IQIS 25
BOLOGNA

BOOKLET OF ABSTRACTS

TALKS

Advanced schemes for quantum states encoding

- Speaker: Giulia Ferrini **Keynote**
- Affiliation: Chalmers University of Technology

The encoding of quantum states is crucial in quantum information and may provide advantages for long-distance quantum communication protocols, both over optical fibres as well as free space links. Due to its inherent robustness, the Sagnac interferometer has been used for several functions in both CV ad DV encoding, showing advancements in the quality of qubit generation, also tested i in the space channel. The possibility of generating high-dimensional quantum states will be also discussed.

Exploring Quantum Structures: Contrasting the Typical and Atypical

- Speaker: Klaus Jons **Keynote**
- Affiliation: Paderborn University

We analyze the following quantum structures: the set Ω_N of mixed quantum states of order N, the set of discrete quantum operations (completely positive, trace preserving maps) acting on Ω_N and the set of Lindblad operators generating continuous dynamics in Ω_N. On one hand, we investigate typical quantum states, operations and Lindblad operators. In each case their statistical properties, studied with suitable ensembles of random matrices, serve as reference points. On the other hand, we look for atypical quantum objects with extremal properties and identify some examples of highly entangled multipartite states and strongly entangling quantum gates. Furthermore, we analyze discrete structures in the Hilbert space, including quantum t-designs: collections of M objects, chosen in such a way that the average over them approximates the average over the measure analyzed for all functions of degree t. In particular, we demonstrate a link between projective designs (consisting of pure quantum states) with classical simplex designs, mixed states quantum designs and quantum operation designs.

Hybrid and Heterogenous Photonic Integration for Photonic Quantum Technologies

- Speaker: Sabrina Maniscalco **Keynote**
- Affiliation: University of Helsinki

To unleash the full potential of photonic quantum technologies we are urged to miniaturize and integrate our systems. Scalability and the integration of all required building blocks on a single platform are the most pressing challenges of photonic quantum technologies. Photon losses in classical photonic circuits are typically orders of magnitude too high for large-scale quantum photonic applications. In recent years' tremendous effort has been put into the integration of architecture for quantum technologies, reducing transmission losses and thus realizing the first complex quantum photonic integrated circuits. In my talk I will discuss the progress on a global scale and highlight important developments on the material platforms used and the integration methods. Furthermore, I will give an overview of necessary building blocks for quantum photonic technologies, including classical control units, and give details on the integration of different quantum light sources. There are several approaches and material platforms to integrate quantum light sources on chip with different advantages and disadvantages.

Classical simulation, quantum resources and error correction of continuous- and discrete-variables quantum computers

- Speaker: Karol Zyczkowski **Keynote**
- Affiliation: Jagiellonian University Cracow

In this talk, I will present an overview of recent research developments from my group, covering three main directions: classical simulation of quantum computers, the resource theory of quantum computation, and the protection of quantum information using bosonic codes. A key challenge in the development of quantum computing architectures is the design of classical algorithms capable of reliably simulating quantum computations. Although such simulations are generally inefficient, they provide essential benchmarks for validating experimental platforms. I will discuss our latest work on classical simulation techniques for both discrete- and continuous-variable quantum systems, highlighting how the computational complexity of these simulations correlates with the resource content of the underlying quantum circuits, as quantified by suitable resource monotones. In the last part of the talk, I will shift focus to quantum error correction in continuous-variable systems. Specifically, I will describe our recent advances in encoding quantum information using bosonic codes. I will compare the performance of codes with rotational and translational symmetries under realistic noise conditions, and analyse their behaviour in the presence of more exotic, non-Markovian, noise models. Finally, I will outline a new construction of multimode bosonic codes with rotational symmetry, demonstrating how they can achieve enhanced protection of quantum information.

Quantum Artificial Intelligence: From Vision to Implementation

- Speaker: Giovanni Acampora **Contributed**
- Affiliation: University of Napoli Federico II

TBA

Non-Markovianity of quantum processes is a fundamental thermodynamic resource

- Speaker: Gerardo Adesso **Contributed**
- Affiliation: University of Nottingham

Quantum thermodynamics studies how quantum systems and operations may be exploited as sources of work to perform useful thermodynamic tasks. In real-world conditions, the evolution of open quantum systems typically displays memory effects, resulting in a non-Markovian dynamics. The associated information backflow has been observed to provide advantage in certain thermodynamic tasks. However, a general operational connection between non-Markovianity and thermodynamics in the quantum regime has remained elusive. Here [1], we analyze the role of non-Markovianity in the central task of extracting work via thermal operations from general multitime quantum processes, as described by process tensors. By defining a hierarchy of four classes of extraction protocols, expressed as quantum combs, we reveal three different physical mechanisms (work investment, multitime correlations, and system-environment correlations) through which non-Markovianity increases the work distillable from the process. The advantages arising from these mechanisms are linked precisely to a quantifier of the non-Markovianity of the process. These results show in very general terms how non-Markovianity of any given quantum process is a fundamental resource that unlocks an enhanced performance in thermodynamics.

[1] G. Zambon and G. Adesso, Phys. Rev. Lett. 134, 200401 (2025).

Universal bounds for noisy quantum metrology in presence of uncorrelated and correlated noise

- Speaker: Francesco Albarelli **Contributed**
- Affiliation: Scuola Normale Superiore

In this talk, I will discuss recent advancements in understanding the ultimate precision limits of noisy quantum metrology for finite-dimensional systems, focusing on scenarios involving N uses of a parameter-encoding channel under the most general adaptive strategies. A key result is the derivation of novel bounds on the quantum Fisher information, based on purifications of the noisy state. These bounds are applicable to both uncorrelated and correlated noise [1]. For uncorrelated noise, the bound is saturable by parallel strategies in the asymptotic regime, which demonstrates the equivalence of parallel and adaptive strategies in achieving optimal precision, irrespective of whether Heisenberg scaling is allowed or forbidden by noise [2]. Additionally, this framework provides insights into more unconventional strategies, such as those involving causal superpositions of channels, showing that these do not offer an asymptotic advantage over parallel strategies, even if an advantage for finite number of uses may be present. While the bounds for correlated noise are not guaranteed to be tight in general, their tightness may be systematically increased by increasing the numerical complexity of the procedure. We applying this framework to study phase estimation in presence of temporally correlated dephasing, showing that i) negative correlations are beneficial for parallel dephasing (no Heisenberg scaling), and ii) the bounds are tight for perpendicular dephasing (Heisenberg scaling). Refs:[1] arXiv:2410.01881[2] Phys. Rev. Lett. 131, 090801 (2023). The activities mentioned herein are performed in the framework of the Marie Skłodowska-Curie Action EU-HORIZON-MSCA-2021PF-01 (project QECANM, grant n. 101068347).

Hybrid state-discrimination strategy exploiting classical and nonclassical resources

- Speaker: Alessia Allevi **Contributed**
- Affiliation: University of Insubria

In communication protocols, reliably discriminating the alphabet in which a message is encoded is crucial. Depending on the complexity of the message and the security of the transmission channel, different discrimination strategies can be employed, based on direct and homodyne detection systems. In most cases, optical communication protocols involve coherent states of light, due to their relative robustness compared to nonclassical states. However, the use of quantum resources could improve the security of transmission channels by enabling detection of eavesdropping attempts. Here we propose a hybrid communication protocol that uses photon-number-resolving detectors to reliably discriminate binary signals by their mean photon number (a classical property) and leverages nonclassical correlations of mesoscopic twin-beam states to ensure security. Operating in the mesoscopic intensity regime enhances robustness, and the protocol supports extension to more complex alphabets.

Precision is not limited by the second law of thermodynamics

- Speaker: Tony John George Apollaro **Contributed**
- Affiliation: University of Malta

Physical devices operating out of equilibrium are affected by thermal fluctuations, limiting their operational precision. This issue is particularly pronounced at microscopic and quantum scales, where its mitigation requires additional entropy dissipation. Understanding this constraint is important for both fundamental physics and technological design. Clocks, for example, need a thermodynamic flux towards equilibrium to measure time, resulting in a minimum entropy dissipation per clock tick. Although classical and quantum models often show a linear relationship between precision and dissipation, the ultimate bounds on this relationship remain unclear. In this talk an autonomous quantum many-body clock model is presented. Such a clock achieves a precision that scales exponentially with entropy dissipation due to the coherent transport in a spin chain with tailored couplings, where dissipation is confined to a single link. The result demonstrates that coherent quantum dynamics can surpass traditional thermodynamic precision limits. Meier, F., Minoguchi, Y., Sundelin, S. et al. Precision is not limited by the second law of thermodynamics. Nat. Phys. (2025). https://doi.org/10.1038/s41567-025-02929-2

Nonlinear integrated photonic circuits with hibrid light-matter excitations

- Speaker: Vincenzo Ardizzone **Invited**
- Affiliation: CNR-Naontech

TBA

Average-computation benchmarking for digital quantum devices

- Speaker: Flavio Baccari **Contributed**
- Affiliation: University of Padova

Benchmarking schemes currently used in quantum computing experiments suffer from a fundamental limitation: they cannot be run on the circuit of interest. Testing a classically-hard computation is restricted to small scale or shallow depth, where a brute force simulation is possible. There is nevertheless clear evidence that errors can change with the system size, the circuit depth and be gate-dependent. It is therefore essential to devise schemes that can test the behaviour of the actual computation in its final form. I will present a benchmarking scheme that solves this issue and is applicable to any near-term quantum computation. The scheme is based on taking data from the desired computation and variations of it, chosen in a way that the average output over all computation admits a classical simulation, even when the single computations do not. I will show benchmarking examples based on a family of solvable channels and argue how the average computation inherits relevant properties of the original computation.

Out-of-distribution generalisation for learning quantum channels with low-energy coherent states

- Speaker: Leonardo Banchi **Contributed**
- Affiliation: University of Florence

When experimentally learning the action of a continuous variable quantum process by probing it with inputs, there will often be some restriction on the input states used. One experimentally simple way to probe the channel is using low-energy coherent states. Learning a quantum channel in this way presents difficulties, due to the fact that two channels may act similarly on low energy inputs but very differently for high energy inputs. They may also act similarly on coherent state inputs but differently on non-classical inputs. Extrapolating the behaviour of a channel for more general input states from its action on the far more limited set of low energy coherent states is a case of out-of-distribution generalisation. To be sure that such generalisation gives meaningful results, one needs to relate error bounds for the training set to bounds that are valid for all inputs. We show that for any pair of channels that act sufficiently similarly on low energy coherent state inputs, one can bound how different the input-output relations are for any (high energy or highly non-classical) input. This proves out-of-distribution generalisation is always possible for learning quantum channels using low energy coherent states.

Dissipative quantum North-East-Center model: steady-state phase diagram, universality and nonergodic dynamics

- Speaker: Alberto Biella **Contributed**
- Affiliation: CNR-INO, Pitaevskii BEC center, Trento

In this talk, we discuss the dissipative quantum North-East-Center (NEC) model: a two-dimensional spin-1/2 lattice subject to chiral, kinetically constrained dissipation and coherent quantum interactions. This model combines kinetic constraints and chirality at the dissipative level, implementing local incoherent spin flips conditioned by an asymmetric majority-vote rule. Using a cluster mean-field approach, we determine the steady-state phase diagram of the NEC model under different Hamiltonians, consistently revealing the emergence of two distinct phases—bistable and normal—across all cases considered. Next, I will discuss the nonergodicity of the model in the bistable phase. Here, chiral dissipation induces the reabsorption of minority spin islands when they are surrounded by a large background of oppositely oriented spins. This reabsorption occurs at a constant velocity, independent of the island's size, a distinctive feature of the NEC model. We propose a phenomenological theory for the reabsorption dynamics to understand how the absorption velocity scales with system parameters, including quantum fluctuations at leading order.

