=51$ ions. In this conference, I will present a practical perspective on Hamiltonian learning methods and their role in establishing trust in analog quantum simulations.

16:30-17:00 **Fabio Franchini** (Rudjer Boskovic Inst., Zagreb)

Title: *Experimental preparation of W states through many-body physics on a quantum simulator*

Abstract: W states are quantum correlated states possessing both bipartite and multipartite entanglement, which makes them useful for several quantum algorithms. We propose a protocol to generate these states by exploiting topological ring frustration, and implement it on a programmable Rydberg atom array up to 11 qubits, successfully generating many-body W states of Rubidium atoms. Numerical simulations show promising scaling of the algorithm to tens of qubits with near-term achievable updates on the quantum machines. To validate our state preparation protocol and probe quantum entanglement, we devise a fidelity estimator that requires only two sets of measurements. To implement it, we develop a novel and efficient Bayesian state-tomography approach that takes advantage of accurate classical numerical simulations to overcome limitations in the experimental setup. Hence, a lower bound fidelity of around 77% is certified for the experimentally prepared state of 11 qubits. This work provides a state-of-the-art procedure to generate high-quality quantum entangled W states, demonstrating once more how principles of physics can overcome traditional barriers of computation, and be exploited for quantum advantage.

17:00-17:30 **Guido Giachetti** (LPENS, Paris)

Title: *Integrable Dynamics and Thermalization in the Quantum $O(n)$ Model at Large- n*

Abstract: The quantum $O(n)$ model has long served as a valuable framework for studying both equilibrium and dynamical properties of quantum many-body systems. In this talk, we investigate its non-equilibrium dynamics following a quantum quench in the large- n limit. While the model is known to be tractable in this regime, we show that it is in fact integrable - with integrals of motions stemming from that of the classical Neumann model - thus enabling a complete analytical solution of its dynamics. This integrability reveals a synchronization mechanism that gives rise to persistent oscillations, interpretable as Higgs modes localized at the edge of the spectral band. We further demonstrate that the long-time behavior is governed by a Generalized Gibbs Ensemble (GGE), in contrast to previous expectations, and we obtain exact critical exponents differing from those commonly reported. Remarkably, integrability persists even in the presence of long-range couplings, allowing us to explore the crossover between mean-field and genuinely many-body regimes in terms of parametric Floquet resonances of the microscopic degrees of freedom.

18:00-19:30
POSTER SESSION
+ APERO
(24 Rue Lhomond – Entrance Hall)

Programme Day 2

(12/03/26)

09:15-10:00 **Zala Lenarcic** (Jozef Stefan Inst. Ljubljana)

Title: *Conserved quantities enable the quantum Mpemba effect in weakly open systems*

Abstract: Observation of the quantum Mpemba effect has spurred much interest in its enabling conditions and its relation to the classical counterpart. In this talk, I will consider weakly open many-body quantum systems initialized in different thermal states and examine when the initially farther state relaxes to the (non-equilibrium) steady state faster. I will show that the number of conserved quantities in the unitary part plays a crucial role: the Mpemba effect is possible only when the Hamiltonian commutes with other extensive operators or is integrable. The reason lies in the dynamical evolution happening in spaces of different dimensions. When energy is the only approximately conserved quantity, dissipation pushes the dynamics within a single-parameter manifold of different thermal states. In contrast, for Hamiltonians with several conserved quantities, the dynamics drift in the multi-dimensional space of generalized Gibbs ensembles, whose distance to the steady state is less trivial. I will support our claim by providing numerical results for large system sizes using tensor networks and free-fermion techniques.

10:00-10:30 Coffee break

10:30-11:15 **Jerome Beugnon** (LKB, Paris)

Title: *Magnetic solitons as probes of 1D quantum gases*

Abstract: In recent experiments, we studied the dynamics of magnetic solitons in a uniform two-component 1D Bose gas. Remarkably, when subjected to a constant uniform force, the solitons exhibit Bloch oscillations. We show that these oscillations constitute a genuine manifestation of the intrinsic properties of 1D quantum gases. We explore both strict and open boundary conditions and reveal the pumping of superfluid currents through the soliton motion in a ring geometry.