[1] Pietro Brighi, AB, https://arxiv.org/abs/2506.19011

Perfect Absorption of Single-Photons in Molecular Spin-based Quantum Circuits

- Speaker: Claudio Bonizzoni **Contributed**
- Affiliation: University of Modena and Reggio Emilia

We have shown that it is possible to encode spin qubits into hybrid architectures obtained by integrating molecular spins into planar microwave superconducting resonators [1,2] and to use them as memories for information [1]. These hybrid architectures can work also for quantum sensing of magnetic fields, where the amplitude or the phase of an AC field synchronized with the microwave sequence driving the spin echo can be inferred [3]. Here sensitivity up to nT/√Hz can be achieved using Dynamical Decoupling [3]. Here we consider molecular spin qubits strongly coupled to a lumped element microwave superconducting Niobium resonator at mK temperature and in the single photon regime [4]. The parameters of the system are chosen to implement an open quantum system without PT-symmetry, and which can be described by a non-Hermitian Hamiltonian. We experimentally show that is it possible to obtain points of Perfect Absorption in which zero reflectivity (i.e. no outcoming single photon) is observed detuned from resonance, at two symmetric positions with respect to it. Our analysis reveals that this is achieved thanks to the interplay and balance between radiative and non-radiative losses mediated by the spin detuning, which controls the spin-photon mixing of each polariton. We then experimentally investigate the transition from the strong to the weak spin-photon coupling regime, showing that Perfect Absorption can be still achieved down to the weak spin-photon coupling regime [4]. Our analysis allows us to directly link and interpretate the observation of Perfect Absorption with the recovery of Hermitian subspaces into our initial non-Hermitian Hamiltonian. These results largely extend the possibility to study Perfect Absorption and to exploit it in quantum technologies, with potential benefits for single-photon switches and for quantum sensing [4].

REFERENCES: [1] C. Bonizzoni, A. Ghirri, F. Santanni, M. Atzori, L. Sorace, R. Sessoli and M. Affronte, Storage and retrieval of microwave pulses with molecular spin ensembles, npj Quantum Inf. 6, 68 (2020). [2] C. Bonizzoni, M. Maksutoglu, A. Ghirri, J. Van Tol, B. Rameev and M. Affronte, Coupling Sub-nanoliter BDPA Organic Radical Spin Ensembles with YBCO Inverse Anapole Resonators, Appl. Magn. Reson. 54, 143 (2023). [3] C. Bonizzoni, A. Ghirri, F. Santanni and M. Affronte, Quantum sensing of magnetic fields with molecular spins, npj Quantum Inf. 10, 41 (2024). [4] C. Bonizzoni, D. Lamberto, S. Napoli, S. Gunzler, D. Rieger, F. Santanni, A. Ghirri, W. Wernsdorfer, S. Savasta and M. Affronte, Observation of Perfect Absorption in Hyperfine Levels of Molecular Spins with Hermitian Subspaces – submitted (2025). Preprint on arXiv:2505.05966

A new regime of non-Markovianity: non-causal revivals VS genuine backflows of information in open quantum systems dynamics

- Speaker: Francesco Buscemi **Contributed**
- Affiliation: Nagoya University

It is well known that convex combinations of Markov processes typically result in non-Markov ones. In this talk I will review some notions of (non-)Markovianity for quantum stochastic processes focusing in particular on a recent proposal to quantify information backflows after classical memories have been suitably "squashed" out. Such a squashed non-Markovianity, besides suggesting a notion of genuine (or causal) information revivals, is also able to resolve the problem of non-convexity, thus clarifying the role of genuine non-Markovianity as a resource for quantum information processing. Reference: PRX Quantum 6, 020316 (2025).

Integrability and Chaos via fractal analysis of Spectral Form Factors: Gaussian approximations and exact results

- Speaker: Lorenzo Campos Venuti **Contributed**
- Affiliation: University of Naples Federico II

We show how to associate to any quantum Hamiltonian H, a random walk on the plane, and study the properties of H via the features of its fractal, in particular the fractal dimension of its frontier d_F. We show that, under two assumptions, in the thermodynamic limit the random walk becomes a Wiener process, the infinite-dimensional generalization of the Gaussian, and is characterized by a frontier with $d_F = 4/3$, the value obtained for Wiener processes via Schramm Loewner Evolution (SLE). We show numerically that, for non-integrable many-body models, indeed $d_f \simeq 4/3$. For integrable models, the relations among the energy levels constrain the frontier to $d_F \simeq 1$. As a byproduct of our analysis, we compute exactly the moments of the spectral form factor, a quantity that has applications in quantum chaos and black-hole dynamics.

Photonic Quantum Processing: From Randomness Manipulation to Adaptive Quantum Machine Learning

- Speaker: Gonzalo Carvacho **Invited**
- Affiliation: QuantumLab - Sapienza University of Rome

This talk presents recent experimental advances in photonic quantum technologies for randomness manipulation and quantum machine learning. Central to the discussion is the quantum-to-quantum Bernoulli factory, a protocol that transforms input quantum randomness into controlled output distributions. We showcase two implementations: one using path-encoded qubits on a programmable integrated photonic chip, enabling modular and bias-independent randomness transformations; the other using polarization-encoded photons from quantum dot sources in bulk interferometric setups, performing algebraic operations like inversion, multiplication, and addition. Exploiting the capabilities of universal integrated devices, we explore the use of Adaptive Boson Sampling via post-selection as a quantum machine learning primitive. Implemented on a reconfigurable photonic circuit built through femtosecond laser writing, this approach introduces adaptivity into non-universal linear optics, enhancing learning capabilities through effective dimensional expansion. Together, these results demonstrate how integrated and bulk photonic platforms can drive scalable quantum information processing, from randomness engineering to machine learning.

Daemonic Ergotropy in Continuously Monitored Dicke Quantum Batteries

- Speaker: Gabriele Cenedese **Invited**
- Affiliation: University of Insubria

Dicke quantum batteries represent a paradigmatic model for quantum energy storage. Previous studies have shown that, even in the presence of dissipation and under strong coupling conditions, these systems can exhibit superextensive power scaling in the thermodynamic limit. However, for finite-size systems, the extractable energy, quantified by the ergotropy, vanishes due to the approach to a passive steady state. In this work, we show that by continuously monitoring the photon output from the cavity - using quantum trajectory methods within the framework of open quantum systems - it is possible to restore a superextensive scaling of the ergotropic power even in finite systems, specifically in terms of the so-called daemonic ergotropy. This result highlights the potential of continuous measurement protocols as a practical route toward experimentally realizable quantum batteries.

Dissipation and non-thermal states in cryogenic cavities

- Speaker: Giuliano Chiriacò **Contributed**
- Affiliation: University of Catania

We study the properties of photons in a cryogenic cavity, made by cryo-cooled mirrors surrounded by a room temperature environment. We model such a system as a multimode cavity coupled to two thermal reservoirs at different temperatures. Using a Lindblad master equation approach, we derive the photon distribution and the statistical properties of the cavity modes, finding an overall non-thermal state described by a mode-dependent effective temperature. We also calculate the dissipation rates arising from the interaction of the cavity field with the external environment and the mirrors, relating such rates to measurable macroscopic quantities. These results provide a simple theory to calculate the dissipative properties and the effective temperature of a cavity coupled to different thermal reservoirs, offering potential pathways for engineering dissipations and photon statistics in cavity settings.

Enhanced control of single-molecules for quantum technologies

- Speaker: Maja Colautti **Invited**
- Affiliation: CNR-INO

The generation and manipulation of quantum states of light is required for key applications, such as photonic quantum simulation, linear optical quantum computing, quantum communication protocols, and quantum metrology. In this context, I will present our recent advancements in using single organic molecules at cryogenic temperature as bright and stable sources of coherent single photons in the solid state [1]. In particular, I will focus on our results on two-photon interference (TPI) experiments performed between distinct molecules on the same chip [2], and our recent insights on how to mitigate the practical limitations on the TPI among distinct emitters via the control of the electrical environment at the nanoscale. Indeed, we recently provided experimental demonstration of a hybrid tuning method for controlling the frequency of quantum emitters and at the same time to reduce the emitter sensitivity to charge noise, controlling spectral fluctuations [3]. This successful strategy is based on the combined use of the electric field generated by electrodes and of optically excited long-lived charge states [4], which provide two efficient knobs for enhanced control of single-molecule emitters for quantum photonic experiments. References [1] [2] [3] [4] Colautti, M. et al., Toninelli, C., et al., Nat. Mater. 20, 1615–1628 (2021). Duquennoy, R. et al., Optica 9 , 731-737 (2022). Duquennoy, R. et al., ACS Nano 18 (47), 32508–32516 (2024). ACS Nano 14 (10), 13584–13592 (2020).

Correlation imaging, from 3D to hyperspectral

- Speaker: Milena D'Angelo **Contributed**
- Affiliation: University of Bari

We shall present recent advances in correlation imaging modalities enabling scanning-free high-resolution hyperspectral imaging, 3D imaging and 3D microscopy, with at least one order of magnitude advantage over typical tradeoffs such as resolution versus depth of field and spatial versus spectral resolution. Both entangled light beams and chaotic light are employed, depending on the specific application scenario. Speed-up unabled by both SPAD arrays and AI denoising approaches are presented, demonstrating the effective capability of the presented approaches to compete with state of the art approaches, while overcoming their intrinsic limitations.

Harnessing Quantum Extreme Learning Machines for image classification

- Speaker: Annalisa De Lorenzis **Contributed**
- Affiliation: IFAE & Qilimanjaro

Interest in quantum machine learning is growing due to its potential to offer more efficient solutions for problems that are difficult to tackle with classical methods. In this context, the research work presented here focuses on the use of quantum machine-learning techniques for image-classification tasks. We exploit a quantum extreme learning machine by taking advantage of its rich feature map provided by the quantum reservoir substrate. We systematically analyze different phases of the quantum extreme learning machine process, from dataset preparation to final image classification. In particular, we test different encodings, together with principal component analysis and the use of autoencoders, and we examine the dynamics of the model through the use of different Hamiltonians for the quantum reservoir. Our results show that the introduction of a quantum reservoir systematically improves the accuracy of the classifier. In addition, our findings indicate that variations in encoding methods can significantly influence performance and that Hamiltonians with distinct structures exhibit the same discrimination rate, depending on how their eigenstates are related to the encoding and measurement basis. We will present the recently published findings along with new insights from our current research, which expands and deepens the work already carried out.

Simulating open quantum systems with structured photons

- Speaker: Francesco Di Colandrea **Contributed**
- Affiliation: University of Ottawa

The evolution of a quantum system interacting with an environment can be described as a unitary process acting on both the system and the environment. In this framework, the system's effective dynamics can be obtained by tracing out the environmental degrees of freedom. By modeling the environment as a discrete lattice space, it is possible to simulate arbitrary open dynamics of a qubit system. We experimentally validate this concept in a photonic circuit, where the system is encoded into single-polarization qubits and the environment into the photons' spatial structure. This approach enables the simulation of arbitrary quantum channels by using a minimal set of three liquid-crystal metasurfaces, whose transverse optic-axis distributions can be patterned to reproduce the target process. We use this technique to simulate common noise processes, such as dephasing and depolarization. Besides providing a practical solution for quantum state purification, this approach could have significant implications for quantum error correction and environment-induced quantum phase transitions.

Quantum Information meets High-Energy Physics

- Speaker: Federica Fabbri **Contributed**
- Affiliation: University of Bologna and INFN Bologna

Some of the most astonishing and prominent properties of Quantum Mechanics, such as entanglement and Bell nonlocality, have been studied extensively in dedicated low-energy laboratory setups. The feasibility of these studies in the high-energy regime explored by particle colliders was only recently shown, and has gathered the attention of the scientific community. For the range of particles and fundamental interactions involved, particle colliders provide a novel environment where quantum information theory can be probed, with energies exceeding by about 12 orders of magnitude those employed in dedicated laboratory setups. Here, I will present the potential, challenges, and goals of this innovative and rapidly evolving line of research, and discuss its expected impact on both quantum information theory and high-energy physics (HEP). One striking example of the potential in HEP is the sensibility of quantum information inspired observables to the presence of new particles, not included in the standard model. I will present both the overall state of the art and plans for the field, summarized in a recent paper presented as input to the European strategy for particle physics, and our work at the University of Bologna.

Critical Parametric Quantum Sensing - Theory and Experiment

- Speaker: Simone Felicetti **Contributed**
- Affiliation: Complex systems Insitute CNR-ISC e Sapienza University of Rome

Critical quantum sensing (CQS) is by now a well-established approach, based on quantum properties spontaneously developed in proximity of phase transitions. Theoretical studies and first experimental demonstrations show that a quantum-enhanced sensing precision can be achieved by exploiting phase transitions in many-body systems. It has been recently shown that CQS protocols can also be implemented using driven-dissipative phase transitions, where the thermodynamic limit is replaced with a rescaling of the system parameters. This class of phase transitions can emerge in small-scale systems, such as quantum resonators with atomic or Kerr-like nonlinearities, and it is of high theoretical and experimental relevance.

Here, we discuss how optimal [1] CQS protocols can be implemented using a critical parametric resonator, without the need to implement and control complex many-body systems. We then show that a collective quantum advantage can be achieved in a multipartite CQS protocol using a chain of parametrical critical resonators [2]. Finally, we report on the experimental implementation [3,4] of a driven-dissipative CQS protocol with a superconducting resonator, with direct applications in quantum magnetometry and superconducting-qubit readout.

[1] U. Alushi et al. Phys. Rev. Lett. 133, 040801 (2024)
[2] U. Alushi et al. Communications Physics 8, 74 (2025)
[3] G. Beaulieu et al. PRX Quantum 6 (2), 020301 (2025)
[4] G. Beaulieu et al. Nat. Comm. 16 (1), 1954 (2025)

Machine Learning Approaches for Quantum Computing at Polimi: Ansatz Design, Minor Embedding, and Bosonic State Preparation

- Speaker: Maurizio Ferrari Dacrema **Invited**
- Affiliation: Polytechnic university of Milan

This talk presents an overview of recent research activities at the Quantum Computing Lab of Politecnico di Milano, focused on the application of artificial intelligence to quantum computing. The first part discusses reinforcement learning approaches for the automated design of variational quantum circuits, aimed at the discovery of new ansatzes for specific combinatorial optimization tasks. The second line of work addresses the minor embedding problem in quantum annealing, where we employ reinforcement learning and graph neural networks to map the general structure of an optimization problem into one that can fit the limited qubit connectivity of the quantum hardware. Finally, we describe ongoing work on state preparation for bosonic quantum computers using the SNAP-displacement protocol. This project, carried out in collaboration with the Superconducting Quantum Materials and

Systems (SQMS) Center at Fermilab, explores strategies to drastically reduce the number of phases in the ansatz that should be optimized and develops a multi-objective optimization goal to combine state fidelity and resource requirements.

Harnessing quantum back-action for time-series processing

- Speaker: Giacomo Franceschetto **Contributed**
- Affiliation: ICFO

Quantum measurements affect the state of the observed systems via back-action. While projective measurements extract maximal classical information, they drastically alter the system. In contrast, weak measurements balance information extraction with the degree of disturbance. Considering the prevalent use of projective measurements in quantum computing and communication protocols, the potential benefits of weak measurements in these fields remain largely unexplored. In this work, we demonstrate that incorporating weak measurements into a quantum machine-learning protocol known as quantum reservoir computing provides advantages in both execution time scaling and overall performance. We analyze different measurement settings by varying the measurement strength across two benchmarking tasks. Our results reveal that carefully optimizing both the reservoir Hamiltonian parameters and the measurement strength can significantly improve the quantum reservoir computing algorithm performance. This work provides a comprehensive and practical recipe to promote the implementation of weak measurement-based protocols in quantum reservoir computing. Moreover, our findings motivate further exploration of experimental protocols that leverage the back-action effects of weak measurements.

Experimental preparation of W-States through many-body physics on a quantum simulator

- Speaker: Fabio Franchini **Contributed**
- Affiliation: Rudjer Boskovic Institute

W-states are quantum states possessing both bipartite and multipartite entanglement and are necessary for several relevant quantum algorithms. We propose a protocol to generate them with an arbitrary number of qubits on a Rydberg atoms platform, by exploiting ring (topological) frustration. To validate our state preparation, we develop a new Bayesian state tomography approach that leverage on accurate classical numerical simulations. In this way we prove high fidelities experimentally (up to 11 qubits) and numerically argue about promising scaling for tens of qubits. With this work, not only do we reach an unparalleled accuracy for the generation of these states compared to the existing approaches, but we also show once more how physics principles can overcome traditional barriers and be exploited toward quantum advantage.

Noise classification in small quantum networks by Machine Learning.

- Speaker: Luigi Giannelli **Invited**
- Affiliation: University of Catania

We investigate a machine learning based classification of noise acting on a three-level system with the aim of detecting spatial or multilevel correlations, and the interplay with Markovianity. We control a three-level system by inducing coherent population transfer exploiting different pulse amplitude combinations as inputs to train a feedforward neural network. We show that supervised learning can classify different types of classical dephasing noise affecting the system. Three non-Markovian ((1) quasi-static correlated, (2) quasi-static anti-correlated and (3) quasi-static uncorrelated) and (4) Markovian noises are classified with more than 99% accuracy. On the contrary, Markovian (4a) correlated and (4b) anti-correlated noise cannot be discriminated with our method. We then extend the protocol to a network of two ultrastrongly coupled qubits driven by symmetric STIRAP-based control. Remarkably, in this case, our approach achieves over 95% accuracy in classifying these noise classes, including classification between Markovian correlated and anti-correlated noise. The method requires minimal experimental resources, relying solely on three inputs to a shallow neural network, without the need for time-series data or real-time monitoring. Our results highlight how the combination of coherent control and machine learning analysis can improve the characterization of quantum-hardware.

Towards ultrafast and ambient temperature quantum logic operations in Mott materials

- Speaker: Claudio Giannetti **Contributed**
- Affiliation: Catholic University of Sacro Cuore

Achieving the full control of the insulator-to-metal transition in Mott materials is key for the next generation of electronics devices, with applications ranging from ultrafast transistors, artificial neurons for neuromorphic computing and quantum computation. We will review the state-of-the-art knowledge of the Mott transition, with specific focus on the paradigmatic Mott insulator V2O3. We will emphasize the current attempts in controlling the Mott switching dynamics via the application of external voltage and electromagnetic pulses and we will address the possibility of achieving quantum coherent control of the transition dynamics. The possibility of implementing ultrafast quantum logic operations at ambient temperature will be discussed.

Maxwell's demon for open quantum systems

- Speaker: Giacomo Guarnieri **Contributed**
- Affiliation: University of Pavia

Feedback control of open quantum systems is of fundamental importance for practical applications in various contexts, ranging from quantum computation to quantum error correction and quantum metrology. Its use in the context of thermodynamics further enables the study of the interplay between information and energy, as exemplified by the famous Maxwell's demon thought experiment that led to the notorious and important Landauer's bound. In this talk I will start by investigating the impact of genuine quantum features on Landauer's erasure in the slow driving regime, demonstrating that quantum coherence generated in the energy eigenbasis of a system undergoing a finite-time information erasure protocol yields rare events with extreme dissipation. The second part of this talk will be devoted to a different aspect of the same problem, namely the one of deriving optimal feedback control strategies. This highly challenging task gets even richer in the quantum regime, as it involves the optimal control of open quantum systems, the stochastic nature of quantum measurement, and the inclusion of policies that maximize a long-term time- and trajectory-averaged goal. In a recent work we employed a reinforcement learning approach to automate and capture the role of a quantum Maxwell's demon: the agent takes the literal role of discovering optimal feedback control strategies in qubit-based systems that maximize a trade-off between measurement-powered cooling and measurement efficiency.

From Classical Internet to the Quantum Internet: primitives and perspectives

- Speaker: Jessica Illiano **Invited**
- Affiliation: University of Naples Federico II

Internet has undergone remarkable transformations since its inception, evolving from a simple network with a handful of static nodes to a highly complex system connecting billions of devices worldwide. However, one fundamental principle has remained constant throughout its five-decade evolution: transmitting information encoded as classical bits. Yet, this foundational assumption is now being challenged by the Quantum domain. Quantum devices require novel communication capabilities such as the distribution of entangled states and the transmission of quantum information. More in detail, quantum networks exploit phenomena that have no direct equivalent in classical networking and demand a communication paradigm shift in network design. Indeed, they prohibit simply adopting classical networking solutions without significant modifications. I will present an overview of the basic communication primitives needed by quantum networking and discuss why entanglement and quantum communications demand a design effort towards different network protocols. The talk will conclude with a discussion of recent works on the interconnection of the building blocks of the Quantum Internet, namely, Quantum Local Area Networks (QLANs), and insights on their practical relevance in the framework of quantum data centers.

Self-testing Slater state

- Speaker: Arturo Konderak **Contributed**
- Affiliation: Center for Theoretical Physics, Polish Academy of Sciences

Self-testing is a procedure that refers to characterizing uniquely quantum states and quantum strategies from the set of quantum correlations. It has been proven that all pure entangled states can be self-tested in the bipartite case, whereas for a general multipartite system, a complete characterization is still lacking. We propose a strategy that allows for self-testing a specific class of multiparticle states, namely, the Slater states, which are multipartite antisymmetric states. Interestingly, this strategy is powerful as the number of local measurements and outcomes is constant and independent of the number of parties.

Information Loss in Quantum Channels Induced by Self-Gravity

- Speaker: Alessio Lapponi **Contributed**
- Affiliation: Scuola Superiore Meridionale

We analyze the information-theoretic consequences of a quantum particle interacting with its own gravitational field, modeled within linearized quantum gravity. By treating the resulting non-unitary time evolution as a quantum channel, we compute its classical and quantum capacities. The particle emits virtual gravitons that subsequently re-interact with it, effectively inducing a composite quantum channel characterized by dephasing and erasure. The dephasing component increases dynamically as gravitons propagate across the particle's spatial extent, saturating when the entire particle becomes causally connected via the gravitational field. This yields a novel prediction: the gravitationally-induced dephasing is proportional to the particle's size. Additionally, the presence of an external gravitational source introduces an erasure probability that increases with proximity to the source, effectively masking quantum gravitational effects. Therefore, to isolate decoherence effects purely from self-gravity, the particle must be sufficiently far from external gravitational fields.

Quantum Extreme Learning Machines for Molecular Modeling and Biochemical Classification.

- Speaker: Salvatore Lorenzo **Invited**
- Affiliation: Physics and Chemistry Department, University of Palermo

Quantum Extreme Learning Machines (QELMs) are emerging as powerful tools for quantum machine learning, offering resource-efficient training and promising performance on near-term quantum devices. We present recent advances in the application of QELMs to two key problems: molecular modeling and biological classification. First, we demonstrate the use of QELMs to learn potential energy surfaces and force fields for molecular systems such as lithium hydride, water, and formamide. Our method is tailored for NISQ devices, requiring only linear regression on a classical backend and a minimal quantum circuit, achieving high predictive accuracy in both noiseless simulations and real hardware implementations on IBM quantum processors. Second, we report one of the first applications of QELMs to a biologically relevant classification task, inferring the activity of peptides based on compositional and structural descriptors. Using feature sets with up to 56 dimensions, we show that QELMs can outperform classical algorithms under ideal conditions and remain competitive in noisy settings comparable to current hardware, such as the Quantinuum H1 processor, without requiring error correction. These results highlight QELMs as a scalable and noise-resilient quantum machine learning framework for realistic scientific problems.