11:15-11:45 **Anna Delmonte** (College de France, Paris)

Title: *Measurement-Induced Phase Transitions and the Post-Selection Problem in Collective Models*

Abstract: One of the central challenges in the study of monitored quantum dynamics is reproducing a specific sequence of measurement outcomes - a quantum trajectory. Such trajectories typically occur with probabilities that decrease exponentially with system size and observation time, making their experimental realization extremely hard to achieve. Recent studies, however, suggest that measurement-induced entanglement phase transitions in certain classes of collective models may exhibit enhanced probabilities, as quantum correlations tend to saturate rapidly. To this end, we investigate the monitored dynamics of a Tavis-Cummings model under continuous measurement, demonstrating the emergence of measurement-induced phase transitions in the entanglement. By analyzing the dynamical properties of quantum correlations, we identify regions with favorable post-selection probabilities, providing insight into which experimental platforms may be best suited for observing monitored phases.

11:45-12:15 **Alessandro Zenesini** (Univ. of Trento)

Title: *False Vacuum and Hot Bubbles in Ferromagnetic Superfluids*

Abstract: Ultracold atoms are among the most versatile tools to explore quantum phenomena on macroscopic scales. Their ability to simulate a wide range of quantum effects extends from ferromagnetism to cosmology, and from single-atom chains to continuous field models. In our experiments, we work with one-dimensional coherently-coupled hyperfine mixtures of sodium. Owing to the specific combination of intra- and inter-state collisional properties, the mixture can be tuned into a ferromagnetic state, allowing us to study both first- and second-order phase transitions. In particular, we observe the formation of bubbles following the decay of a metastable state—a yet-unverified prediction of quantum field theory known as False Vacuum Decay. More recently, we have investigated how temperature affects this decay process and extended our study to the dynamics and interactions of bubbles in flat potentials.

12:15-13:30 Lunch break

13:30-14:15 **Marko Ljubotina** (TU Munich)

Title: *Quantum control in variational manifolds*

Abstract: Matrix product states (MPS) provide an efficient variational description of low-entanglement quantum many-body systems, but their role as a platform for direct quantum control has remained largely unexplored. In this talk, I present a new framework for quantum control formulated intrinsically on variational state manifolds, offering a scalable alternative to traditional approaches such as counter-diabatic driving. Building on our earlier work, we develop tangent-space methods that enable controlled dynamics and optimization directly within the MPS manifold. I then discuss recent progress on

constructing quasi-local generators that implement prescribed variational trajectories and enable efficient preparation of structured many-body states.

14:15-14:45 **Luca Tagliacozzo** (CSIC)

Title: *Characterizing ergodicity through temporal entropies*

Abstract: I will discuss how to detect ergodicity based on the scaling of temporal entropies showing fresh data on these quantities for the Ising model in both parallel and transverse field.

14:45-15:25

FLASH TALK SESSION

1) **Matteo Scandi** (IFT)

Title: *Microscopic derivation of a thermalizing Lindblad equation for many-body systems*

Abstract: Despite the obvious fact that systems weakly coupled to a thermal bath will generically reach thermal equilibrium, up until recently this was proven to hold only for small quantum systems. Indeed, the main ingredient needed in order to guarantee that thermality would be attained, the concept of detailed balance, in its most common expression leads to unphysical results when applied to systems comprised of many particles. In this talk we present a solution to this problem, describing how through a series of approximations of the global unitary evolution, one can obtain a provably thermalizing dynamics for the reduced density matrix of the system (regardless of its size), by using a refined notion of detailed balance that is better suited for quantum systems. Moreover, we also provide error bounds on all our approximations that exponentially improve previous results from the literature.