Non-Gaussianity and the Restoration of Quantum Complexity

- Speaker: Luca Lumia **Invited**
- Affiliation: SISSA, ICTP

Non-Gaussianity, entanglement, and non-stabilizerness are fundamental quantum resources, each capturing distinct facets of quantum complexity that are necessary for achieving quantum advantage. Free fermionic systems are known to exhibit atypical behavior compared to generic quantum many-body systems. For instance, in random matchgate circuits, the bipartite entanglement entropy grows only diffusively with time, and the volume-law entangled phase is unstable under any weak monitoring, which reduces it to a logarithmic scaling. We investigate how generic many-body features can be recovered by introducing a controlled amount of non-Gaussian resources, effectively inducing interactions among the fermions. We study both unitary injections of non-Gaussianity and non-unitary injections through measurements, analyzing their impact on entanglement growth and highlighting the unique dynamical properties of this resource, quantified by the relative entropy of non-Gaussianity.

Dynamics and Energetics of wQED from Collision Model

- Speaker: Maria Maffei **Invited**
- Affiliation: University of Bari Aldo Moro

Waveguide Quantum Electrodynamics (wQED) studies quantum emitters coupled to propagating electromagnetic fields. In the weak coupling regime, the standard approach is to treat the field like an environment, solving the open emitters dynamics with master equations. This treatment fails when the field between the emitters creates a feedback effect making the dynamics non-Markovian. It is hence attractive to solve the closed emitters-field dynamics, that can be done with analytical and numerical tools based on the Collision Model as I will show [1,2]. I will then show how the Collision Model framework suggests operational definitions of work-like and heat-like energy exchanges in the emitters-field system that may lead to a reduction of the emitters entropy production [3]. [1] M. Maffei, D. Pomarico, P. Facchi, G. Magnifico, S. Pascazio, and F. V. Pepe, "Directional emission and photon bunching from a qubit pair in waveguide," Phys. Rev. Res., vol. 6, p.L032017, 2024. [2] G. Magnifico, M. Maffei, D. Pomarico, P. Facchi, S. Pascazio, and F. V. Pepe, "Non-Markovian dynamics of BIC generation via single-photon scattering", arXiv:2501.04691, 2025. [3] S. P. Prasad, M. Maffei, P. A. Camati, C. Elouard, A. Auffèves, "Tracking light-matter correlations in the Optical Bloch Equations: Dynamics, Energetics" arXiv:2404.09648

Maximal entanglement in quantum electrodynamics

- Speaker: Bruno Micciola **Contributed**
- Affiliation: University of Salerno

We present recent results on the generation and distribution of helicity entanglement in quantum electrodynamics scattering processes. In particular, we study the mechanisms by which maximal entanglement is both produced and preserved. By employing the framework of complete comple- mentarity relations, we analyze the interplay between local and non-local properties of particles interacting in QED.

Optimal Control for Quantum Technology with NV-Centers in Diamond

- Speaker: Matthias Müller **Contributed**
- Affiliation: Forschungszentrum Jülich

Diamond-based quantum technology is a fast-emerging field with both scientific and technological importance. The performance relies on unique features like superposition and entanglement and depends on sophisticated mechanisms of control to perform the desired tasks. Quantum Optimal Control (QOC) has proven to be a powerful tool to accomplish this task. I will give a brief overview on the use of QOC for NV-centers in diamond [1], the CRAB algorithm for Optimal Control [2], the optimal-control software QuOCS [3] and report on recent applications toward quantum sensing and quantum computing [4,5,6].

[1] P. Rembold et al., AVS Quantum Sci. 2, 024701 (2020) [2] M. M. Müller et al., Rep. Prog. Phys. 85 076001 (2022) [3] M. Rossignolo et al. Comp. Phys. Comm. 291, 108782 (2023) [4] N. Oshnik et al., Phys. Rev. A 106, 013107 (2022) [5] N. Grimm et al., Physical Review Letters 134 (4), 043603 (2025) [6] P. Vetter et al., npj Quantum Information 10 (1), 96 (2024)

Low-loss microsecond-scale imaging of ytterbium atom arrays

- Speaker: Alessandro Muzi Falconi **Invited**
- Affiliation: University of Trieste

Detecting and manipulating individual atoms with high fidelity is crucial in state-of-the-art quantum simulators, processors and atomic clocks. In particular, fast high-fidelity, low-loss imaging of individual atoms is crucial for fast mid-circuit measurements and error correction protocols. I this talk I will present recent results for our Yb tweezers platform, aiming to develop novel clock protocols and engineer many-body systems with single-particle resolution. In our experiment, we load a tweezer array from a narrow-line MOT operating in a five-beam (5B) configuration, so far demonstrated only for lanthanides. We image single atoms with a fast and low-loss single-atom imaging in optical tweezers without active cooling, enabled by the favorable atomic properties of ytterbium. Using a pulsed excitation scheme, we collect fluorescence on microsecond timescales, reaching single-atom discrimination fidelities above 99.9% and single-shot survival probabilities above 99.5%. Through interleaved recooling pulses, as short as a few hundred microseconds magic trapping conditions, we perform several tens of consecutive detections with constant loss per. Unlike conventional imaging protocols, our scheme does not induce parity projection in multiply-occupied traps, enabling us to achieve number-resolved single-shot detection of up to several atoms per tweezer. We utilize such atom-counting imaging to characterize the near-deterministic preparation of single-atom occupations, driven by blue-detuned light-assisted collisions. The near-diffraction-limited spatial resolution associated with our low-loss imaging enables atom number-resolved detection in dense arrays, opening the way to multiple site-occupancy readout in quantum gas microscopes. Finally, we can employ this technique to detect single and multiple atoms in free space for variable time of flights (TOFs), allowing us to perform TOF thermometry of single- or few- atoms ensembles and, in the near future, to measure fermionic and bosonic multiparticle correlations in mesoscopic ensembles.

Non-Markovian Open Quantum Systems and Dynamical Entropy: A Collisional Model Perspective

- Speaker: Giovanni Nichele **Contributed**
- Affiliation: University of Trieste

Collisional models for open quantum systems will be discussed using the Alicki–Lindblad–Fannes (ALF) entropy. In particular, the focus will be on a finite-level open quantum system coupled to a classical Markov chain, which nevertheless exhibits memory effects in its reduced dynamics with no classical counterpart. The operational interpretation of the ALF entropy is neatly obtained through the GNS construction and will be discussed in relation to the activation and superactivation of memory effects.

Multiparameter quantum metrology beyond the Cramér-Rao bound

- Speaker: Matteo Paris **Invited**
- Affiliation: University of Milan

TBA

Training quantum GANs with classical data

- Speaker: Davide Pastorello **Contributed**
- Affiliation: University of Bologna

After an introduction to the notion of quantum generative adversarial networks (qGANs), I will summarize the so-called shadow tomography protocol for constructing a classical estimate of an unknown quantum state by performing repeated measurements on a n-qubit system. I will then discuss the convergence of the protocol with respect to a quantum version of the first-order Wasserstein distance, a fundamental notion of the theory of optimal mass transport. In particular, I will show how this convergence result allows us to conclude that a qGAN can be equivalently trained using classical estimators of quantum states instead of quantum data. This fact is important in practice, as it enables the training of quantum models without requiring direct access to quantum memory or coherent quantum data streams.

Enhancing Revivals Via Projective Measurements in a Quantum Scarred System

- Speaker: Alessio Paviglianiti **Contributed**
- Affiliation: SISSA

Quantum many-body scarred systems exhibit atypical dynamical behavior, evading thermalization and featuring periodic state revivals. In this talk, I will discuss the impact of projective measurements on the dynamics in the scar subspace for the paradigmatic PXP model, revealing that they can either disrupt or enhance the revivals. Local measurements performed at random times rapidly erase the system's memory of its initial conditions, leading to fast steady-state relaxation. In contrast, a periodic monitoring amplifies recurrences and preserves the coherent dynamics over extended timescales. We identify a measurement-induced phase resynchronization, countering the natural dephasing of quantum scars, as the key mechanism underlying this phenomenon.

New strategies for quantum error correction with Rydberg atoms

- Speaker: Laura Pecorari **Contributed**
- Affiliation: University of Strasbourg

High-rate quantum error correcting (QEC) codes with moderate overheads in qubit number and control complexity are highly desirable for achieving fault-tolerant quantum computing. Recently, quantum error correction has experienced significant progress both in code development and experimental realizations, with neutral atom qubit architecture rapidly establishing itself as a leading platform in the field. Scalable quantum computing will require processing with QEC codes that have low qubit overhead and large error suppression, and while such codes do exist, they involve a degree of non-locality that has yet to be integrated into experimental platforms. In this work, we analyze a family of high-rate Low-Density Parity-Check (LDPC) codes with limited long-range interactions and outline a near-term implementation in neutral atom registers. By means of circuit-level simulations under range-dependent depolarizing noise, we find that these codes outperform surface codes in all respects at experimentally achievable noise rates. By using multiple laser colors, we show how these codes can be natively integrated in two-dimensional static neutral atom qubit architectures with open boundaries, where the desired long-range connectivity can be targeted via the Rydberg blockade interaction. Finally, we show how circuit-level thresholds and logical error probabilities can be significantly improved by exploiting hardware-specific noise biases. In particular, we analyze the case where most errors are erasures, i.e. heralded qubit losses, which can be realized in Alkaline-earth(-like) atom qubits and compare the performance of our code family against bivariate bicycle quantum LDPC codes.

References: Nature Commun. 16, 1111 (2025); arXiv:2502.20189; works in preparation.

Quantum noise limited transducers for quantum networks

- Speaker: Paolo Piergentili **Invited**
- Affiliation: University of Camerino

The transduction of quantum signals at different energy scales plays a crucial role in Quantum Technologies, specifically in distributed quantum computation and quantum networks [1]. Achieving coherent conversion between optical and microwave/radiofrequency (mw/rf) photons is one of the primary tasks of the realization of a quantum transducer since optical spectrum is well-suited for long-distance communication, while lower frequencies of the electromagnetic field prove advantageous for precise local quantum operations employing superconducting and other solid-state processors. A quantum transducer would enable an efficient detection of microwave photons by exploiting the most efficient detectors for optical photons, or the other way round one could perform non-demolition measurements of optical photons using superconducting qubits coupled to microwave cavities. The easiest way to bridge the enormous energy gap is to use a mediator simultaneously coupled to both mw/rf and optical modes. An approach is to combine solid-state deterministic quantum photon emitters with quantum mechanical oscillators based on surface acoustic wave cavities [2]. Another approach is to integrate piezoelectric (mw to acoustic wave) and optomechanical (acoustic wave to optical wave) devices into a common transducer platform [3]. Here we focus on the electro-optomechanical platforms where a mechanical resonator is coupled to mw/rf photons capacitively, and dispersively via radiation pressure with the optical mode [4]. We present the steps towards the realization of a quantum electro-optomechanical transducer and a complete characterization of a nanomechanical oscillator [5], which might be used for the realization of a novel electro-optomechanical device that can be implemented for the sympathetic cooling of the LC circuit [6], and as building block of a mw/rf optical transducer [7]. Such a transducer paves the way for metrology and sensing applications at the quantum level [8], allowing the realization of a global quantum internet, a network of quantum computers, or distributed quantum tasks including computing or sensing.

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Preparing many-body quantum states with quantum circuits and measurements

- Speaker: Lorenzo Piroli **Invited**
- Affiliation: University of Bologna and INFN Bologna

Quantum-state preparation is a well established branch of quantum information and quantum simulation theory. While several existing algorithms rely on assuming a perfect quantum computer, current noisy intermediate-scale quantum (NISQ) devices are limited in the number of qubits and the coherence time. Therefore, it is very important to devise efficient preparation schemes making use of the minimum amount of resources. Following early ideas, an emerging theme is that preparation protocols using unitary circuits can be improved making use of additional ancillas, measurements, and feedforward operations. In this talk, I will discuss how many-body quantum-state preparation can be further enhanced by lifting the requirement that the propocols are exact and deterministic, realising simple states that eluded previous protocols. I will show in particular how the so-called W and Dicke states can be prepared by shallow quantum circuits whose depth and number of ancillas per site that are independent of the system size. This is made possible by the introduction of an efficient scheme to implement certain non-local, non-Clifford unitary operators. I will discuss implications for efficient realization of non-trivial states and phases of matter in current NISQ devices.

Quantum Coherence and Anomalous Work Extraction in Qubit Gate Dynamics

- Speaker: Francesco Plastina **Contributed**
- Affiliation: University of Calabria

We develop a framework based on the Kirkwood-Dirac quasiprobability distribution to quantify the coherent contribution to work extraction during generic, cyclic quantum evolutions. In particular, we focus on ”anomalous processes”, enabled by the negativity of the quasiprobability distribution, in which work can be extracted even as the system gains energy. Applying this framework to qubits undergoing sequences of single- and two-qubit gate operations, we identify specific conditions under which such anomalous work exchange occurs, highlighting the role of coherence in the thermodynamics of quantum computation.

Witnessing Non-stabilizerness with causal inequalities.

- Speaker: Davide Poderini **Invited**
- Affiliation: University of Pavia

Non-stabilizerness is a fundamental resource for quantum computation, enabling quantum algorithms to surpass classical capabilities. Despite its importance, characterizing this resource remains challenging due to the intricate geometry of stabilizer polytopes and the difficulty of simulating non-stabilizer states. In recent works, we explored the connection between non-stabilizerness and other forms of nonclassicality. First, we showed that although maximally entangled stabilizer states can violate Bell inequalities, tailored Bell inequalities can act as witnesses of this resource. This result allowed us to bridge two key quantum resources, uncovering a novel relationship between the device-independent framework and resource-theoretic properties of quantum computation. Moreover, We develop a semi-device-independent framework for certifying non-stabilizer states in prepare-and-measure (PAM) scenarios, relying only on assumptions about the system’s dimension. Within this framework, we introduce dimensional witnesses that can distinguish stabilizer from non-stabilizer states, and we provide analytical proofs that threshold violations of these witnesses certify non-stabilizerness. These results offer a set of semi-device-independent tools for practically and systematically verifying non-stabilizer states using dimensional witnesses in PAM scenarios.

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

- Speaker: Sunny Pradhan **Contributed**

- Affiliation: University of the Basque Country

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.

Single-pair measurement of the Bell parameter

- Speaker: Enrico Rebufello **Contributed**
- Affiliation: INRiM

In 1964, J. S. Bell introduced the Bell inequalities, turning a philosophical debate into a physical experiment capable of extracting the true nature of correlations within physical systems. This opened, in turn, several research fields spanning from quantum mechanics foundations to quantum technologies. Over the past decades, the scientific community has thoroughly investigated Bell inequalities, eventually achieving loophole-free tests. However, some issues persist: for instance, the Heisenberg uncertainty principle and wavefunction collapse forbid performing all the measurements needed for evaluating the entire Bell parameter on the same quantum system with the usual projective measurements.

To overcome these limitations, we demonstrate a method able to estimate the entire Bell parameter from each entangled pair while preserving entanglement, ensuring its availability for further applications. This method relies on weak measurements, a measurement procedure in which a tiny coupling between the observed system and the measurement device allows the estimating the observables of interest while preventing the state from collapsing. We exploit this feature of weak measurements to measure multiple observables on the same quantum state, extracting all the correlations needed to evaluate the full Bell parameter from each pair (although with a large uncertainty).

Our results obtain an average Bell parameter in agreement with the Tsirelson bound and highlighting a violation of the classical bound above 5 sigmas. Furthermore, we show how our procedure preserves the entanglement between the two photons, leaving it available for other purposes.

Our experiment provides new insights into understanding the foundations of quantum mechanics, such as the concept of counterfactual definiteness. Furthermore, the entanglement certification leaves the quantum state almost unaltered, ready to be exploited for other quantum information protocols or quantum foundations investigations, such as testing novel bounds intertwining local and nonlocal correlations.

Many-Body Quantum Optics in a Bose-Hubbard Waveg-

uide

- Speaker: Federico Roccati **Contributed**
- Affiliation: University of Palermo

Waveguide quantum electrodynamics (QED) studies the interaction between quantum emitters and guided photons in one-dimension. When the waveguide hosts interacting photons, it becomes a platform to explore many-body quantum optics. However, the influence of photonic correlations on emitter dynamics remains poorly understood. In this work, we study the collective decay and coherent interactions of quantum emitters coupled to a one-dimensional Bose-Hubbard waveguide, an array of coupled photonic modes with repulsive on-site interactions that supports superfluid and Mott insulating phases. We show that photon-photon interactions alone can trigger a superradiant burst, independent of emitter spacing and transition frequency. In the off-resonant regime, emitters exhibit two distinct types of mediated interactions: delocalized superfluid excitations yield distance-independent couplings, while Mott-insulator quasiparticles generate short-range interactions mediated by doublons and holons. Our work bridges many-body physics and waveguide QED, revealing how photonic many-body states shape emitter dynamics.

Secure and Distributed Information Processing over Quantum Networks

- Speaker: Matteo Rosati **Invited**
- Affiliation: University of "Roma Tre"

As quantum networks become increasingly viable, a natural question arises: what kinds of information processing will they enable? In this talk, we explore a class of applications where quantum communication supports secure, distributed protocols between a powerful quantum provider and end-users with limited quantum capabilities.

We present two protocols that exemplify this framework. The first is a secure delegated quantum sensing scheme, in which a client performs quantum-enhanced sensing using entangled probes remotely prepared by a provider. The protocol remains secure against collective attacks, preserving the privacy of the client's sensing target and outcome. The second is a distributed quantum bit commitment protocol, achieving binding and concealing commitments between spatially separated parties—an important foundational primitive, whose implementation leverages LOCC constraints among the users.

These results highlight how quantum communication can enable asymmetric, yet secure, collaboration between network nodes—suggesting new use-cases for the emerging quantum internet infrastructure.

Quantum-enhanced differential measurements in atom interferometry beyond classical limits

- Speaker: Leonardo Salvi **Invited**
- Affiliation: Physics Deparment, University of Florence

Atom interferometers are approaching sensitivity levels fundamentally limited by quantum fluctuations. A key challenge is integrating entanglement—particularly spin squeezing—into quantum sensing protocols to enhance precision while maintaining robustness to noise and systematics. I will present a study of differential phase estimation using two spin-squeezed atom interferometers, accounting for realistic common-mode phase noise spanning the full 360-degree range. Our results show that carefully chosen squeezed states can surpass the Standard Quantum Limit, with optimal states achieving differential phase variance scaling as $N^(- 2/3)$ and eliminating biases inherent in traditional estimation methods. In addition to this theoretical contribution, I will highlight our group's experimental efforts: (1) implementing spin-squeezed states in matter-wave interferometry; (2) performing a high-precision measurement of the Newtonian gravitational constant G with a target uncertainty of 10 ppm; and (3) developing techniques for gravity sensing using positronium. These activities aim to advance quantum-enhanced metrology and precision tests of fundamental physics using atom interferometry.

Simulation of fluid dynamics on a quantum computer

- Speaker: Claudio Sanavio **Contributed**
- Affiliation: Italian Insitute of Technology

In this talk we go through different attempts to simulate the nonlinear and dissipative dynamics of classical fluids using a quantum computer. We show that Carleman linearization truncated at second order, when applied on the Lattice Boltzmann (CLB) representation of fluid flows, is able to provide a good description of the dynamics with a low relative error (10^{-3}), for a range of the Reynolds number up to a few hundreds. We then show how to build an efficient quantum circuit to block-encode the CLB matrix by exploiting its sparse nature. We show that this technique dramatically reduces the gate complexity of the algorithm from exponential to quadratic, although it yields a probabilistic circuit with a very low success probability. Finally, we outline different possible strategies to mitigate or even circumvent this problem.

The ontological fracture and its cosmoillogical implications

- Speaker: Alessio Serafini **Contributed**
- Affiliation: University College London

This talk would like to emphasise how, at variance with any other scientific theory ever developed by humankind, the measurement problem prevents quantum mechanics from delivering a consistent narrative. A roundup of the existing interpretations developed to confront the problem is then presented under a new light, and several epistemological perspectives in this regard are put forward for discussion. Finally, we consider the two-way implications relating the measurement problem and quantum interpretations on one side to the birth of large-scale structures and quantum estimation in inflationary cosmology, and present some technical findings on the latter.

Hybrid Quantum Reservoir Computing applied to complex systems

- Speaker: Jacopo Settino **Invited**
- Affiliation: University of Calabria

Reservoir computing (RC) has emerged as an effective paradigm for forecasting the dynamics of complex and chaotic systems by employing a high-dimensional nonlinear reservoir with fixed internal connections, while confining learning to a linear readout stage. This architecture simplifies training and dramatically reduces computational overhead compared to common machine learning algorithms. Quantum reservoir computing (QRC) further leverages the exponential scaling of Hilbert spaces in quantum platforms. However, in the original QRC proposal, coherent input injections must be repeatedly applied, posing significant practical challenges for implementation.

We have introduced a hybrid quantum–classical framework that realizes temporal memory through classical post-processing of quantum measurement outcomes, thereby eliminating the need for multiple coherent input injections.

We have simulated different quantum substrates and geometries, including Ising networks, Rydberg atom arrays, and flux-qubit arrays coupled to a superconducting transmission line. For each setting, we have identified optimal reservoir parameters and established a quantitative mapping between the intrinsic dynamical features of the target complex system and the physical properties of the quantum reservoir.

In addition to standard benchmark tasks such as the nonlinear autoregressive moving average (NARMA) and short-term memory tests, our quantum reservoir computing model has been trained to forecast the dynamics of significantly more complex systems. These include paradigmatic models from classical fluid dynamics that are central to the study of turbulence, such as the chaotic evolution resulting from a low-order Galerkin truncation of the incompressible two-dimensional Navier–Stokes (NS) equations and the three-dimensional Lorenz '63 system.

These results have demonstrated the versatility and predictive power of our hybrid quantum reservoir framework across a broad spectrum of dynamical regimes

Entanglement transitions in a boundary-driven open quantum many-body system

- Speaker: Pietro Silvi **Invited**
- Affiliation: University of Padova & INFN

We present a numerical framework based on tree tensor operators that enables large-scale simulation of out-of-equilibrium open quantum many-body systems. By design, it protects density operator positivity and provides direct access to entanglement monotones, such as entanglement of formation and logarithmic negativity. To demonstrate the framework's ability to probe entanglement in open quantum many-body systems and distinguish it from other correlations, we study a paradigmatic open system problem: the boundary-driven XXZ spin-chain. We uncover entanglement transitions driven by both the coupling to the environment and the anisotropy parameter. These transitions reveal an immediate connection between entanglement and spin-current, and link the known transport regimes of the model to distinct entanglement regimes, i.e., separable, area-law, and volume-law. Our work enables the analysis of entanglement in open quantum many-body systems out of equilibrium, a necessary step for developing scalable quantum technologies.

Weak values and multivariate traces: Structure and efficient estimation

- Speaker: Kyrylo Simonov **Contributed**
- Affiliation: University of Vienna

Weak values of quantum observables are a powerful tool for investigating quantum phenomena. Some methods for measuring weak values in the laboratory require weak interactions and postselection, while others are deterministic, but require statistics over a number of experiments that grows linearly with the dimension of the measured system in the worst case over all possible observables. Here we propose a deterministic dimension-independent scheme for estimating weak values of arbitrary observables. The scheme is based on controlled SWAP operations, and associates states and observables in the mathematical expression of the weak value to preparations devices and measurements devices in the experimental setup, respectively. Thanks to this feature, it provides insights into the relation between states of two identical quantum systems at a single moment of time and states of a single quantum system at two moments of time, also known as two-time states. Specifically, our scheme provides an alternative expression for two-time states, and establishes a link between two-time states accessible through the controlled-SWAP scheme and bipartite quantum states with positive partial transpose. Furthermore, we discuss its generalizations applicable to a situation where N systems are given and unknown, and classical information on M systems ($M < N$) is available, allowing estimation of multivariate traces of order n+m. The use of classical information on some of the states enables circuits on fewer qubits and with fewer gates, decreasing the experimental requirements for their estimation.