2+3) **Sun Woo Kim** (King's College London) & **Friedrich Hübner** (LPENS, Paris)

Title: *MPS equivalence and solvability for brickwork circuits*

Abstract: 'Solvable' circuits, such as dual unitaries and their extensions, have arisen as paradigmatic examples of tractable chaotic non-equilibrium dynamics, both in classical and quantum systems. These correspond to local algebraic properties which allow for calculation of observables due to a simplification of the corresponding tensor network. However, an exhaustive classification of such properties has not been found. Moreover, given a particular circuit, it is not unclear if it is solvable or not. We fill this gap by providing a necessary and sufficient local condition under which a circuit is solvable, in the sense that its bath can be written as a constant bond-dimension MPS. To do this, we develop a general theory of necessary and sufficient conditions for when two MPSs of different bond-dimensions are equivalent. Then, we apply these conditions to study the simplest case of factorised initial states and Markovian baths. For this case we classify all solvable classical and quantum circuits up to local dimension 3 and 2, respectively.

4) **Oscar Michel** (Qilimanjaro Quantum Tech)

Title: *Quantum State Transfer with Ising Hamiltonians*

Abstract: Quantum state transfer is a fundamental requirement for scalable quantum computation, particularly in analog and hybrid architectures where fast, reliable communication between distant qubits is essential. Our work presents a protocol for perfect state transfer in one-dimensional spin chains governed by a simplified Ising-like Hamiltonian containing only ZZ interactions. Unlike conventional schemes that rely on XX or full Heisenberg couplings, our approach encodes quantum information in domain wall excitations, which reproduce Heisenberg-like dynamics using only first- and second-neighbor ZZ terms. This reduction in Hamiltonian complexity makes the protocol more accessible for experimental implementation across various quantum hardware platforms capable of modeling spin chain dynamics. Our simulations demonstrate high-fidelity transfer of both single- and multi-qubit states across arbitrary distances, and show robustness to disorder in local fields and interaction strengths, as well as qubit decoherence. Additionally, the ends of the spin chain can also function as quantum repeaters, enabling passive state reception and forwarding without prior knowledge or measurement of the transmitted state. This feature suggests a role for our system in quantum communication within larger processors.

5) **Cristiano Muzzi** (Université libre de Bruxelles)

Title: *Superdiffusion and anomalous fluctuations in chiral integrable dynamics*

Abstract: Symmetries strongly influence transport properties of quantum many-body systems, and can lead to deviations from the generic case of diffusion. In this work, we study the impact of time-reversal symmetry breaking on the transport and its universal aspects in integrable chiral spin ladders. We observe that the infinite-temperature spin transport is superdiffusive with a dynamical critical exponent $z = 3/2$, matching the one of the Kardar-Parisi-Zhang (KPZ) universality class, which also lacks the time reversal symmetry. However, we find that fluctuations of the net magnetization transfer deviate from the KPZ predictions. Moreover, the full probability distribution of the associated spin current obeys fluctuation symmetry despite broken time-reversal and space-reflection symmetries. To further investigate the role of conserved quantities, we introduce an integrable quantum circuit that shares the essential symmetries with the chiral ladder, and which exhibits analogous dynamical behaviour in the absence of energy conservation. Our work shows that time-reversal symmetry breaking is compatible with superdiffusion, but insufficient to stabilize the KPZ universality in integrable systems. This suggests that additional fundamental features are missing in order to identify the emergence of such dynamics in quantum matter.

6) **Aleix Bou Comas** (CSIC)

Title: *Measuring temporal entropies in experiments*

Abstract: We propose a novel experimental protocol to measure generalized temporal entropies in many-body quantum systems. Our approach involves using local operators as probes to characterize the out-of-equilibrium dynamics induced by a geometric double quench on a replicated system. Such protocol mimics the path-integral on the corresponding Riemann surface encoding generalized temporal entanglement. We present the results of tensor network simulations of one-dimensional systems which validate the protocol and demonstrate the experimental feasibility of measuring generalized temporal entropies, and we outline the experimental requirements for implementing these quenches using state-of-the-art quantum simulators. Therefore, our results provide a physical interpretation of the meaning of generalized temporal entropies. Furthermore, they reveal that the dynamics induced on two replicas of the Ising model in a transverse field differ qualitatively from the ones of its non-integrable extension, suggesting that generalized temporal entropies can be used as a tool for identifying different dynamical classes in quantum systems.