Non-demolition measurements and quasi-probability distributions in quantum mechanics.

- Speaker: Paolo Solinas **Contributed**
- Affiliation: University of Genova

In addition to standard projective measurements, quantum mechanics allows for alternative methods of extracting information from a quantum system. Some of these approaches give rise to quasi-probability distributions. In this talk, I will present a non-demolition protocol for extracting information about generalized observables through their sequential measurement. The relevant information is encoded in the phase of a quantum detector, which is eventually measured. This protocol naturally leads to a non-positive quasi-probability distribution, where the presence of negative values serves as a signature of quantum behavior. I will illustrate several applications and present recent results. In particular, I will show how this approach can be used to characterize the Wigner function and its negativity. These results offer new insights into the still unresolved problem of fully characterizing the negativity of the Wigner function for a generic density matrix.

Experimental measurement of Magic at the superconducting quantum computer Partenope

- Speaker: Viviana Stasino **Invited**
- Affiliation: Università degli studi di Napoli Federico II

The concept of Quantum Advantage represents an ambitious goal in the field of quantum computation. It is related to scientific and technological achievements for which quantum computers overcome the computational capabilities of classical computers [1], offering great potential in solving hard problems. In the frame of ICSC High-Performance, Big Data and Quantum Computing National Center (spoke 10), we are aiming to build the first academic superconducting quantum computing (QC) node in Italy for the implementation of hybrid classical/quantum and fully quantum algorithms. Since the installation of the quantum computing center Partenope in Napoli in 2024, we have fully characterized the 25-qubit Superconducting Quantum Processing Unit (sQPU) and we are currently implementing proof-of-concepts quantum algorithms on subregisters of the sQPU in collaboration with either academic and industrial partners. In this work, we will discuss the fundamental role played by calibration and gate pulse optimization procedures, both for single and two-qubit operations, in the Noisy Intermediate-Scale Quantum (NISQ) era [2]. These are essential for the implementation of proof-of-concept algorithms [3-5], such as the generation of Gaussian distributions in collaboration with industry partners. We will then present the results of the investigation of the system's capability of generate quantum resources that cannot be effectively simulated on a classical computer, through the experimental estimation of the stabilizer Rényi entropy, also known as Magic [6]. This quantity is claimed to be fundamental to achieve the quantum advantage. It measures how much a quantum state deviates from being a stabilizer. In an ideal noiseless device, the magic of a stabilizer state is theoretically predicted to be zero [6]. However, in a NISQ (Noisy and Intermediate Scale Quantum) device, any source of noise that affects the system, such as decoherence, error in the gate implementation, readout error, will cause injection of magic in the quantum state. We have used the magic to determine in a self-consistent way the noise affecting our system, by implementing key single- and two-qubit quantum circuits with different level of complexity (e.g. on isolated qubits, and on coupled qubits with and without the inclusion of entanglement). The experimental measurement of magic on subregisters of the sQPU characterized by different readout and gate fidelities, as well as coherence metrics, allows to provide a direct correlation between hardware performances and the theoretical expectations in the presence of noise. This work poses fundamental basis for the experimental investigation of magic resources in real hardware, such as the non-local magic, i.e., the resource that cannot be distilled or erased by local unitary operations [7], in real-life scenarios where noise cannot be neglected. Our goal for future experiments is to find an efficient way to identify unitary transformations capable of isolating the non-local magic component from the spurious magic induced by noise. We also believe that the results obtained until now will strengthen the computational capabilities of our infrastructure, and will pose the foundations for further quantum algorithms implementation planned to be run in the near future. This will enforce the fundamental concept that hardware capabilities correlate with software performances in the NISQ era.

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Recent developments in quantum communication

- Speaker: Giuseppe Vallone **Invited**
- Affiliation: Università di Padova

Within the last two decades, Quantum Technologies have made tremendous progress, from proof of principle demonstrations to real life applications, such as Quantum Key Distribution (QKD) and Quantum Random Number Generators (QRNGs). We will discuss the results that we have recently obtained at the University of Padova towards the realization of secure QRNGs and mature and efficient QKD systems.

Advanced QKD Applications on National Fiber Infrastructures: INRiM's Contribution to EuroQCI

- Speaker: Salvatore Virzì **Invited**
- Affiliation: INRiM

Quantum Key Distribution (QKD) enables the secure sharing of cryptographic keys between distant users, with security rooted in the principles of quantum mechanics. As QKD technology matures, all 27 EU member states are contributing to the EuroQCI initiative to establish a pan-European quantum communication infrastructure. Within this framework, Italy is deploying the Italian Quantum Backbone, coordinated by the QUID project, with INRiM as a key technical partner. One of the main challenges in real-world deployment of QKD is its integration over existing long-haul fiber links. Twin-Field QKD (TF-QKD) [1] is a promising protocol capable of extending secure communication distances by exploiting interference at an untrusted intermediate node. However, its performance strongly depends on the phase stability of the optical paths. INRiM has developed and demonstrated a robust phase stabilization solution [2], tested over a segment of the Italian Quantum Backbone, achieving a significant performance improvement even in protocols declared to be tolerant to phase noise [3]. In addition to long-distance QKD, INRiM has also demonstrated the application of QKD to protect critical infrastructures for time and frequency (TF) dissemination. By combining QKD with the White Rabbit protocol, it is possible to securely distribute traceable and highly stable time signals over optical fiber links, enabling encrypted synchronization between remote clocks with minimal degradation in time stability [4]. These results highlight INRiM's contribution to the development of secure quantum communication services and their integration into national infrastructures, both for cryptographic purposes and for the protection of essential services such as time dissemination. References [1] M. Lucamarini et al., Nature 557, 400–403 (2018) [2] C. Clivati et al., Nat. Commun. 13, 157 (2022) [3] G. Bertaina et al., Adv. Quantum Technol. 7(6), 2400032 (2024) [4] A. Meda et al., Sci. Rep. 15, 13419 (2025)

Characterizing entanglement dimensionality with covariances and randomized measurements

- Speaker: Giuseppe Vitagliano **Contributed**
- Affiliation: TU Wien

High-dimensional entanglement has been identified as an important resource in quantum information processing, and also as a main obstacle for simulating quantum systems. Its certification is often difficult, and most widely used methods for experiments are based on fidelity measurements with respect to highly entangled states. Here, instead, we consider covariances of collective observables, as in the well-known Covariance Matrix Criterion (CMC). In the first part of the talk, I will present a generalization of the CMC for determining the Schmidt number of a bipartite system [1]. In the second part, I show an inequality that is invariant under local changes of su(□□) bases and can be used to find regions in the space of moments of randomized correlations that allow to distinguish states with different entanglement-dimensionalities [2]. In particular, we find analytical boundary curves for the different entanglement dimensionalities in the space of second- and fourth-order moments of randomized correlations for all dimensions □□ of a bipartite system. Finally, I will show how our method works in practice by presenting an experimental certification of three-dimensional entanglement in a five-dimensional two-photon state using 800 Haar-random measurements implemented via a 10-plane programmable light converter [3]. We further demonstrate the robustness of this approach against random rotations, certifying high-dimensional entanglement despite arbitrary phase randomization of the optical modes. This method, which requires no common reference frame between parties, opens the door for high-dimensional entanglement distribution through long-range random links.

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Mid-circuit measurements in quantum simulations of lattice gauge theories: from the quantum Zeno effect to error correction

- Speaker: Matteo Michele Wauters **Invited**
- Affiliation: University of Trento

Quantum measurements profoundly influence system dynamics, leading to complex nonequilibrium phenomena like the quantum Zeno effect. Leveraging this effect can mitigate coherent errors in quantum simulations caused by imperfect implementations. This is particularly crucial for lattice gauge theories, where tailored quantum measurements can prevent violations of local conservation laws. We investigate a dynamical post-selection protocol for digital quantum simulations of a 1+1d Z2 lattice gauge theory by using projective measurements of ancillary qubits linked to local symmetry generators. This protocol triggers a Zeno transition with increasing measurement rates, stabilising a symmetry-protected phase resistant to simulation errors. In the time-continuous limit, the resulting state ensemble follows the same Liouvillian dynamics as those from continuous weak measurements of local gauge charges. However, despite their shared physical basis, the two approaches yield distinct stochastic trajectory unravelings. Additionally, we enhance the discrete-time scheme with a feedback mechanism that corrects incoherent bin-flip errors, utilising the redundancy from local conserved charges. Crucially, this approach also extends to non-Abelian symmetries, where simple post-selection based on noncommuting transformations does not work. Outside of the Zeno regime, the interplay between symmetry-breaking errors and monitoring of local charges induces a fast equilibration that hints at a measurement-induced thermalisation.

Photonic realization of a Hopfield associative memory by multiphoton entanglement and interference

- Speaker: Gennaro Zanfardino **Invited**
- Affiliation: University of Salerno

In this talk we will discuss a recently discovered connection [1] between multiphoton quantum interference—a key component of emerging photonic quantum technologies—and Hopfield-like Hamiltonian models associated with classical neural networks, which are paradigmatic models of associative memory and machine learning in systems of artificial intelligence. A major challenge in this context is that simulating the dynamics of fully connected networks with multi-neuronal synaptic couplings requires a computational time that scales super-extensively with the number of neurons, typically scaling with M, the average per neuron connectivity index.

Analog photonic computation offers a promising path to drastically reduce this computational cost as pointed out in a previous study [2] in which incoherent classical light was used to simulate a 2-body Hopfield model. In order to generalize this correspondence to the multi-synaptic, large-storage regime, an additional mechanism is required in the proposed photonic architecture for energy measurement: the use of entangled photons and interferometry.

Specifically, we demonstrate that a system composed of Np indistinguishable photons in superposition over M field modes, combined with a controlled array of M binary phase-shifters and a linear-optical interferometer, produces output photon statistics that can be described by a p-body Hopfield Hamiltonian. This Hamiltonian involves M Ising-like neurons (with states ±1), where the interaction order is given by $p = 2Np$.

Hopfield models are characterized by two key parameters: the temperature T, and the storage load α, defined as the number of stored patterns per neuron. These models exhibit three distinct phases: the retrieval phase (low T, low α), the glassy phase (low T, high α), and the paramagnetic phase, which emerges at sufficiently high T. In our proposed photonic implementation, both of these parameters can be experimentally controlled, enabling the exploration of the different phases of the system.

We performed a detailed study of the generalized 4-body Hopfield model arising from our design. We show that it undergoes a transition from a memory retrieval phase to a memory blackout (spin-glass) regime as the number of stored patterns increases.

Our mapping provides a new avenue toward the implementation and investigation of disordered and complex classical systems via efficient photonic quantum simulators. Conversely, it allows for the interpretation of structured photonic systems through the lens of classical spin Hamiltonians.

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Posters

Analog Quantum Teleportation

- Author: Uesli Alushi — Poster code: **5A**
- Affiliation: Aalto University

Digital teleportation protocols make use of entanglement, local measurements, and a digitally error-corrected classical communication channel to transfer quantum states between remote parties. We investigate analog teleportation protocols that replace classical communication and digital error correction with transmission and analog error correction through a noisy quantum channel. We show that analog teleportation protocols outperform digital protocols if and only if Alice and Bob are linked by a channel that does not reduce entanglement when applied to a part of the resource state. We first derive general analytical results in the broader context of Gaussian-channel simulation. Then, we apply it to the quantum teleportation of a uniformly distributed codebook of coherent states, showing that an analog protocol is optimal for a wide range of communication channel transmissivities. Our result contributes to mitigating noise in the intermediate case when the communication channel is far from being ideal but is not too lossy, as is the case of cryogenic links in microwave superconducting circuits.