7) **Samuel Pickering** (Univ. of Birmingham)

Title: *Asymptotically Solvable Quantum Circuits*

Abstract: The discovery of chaotic quantum circuits with (partially) solvable dynamics has played a key role in our understanding of non-equilibrium quantum matter and, at the same time, has helped the development of concrete platforms for quantum computation. It was shown that solvability does not prevent the generation of chaotic dynamics, however, it imposes non-trivial constraints on the generated correlations. A natural question is then whether it is possible to gain insight into the generic case despite the latter being very hard to access. To address this question here we introduce a family of 'asymptotically solvable' quantum circuits where the solvability constraints only affect correlations on length scales beyond a tuneable threshold. This means that their dynamics are only solvable for long enough times: for times shorter than the threshold they are generic. We show this by computing both their dynamical correlations on the equilibrium (infinite temperature) state and their thermalisation dynamics following quantum quenches from compatible (asymptotically solvable) non-equilibrium initial states. The class of systems we introduce is generically ergodic but contains a non-interacting point, which we use to provide exact analytical results, complementing those of numerical experiments, on the non-solvable early time regime.

8) **Angelo Russotto** (SISSA, Trieste)

Title: *Diffusive entanglement spreading in the $\nu=1$ QSSEP model*

Abstract: We discuss the $\nu=1$ Quantum Symmetric Simple Exclusion Process, a one-dimensional system of free fermions with time-dependent, spatially uniform stochastic hopping amplitudes. We investigate the out-of-equilibrium entanglement spreading following global and inhomogeneous quantum quenches. For global quenches, we develop a diffusive quasiparticle picture that describes the full-time probability distribution of the entanglement entropy. For inhomogeneous quenches, we extend the framework of quantum generalized hydrodynamics to account for the underlying stochastic dynamics of the local quasiparticle occupation function.

15:25-16:00 Coffee break

16:00-16:30 **David Szasz-Schagrin** (Univ. of Bologna)

Title: *Construction and simulability of quantum circuits with free fermions in disguise*

Abstract: We provide a systematic construction for local quantum circuits hosting free fermions in disguise (FFD), both with staircase and brickwork architectures. Similar to the original Hamiltonian model introduced by Fendley, these circuits are defined by the fact that the Floquet operator corresponding to a single time step can not be diagonalized by means of any Jordan–Wigner transformation, but still displays a free-fermionic spectrum. Our construction makes use of suitable non-local transfer matrices commuting with the Floquet operator, allowing us to establish the free fermionic spectrum. We also study the dynamics of these circuits after they are initialized in arbitrary product states, proving that the evolution of certain local observables can be simulated efficiently on classical computers. Our work proves recent conjectures in the literature and raises new questions on the classical simulability of FFD.

16:30-17:00 **Viktor Eisler** (Univ. of Graz)

Title: *Hydrodynamics and entanglement under inhomogeneous driving*

Abstract: Time evolution and transport properties of integrable quantum many-body systems has been the topic of numerous investigations. While the hydrodynamic description starting from inhomogeneous initial states has been largely understood, much less is known about the setup where the time evolution operator itself is nonuniform. We present results for noninteracting fermions in two different setups: with periodically modulated hopping amplitudes, or a chemical potential gradient with arbitrary time-dependent slope. It is demonstrated that both cases admit a hydrodynamic description, while the driven ramp even allows for a complete analytic solution on the lattice. Moreover, we also show how these results help us to understand entanglement spreading along the chain.