Link: https://doi.org/10.48550/arXiv.2502.10253

Asymptotic evolution of open quantum systems

- Author: Daniele Amato — Poster code: **21A**
- Affiliation: University of Bari & INFN Bari

In this talk, we will provide various results about the asymptotic discrete-time dynamics of open quantum systems induced by a quantum channel. In particular, we will present general structure theorems regarding the asymptotic subspace and the large-time evolution, as well as universal constraints for the number of linearly independent steady and asymptotic states of the dynamics. Joint work with Paolo Facchi (UNIBA & INFN Bari) and Arturo Konderak (CFT-Warsaw)

Phaseonim Engine Thermodynamics

- Author: Federico Amato — Poster code: **4A**
- Affiliation: University of Palermo

We present a realistic implementation of a Quantum Engine powered by a phaseonium gas of coherently prepared three-level atoms, and we leverage quantum coherence as a thermodynamic resource. Using a collision model framework, we derive the exact thermalization dynamics of a cavity field interacting with phaseonium and construct a full engine cycle based on two non-thermal reservoirs, each characterized by coherence-induced effective temperatures. This configuration enhances the efficiency of a simple optomechanical engine operating beyond standard thermal paradigms. We further address scalability by coupling a second cavity in cascade configuration, where the same phaseonium gas drives both cycles. Our results demonstrate the operational viability of coherence-driven quantum engines and their potential for future thermodynamic applications.

Eigenstate Thermalization Hypothesis for discrete non-Abelian lattice gauge theories

- Author: Edoardo Ballini — Poster code: **31A**
- Affiliation: University of Trento

The Eigenstate Thermalization Hypothesis (ETH) describes how nonintegrable quantum many-body systems thermalize, provided that the Hamiltonian lacks symmetries. In case the Hamiltonian has non-commuting symmetries, the usual ETH conflicts with conserved charges, and the Hamiltonian will have degeneracies, which in principle should be resolved to get reliable results from the ETH. Here, we show how a quasi-2+1D Lattice Gauge Theory, where D_3 is the gauge group, can be handled to test non-Abelian ETH. First, we map the 1-ladder Hamiltonian to a flux ladder by performing a gauge fixing. Then, one must take care of the degeneracies caused by two different symmetries. Once resolved them, we tested some common aspects of the ETH, showing how discrete non-Abelian LGTs thermalize.

Indistinguishability-assisted two-qubit entanglement distillation

- Author: Bruno Bellomo — Poster code: **23A**
- Affiliation: Institut UTINAM, Université Marie et Louis Pasteur, Besançon, France

Quantum coherence and entanglement are essential resources for quantum-enhanced technologies. Nonetheless, noise induced by the interaction with the environment is unavoidable, leading to decoherence and entanglement degradation. Many protection schemes have been proposed to preserve such quantum resources and various types of distillation protocols have been conceived to convert mixed states to entangled states.

Indistinguishability plays an important role in understanding systems made of identical quantum entities. Tailoring spatial overlap of identical particles can be exploited in entanglement generation schemes and can become a resource for some quantum information tasks.

Here, we provide a conditional yet efficient entanglement distillation protocol which functions within the framework of spatially localized operations and classical communication. This protocol exploits indistinguishability effects due to the spatial overlap between two identical qubits in distinct sites and depends on particle statistics. The spatial overlap is created by means of a spatial deformation of the wave functions which are distributed towards two distinct measurement sites. The protocol is characterized by a success probability, linked to postselecting the cases where only one particle is found at each site. We have derived the general conditions for the maximum entanglement distillation out of mixed states [1].

We have then studied the trade-off between the amount of distilled entanglement and the success probability of the procedure using for the initial configuration typical noisy states, such as thermal Gibbs states and Werner states. The influence of local temperatures and of a noise parameter is discussed, respectively, in these two cases [1]. The proposed scheme paves the way towards quantum repeaters in composite networks made of controllable identical quantum particles.

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Continuous and discrete variables: a new unified treatment of boson sampling and Bell measurements.

- Author: Luca Bianchi — Poster code: **1B**
- Affiliation: University of Florence

Quantum optical platforms stand out as a promising avenue for scalable and efficient architectures. Photonic systems enable information to be encoded either in discrete variables (DV) —such as polarization, path, frequency, or angular momentum—or in continuous variables (CV) of the optical field, such as quadratures. A new formalism is developed for the joint description of multiphoton and multimode light undergoing Gaussian transformations. We use this new framework to explore two DV-CV hybrid protocols. The first one regards the unification and extension of distinct forms of boson sampling, where we develop the merging of DV scattershot boson sampling with CV Gaussian boson sampling. Thereby, it is possible to advance different physical systems by extending boson samplers to, for example, squeezed photons for demonstrating quantum advantage. To this end, numerical simulations of unified sampling are carried out, benchmarking its performance, complexity, scalability and characterizing its quantum correlations. Secondly, high dimensional Bell state measurements are addressed by combining linear interferometry with multiple single-mode squeezers. The new proposal is numerically simulated and proves to outperform any state-of-the-art protocols based on linear optics, without the hurdle of adding any auxiliary states.Within our works, we prove how bridging the DV and CV frameworks presents a unique opportunity to combine their strengths and mitigate their limitations.

Weak measurements: how to gently extract information

- Author: Gabriele Bizzarri — Poster code: **8B**
- Affiliation: Università degli Studi "Roma Tre"

A distinctive trait of Quantum Mechanics is the peculiar meaning attributed to the measurement of the state of a quantum system. More precisely, a fundamental postulate of quantum theory states that the measurement of any physical observable unavoidably perturbs the original state. However, it may be desiderable to not completely tamper the original state, so as to preserve some of its original features, while still being able to extract some information out of it. To this extent, weak measurements proved to be an invaluable tool: while not completely perturbing the initial state, they lead to coarse-grained information extracted from the probed state. Here we present two different scenarios in which the toolbox of weak measurements has been used: 1. Quasiprobability distributions, whose negative values flag out genuine quantum behavior, are usually built relying on projective measurements of the quantum system under exam. Here, we design a theoretical and experimental protocol, involving weak measurements, to reconstruct two different quasiprobability distributions, highlighting peculiar quantum behavior, such as the incompatibility of two physical observables, or the contextuality of two subsequent measurements on the probe state. We showed how, by using a sufficiently strong measurement (although not fully projective), it is still possible to certify the desired genuine quantum property; 2. Several complex systems may be described by a "sloppy" model: in such a scenario the system is characterized by an relatively large number of parameters, while its dynamics is ruled by only a few combinations of a few of them. As a result, some combinations can be estimated with arbitrarily high precision, with other sloppy combinations being poorly determined. Therefore, full information about the system under exam is prevented from being retrieved. We tested these ideas in a quantum optics experiment, proving that a weak measurement with tunable strength can allow the experimenter to gather information about the individual parameters, countering the precision limits imposed by a sloppy model. Our work figures as a testbed for several applications, ranging from quantum sensing to quantum communication and monitoring of quantum systems.

EPR Paradox and Bell's Inequalities in High School

- Author: Maria Bondani, Alberto Carlini, Elena Losero & Matteo Oñate Orozco Poster code: **19B**
- Affiliation: National Council of Research - Photonics and Nanotechnologies Institute (CNR-IFN)

The EPR paradox and Bell's inequalities challenge classical notions of locality and realism, raising profound scientific and epistemological questions. We report on an innovative educational project developed through collaboration between researchers and educators and implemented at M.L. King High School in Genoa. Unlike traditional historical approaches to quantum mechanics education, this initiative engaged thirteen students and twelve teachers in two parallel courses. Using a two-state Dirac framework, the program introduced core quantum concepts with minimal prerequisites—light polarization, vector algebra, and complex numbers—tools already accessible to third-year students. A crucial element was the creation of a dedicated quantum optics laboratory within the school, funded by PNRR resources. This enabled students to conduct a hands-on experiment replicating, for the first time in an Italian high school, the violation of Bell's inequalities, an experiment central to the 2022 Nobel Prize in Physics awarded to Aspect, Clauser, and Zeilinger. Achieved in April 2025, this milestone underscores the feasibility of engaging high school students directly with frontier topics in quantum science.

Spectral properties of Bose-Fermi mixtures in two dimensions

- Author: Pietro Bovini Poster code: **6B**
- Affiliation: University of Bologna

Spectral properties of Bose-Fermi mixtures in two dimensions *Pietro Bovini*, Leonardo Pisani, Pierbiagio Pieri Dipartimento di Fisica e Astronomia "Augusto Righi", Universit'a di Bologna, Via Irnerio 46, I-40126, Bologna, Italy INFN, Sezione di Bologna, Viale Berti Pichat 6/2, I-40127, Bologna, Italy Ultracold dilute Bose-Fermi mixtures are highly tunable and controllable sys- tems, allowing for the investigation of substantially different conditions and quantum effects in matter. In such mixtures with a pairing interaction, one can study the competition between the formation of fermionic composite molecules and the tendency of bosons to condense. One possible application is a recent proposal to obtain a quantum simulator for p-wave superfluidity ([1]). In a pre- vious work ([2]), we considered a 2D ultracold Bose-Fermi mixture at $T = 0$. We described the system applying to two dimensions an (imaginary-time) T- matrix many-body approach in the ladder approximation, which has also been successfully applied to 3D systems ([3], [4]). In the present work, we focus on single-particle spectral properties, which could be relevant for future radio- frequency spectroscopy experiments (as done in 3D in [5]). To calculate dynamic quantities, we reformulate our theory for real-time and frequencies (as done in 3D in [6]). We study the evolution from the (Fermi) polaron regime to the case of a finite concentration of partially condensed bosons. In the literature, the Fermi polaron has been abundantly studied (e.g., in [7]), while the study of a finite bosonic density with arbitrary boson-fermion attraction is almost absent. Our main results for the bosonic spectral weight function are: - The dispersions of the attractive and repulsive branches are only slightly modified from the polaronic case but acquire, however, a finite width and thus a finite lifetime even at small momenta. - The presence of the condensate introduces at negative frequencies a new dis- persion of poles of the T-matrix (first predicted in 3D mixtures in [8]). This, in turn, creates in the bosonic spectral weight function a new structure at negative frequencies, whose prediction could be verified by radio-frequency spectroscopy experiments. - The polaronic picture is no longer valid going towards the density-matched case, where we observe the appearance of a third excitation branch. This could be related to the observations done in a 3D system in [5]. *References*: [1]: B. Bazak and D. S. Petrov. Phys. Rev. Lett.,121:263001, Dec 2018. [2]: L. Pisani, P. Bovini, F. Pavan, P. Pieri, SciPost Phys. 18, 076 (2025) [3]: A. Guidini, G. Bertaina, D. E. Galli, and P. Pieri. Phys. Rev. A, 91:023603, Feb 2015. [4]: M. Duda, X.-Y. Chen, A. Schindewolf, R. Bause, J. von Milczewski, R. Schmidt, I. Bloch, and X.-Y. Luo. Nature Physics, Feb 2023. 1 [5]: I. Fritsche, C. Baroni, E. Dobler, E. Kirilov, B. Huang, R. Grimm, G. M. Bruun, and P. Massignan. Phys. Rev. A, 103:053314, May 2021. [6]: E. Fratini and P. Pieri. Phys. Rev. A, 88:013627, Jul 2013. [7]: R. Schmidt, Tilman Enss, v. Pietil ¨a and E. Demler , Phys. Rev. A 85, 021602(R). [8]: T. Sogo, P. Schuck, and M. Urban, Phys. Rev. A 88, 023613

Latin Cross error correcting codes

- Author: Marko Brnovic Poster code: **14B**
- Affiliation: University of Bologna

We use the hypergraph product code construction to extend the well-known toric code to a so called latin cross code. The latin cross stabilisers have the usual vertex and plaquette terms, with additional 'tails'. We show the improvement in encoding rate compared to the toric code, and comment on error-correcting capabilities of such codes. We prove the degeneracy of the ground state is of a topological nature, and compute the entanglement entropy of the ground states. We describe the anyon theory of such codes and describe them as lattice gauge theories, where the underlying gauge group depends on the shape of the latin cross.