17:00-17:30 **Guglielmo Lami** (CY Cergy-Paris)

Title: *Universality in the Anticoncentration of Noisy Quantum Circuits at Finite Depths*

Abstract: We present universal properties of anticoncentration in weakly noisy quantum circuits at finite depth. We develop a generic framework for single- and multi-qubit noise channels in the weak-noise limit and introduce an effective description in terms of a random matrix product operator (RMPO). Within this weak-noise regime, we show that distinct noise mechanisms act in a quantitatively similar way, yielding a universal distribution of bit-string probabilities that is largely independent of the microscopic noise channel and of the circuit architecture. We identify three depth-dependent regimes, each characterized by a distinct scaling of cross-entropy benchmarking (XEB) with rescaled

depth. In the shallow-depth regime, noise effects are perturbatively small; in the intermediate regime, circuit-induced fluctuations and noise compete on equal footing; and in the deep-depth regime, the output distribution becomes effectively classical, up to corrections that are exponentially small in the noise strength. We provide quantitative predictions for anticoncentration in generic finite-depth circuits and benchmark them against numerical simulations, finding excellent agreement even at shallow depths. Moreover, we show that, contrary to previous expectations, the late-time value of XEB provides direct access to the global circuit fidelity, even at large noise strengths. Our results are directly applicable to current quantum processors and demonstrate universal behavior beyond the pure random-matrix-theory regime, which only emerges at asymptotically large depths.

18:00-19:30

POSTER SESSION

+ APERO

(24 Rue Lhomond — Entrance Hall)

Programme Day 3

(13/03/26)

09:15-10:00 **Sara Murciano** (LPTMS, Paris)

Title: *Experimental observation of conformal field theory spectra*

Abstract: Conformal field theories (CFTs) feature prominently in high-energy physics, and condensed matter. For example, CFTs govern emergent universal properties of systems tuned to quantum phase transitions, including their entanglement or correlations. Much of the rich structure predicted by CFTs nevertheless remains unobserved in experiments. In this talk, I will present direct observations of the energy excitation spectra of emergent CFTs at quantum phase transitions, recovering universal energy ratios characteristic of the underlying field theories. By using a variant of the modulation technique, we furthermore study the dynamical structure factor of the critical system, which is closely related to the correlation of an underlying Ising conformal field.

10:00-10:30 Coffee break

10:30-11:15 **Gregoire Misguich** (IPhT, Saclay)

Title: *Global correlation surge in the quantum Ising chain*

Abstract: tba

11:15-11:45 **Harold Erbin** (CEA, Saclay)

Title: *Many-body Quantum Score: A scalable benchmark for digital and analog QPUs and first results on a commercial neutral-atom device*

Abstract: We propose the Many-body Quantum Score (MBQS), a practical and scalable application-level benchmark protocol designed to evaluate the capabilities of quantum processing units (QPUs) – both gate-based and analog – for simulating many-body quantum dynamics. MBQS quantifies performance by identifying the maximum number of qubits with which a QPU can reliably reproduce correlation functions of the transverse-field Ising model following a specific quantum quench. In this talk, I will present the MBQS protocol and highlight its design principles, supported by analytical insights, classical exact and noisy simulations, and experimental data. I will also share preliminary results obtained with Ruby, an analog QPU based on Rydberg atoms developed by Pasqal, which is soon to be deployed at the TGCC. These findings demonstrate MBQS's potential as a robust and informative tool for benchmarking near-term quantum devices for many-body physics.

11:45-12:15 **Maciej Łebek** (Univ. of Warsaw)

Title: *Kinetic theory and effective hydrodynamic equations in nearly integrable gases*

Abstract: When a gas of particles interacts with much a larger reservoir the density dynamics on large scales is typically governed by diffusion. We study this paradigmatic problem for weakly coupled integrable systems and show that this picture gets altered, when transport is investigated on top of long-lived non-thermal states. Remarkably, for states non-invariant under parity we find Burgers equation arising in the hydrodynamic limit. We explicitly compute the diffusion constant and nonlinear advective coefficient of the Burgers equation using a variant of the Chapman-Enskog theory. We find an excellent agreement between our theory and numerical simulations of a simplified model of stochastic two-body collisions. Our conclusions are based only on Galilean invariance, existence of a small system-bath coupling parameter and a small momentum exchange between the system and the bath particles during two-body scattering.

12:15

END OF THE CONFERENCE