Exploring the Role of Hamiltonian Expressibility in Ansatz Selection for Variational Quantum Algorithms

- Author: Filippo Brozzi Poster code: **24B**
- Affiliation: University of Florence

In the context of Variational Quantum Algorithms (VQAs), selecting an appropriate ansatz is critical to solve a given problem efficiently. In this regard, the concept of Hamiltonian expressibility has been proposed as a metric to quantify a circuit ability to explore the problem energy landscape similarly to the Haar distribution. However, its potential to enhance the likelihood of obtaining high-quality solutions remains underexplored. In this work, we conduct a detailed analysis of Hamiltonian expressibility by applying a Monte Carlo method to estimate it for a set of known circuits on 4 and 8 qubits problems. We explore the relationship between ansatz depth and expressibility, identify the most and least Hamiltonian expressive circuits for different problem classes, and, most importantly, apply the Variational Quantum Eigensolver (VQE) protocol to train each ansatz across all problems to detect any correlation between final solution accuracy and Hamiltonian expressibility or other related metrics. Our results suggest that in an ideal or low noise setting, for 4 qubits problems, Hamiltonian-expressive ansätze perform better for problems with non-diagonal Hamiltonians or superposition-state solutions, while less expressive circuits are more effective for problems with diagonal Hamiltonians or basis-state solutions. In contrast, under noisy conditions, low expressibility remains beneficial for basis state solution problems, whereas for superposition-state solution problems, circuits with intermediate levels of expressibility yield better performance.

Advances in Algebraic Quantum Control

- Author: David Edward Bruschi — Poster code: **20A**
- Affiliation: Institute for Quantum Computing Analytics (PGI-12) - Forschunsgzentrum Jülich

Determining exactly the dynamics of a physical system is the paramount goal of any branch of physics. Quantum dynamics are characterized by the non-commutativity of operators, which implies that the dynamics usually cannot be tackled analytically and require ad-hoc solutions or numerical approaches. A priori knowledge on the ability to obtain exact results would be of great advantage for many tasks of modern interest, such as quantum computing, quantum simulation and quantum annealing.

In this work we build on our seminal approach previously introduced to determine the dimensionality of a Hamiltonian Lie algebra of bosonic systems (quantum harmonic oscillators) by appropriately characterizing its generating terms. In the original exact and fully general approach, we started to develop new tools to determine the final dimension of the algebra itself. We here extend the initial proposal by including a time-independent free Hamiltonian drift term, which improves the original proposal by allowing to tackle all bosonic Hamiltonians. We are able to provide statements on the ultimate ability to exactly control the dynamics or simulate specific classes of physical systems of coupled quantum harmonic oscillators. This work has important implications not only for theoretical physics, but it also aids our understanding of the structure of the Hilbert space, as well as Lie algebras.

Precision bounds for multiple currents in open quantum systems

- Author: Alessandro Candeloro — Poster code: **26A**
- Affiliation: University of Palermo

Thermodynamic (TUR) and kinetic (KUR) uncertainty relations are fundamental bounds constraining the fluctuations of current observables in classical, nonequilibrium systems. Several works have verified, however, violations of these classical bounds in open quantum systems, motivating the derivation of new quantum TURs and KURs that account for the role of quantum coherence. Here, we go one step further by deriving multidimensional KUR and TUR for multiple observables in open quantum systems undergoing Markovian dynamics. Our derivation exploits a multiparameter metrology approach, in which the Fisher information matrix plays a central role. Crucially, our bounds are tighter than previously derived quantum TURs and KURs for single observables, precisely because they incorporate correlations between multiple observables. We also find an intriguing quantum signature of correlations that is captured by the off-diagonal element of the Fisher information matrix, which vanishes for classical stochastic dynamics. By considering two examples, namely a coherently driven qubit system and the three-level maser, we demonstrate that the multidimensional quantum KUR bound can even be saturated when the observables are perfectly correlated.

Andreev non-Hermitian Hamiltonian for open Josephson junctions from Green's functions

- Author: Roberto Capecelatro — Poster code: **15A**
- Affiliation: University of Salerno

We investigate the transport properties of open Josephson junctions (JJs) through a minimal effective non-Hermitian (NH) approach derived from the equilibrium Green's function (GF) formalism. Specifically, we consider a JJ with a quantum dot (QD) barrier coupled to a normal metal reservoir. The coupling introduces an imaginary self-energy term in the JJ Hamiltonian which can be naturally accounted for in the NH formalism. We propose a scheme for deriving an effective NH Hamiltonian for the Andreev levels only, which we compute from the singular part of the barrier GF. To establish the range of applicability of this NH model, we benchmark our results for both the dot density of states and the supercurrent against exact GF predictions in different transport regimes. We find that, as a rule of thumb, the Andreev NH description is accurate when the spectral overlap between the Andreev bound states (ABS) and the near-gap continuum states is negligible, i.e., when the ABS energies lie sufficiently far from the superconducting gap relative to their linewidth. We also start applying the Andreev NH approach to study transport in QD junctions involving magnetic fields when coupled to normal and ferromagnetic reservoirs. Our goal will be to investigate the effects of decoherence on key phenomena such as 0-π transitions, as well as to explore the possible presence of exceptional points in these systems and their impact on the transport.

Tensor Network simulation of a waveguide QED architecture with multiple emitters

- Author: Rosa Lucia Capurso — Poster code: **2A**
- Affiliation: Università degli Studi di Bari "Aldo Moro" - INFN Bari

Waveguide Quantum Electrodynamics (Waveguide QED) is a promising and versatile platform for studying fundamental light-matter interactions and quantum technology implementations. Notably, interesting effects emerge when two or more quantum emitters are coupled to the waveguide, including collective phenomena, e.g., superradiance and formation of bound states in the continuum (BICs). An effective approach to address the behaviour of such systems is via Tensor Network quantum-inspired simulation techniques, enabling to efficiently simulate the real-time dynamics of many-body quantum systems, i.e, a waveguide QED platform. In particular, I will present a method based on Matrix Product States (MPS) to model a waveguide QED architecture featuring multiple emitter pairs and simulate its dynamics in the non-Markovian regime. Then, I will discuss the obtained results, focusing on the emergence of BICs and other collective effects in the long-time limit.

Measurement-Induced Phase Transitions Under Information Loss

- Author: Angelo Carollo Poster code: **27B**
- Affiliation: University of Palermo

The behavior of a quantum many-body system undergoing measurements is best understood through an ensemble of quantum trajectories, which can exhibit measurement-induced phase transitions (MIPTs). These transitions, however, cannot be detected using ensemble-averaged observables; instead, they require the ability to distinguish each individual trajectory, making their experimental detection highly challenging. In this study, we investigate how MIPTs are affected when an observer's capacity to distinguish measurement outcomes is reduced. This limitation introduces uncertainty into the system's state, causing observables to reflect a limited subset of trajectories rather than a single one. By analyzing an exactly-solvable Liouvillian model, we explore how long-range spatial correlations are impacted by varying levels of trajectory averaging. We precisely calculate the correlation matrix, Liouvillian gap, and entanglement negativity, revealing that averaging over multiple realizations introduces an effective finite lengthscale. Beyond this scale, long-range correlations are diminished. This indicates that partial trajectory averaging obscures the critical characteristics of individual realizations, effectively masking the distinct signatures of measurement-induced phases.

Experimental purification of photon indistinguishability via quantum interference.

- Author: Lorenzo Carosini Poster code: **29B**
- Affiliation: University of Vienna

Achieving highly indistinguishable photons is essential for multiphoton interference, a fundamental process in photonic quantum technologies. Purification, a well-known concept in quantum information processing, involves consuming multiple noisy quantum states to produce a single, noise-suppressed state (e.g., entanglement purification). Recent theoretical works [1,2] extend this concept to enhance photon indistinguishability by processing multiple partially distinguishable photons through quantum interference in linear-optical circuits. We present the first experimental demonstration of this approach, purifying partially distinguishable single photons emitted by a semiconductor quantum dot source into near unity indistinguishable photons. This is achieved via quantum interference with ancillary photons and heralded detection. By interfering two purified photons, we demonstrate a 2.774(3) % enhancement in indistinguishability under low-noise conditions, increasing to 10.2(5) % in high-noise conditions.

[1] C. Sparrow, Ph.D. thesis, Imperial College London (2017) [2] J. Marshall, Phys. Rev. Lett. 129, 213601 (2022)

Efficient quantum machine learning training in near-term implementations

- Author: Emanuele Casciaro — Poster code: **8A**
- Affiliation: University of Florence

Quantum Machine Learning (QML) offers a promising new approach to computational problems, but its scalability is often limited by current hardware, which remains small in scale and prone to noise, factors that can hinder its viability. Although simulators enable exact computations, their exponential resource demands quickly outweigh the benefits of quantum-inspired methods. In this work, we present a hybrid QML protocol designed to address these limitations by decomposing variational models into smaller components and reducing the hardware requirements for quantum implementation. We evaluated this approach on benchmark datasets and a real-world regression task and analyzed its efficacy, offering insights into its potential for generalization across different applications.

Frequency estimation by frequency jumps

- Author: Simone Cavazzoni — Poster code: **21B**
- Affiliation: University of Modena and Reggio Emilia

The frequency of a quantum harmonic oscillator cannot be precisely determined through static measurement strategies on a prepared state. Therefore, dynamical procedures must be employed, involving measurements taken after the system has evolved and encoded the frequency information. This talk explores the precision achievable in a protocol where a known detuning suddenly shifts the oscillator's frequency, which then reverts to its original value after a specific time interval. The results demonstrate that the squeezing induced by this frequency jump can effectively enhance the encoding of frequency information, significantly improving the quantum signal-to-noise ratio (QSNR) compared to standard free evolution at the same resource (energy and time) cost. The QSNR exhibits minimal dependence on the actual frequency and increases with both the magnitude of the detuning and the overall duration of the protocol. Furthermore, incorporating multiple frequency jumps into the protocol could further enhance precision, particularly for lower frequency values.

Ergotropic characterization of continuous variable entanglement

- Author: Federico Centrone — Poster code: **40B**
- Affiliation: ICFO

Continuous-variable quantum thermodynamics in the Gaussian regime provides a promising framework for investigating the energetic role of quantum correlations, particularly in optical systems. In this work, we introduce an entropy-free criterion for entanglement detection in bipartite Gaussian states, rooted in a distinct thermodynamic quantity: ergotropy—the maximum extractable work via unitary operations. By defining the relative ergotropic gap, which quantifies the disparity between global and local ergotropy, we derive two independent analytical bounds that distinguish entangled from separable states. These bounds coincide for a broad class of quantum states, making the criterion both necessary and sufficient in such cases. Unlike entropy-based measures, our ergotropic approach captures fundamentally different aspects of quantum correlations and entanglement, particularly in mixed continuous-variable systems. We also extend our analysis beyond the Gaussian regime to certain non-Gaussian states and observe that ergotropy continues to reflect thermodynamic signatures in entangled states. These findings establish a direct operational link between entanglement and energy storage, offering an experimentally accessible approach to entanglement detection in continuous-variable optical platforms.

Bosonic Two-Stroke Heat Engines with Polynomial Nonlinear Coupling

- Author: Giovanni Chesi — Poster code: **3A**
- Affiliation: University of Pavia

We discuss the thermodynamics of two-stroke heat engines where two bosonic modes are coupled by the most general nonlinear interaction, which typically corresponds to nonlinear processes in quantum optics [1]. Within the framework of the two-point measurement scheme [2], we derive the distribution of the stochastic work, and hence the mean value and the relative fluctuations (RFs) of the extracted work, up to the second order in the coupling. We optimize the nonlinear interaction with respect to the nonlinear order to provide the largest average work and/or to dampen the RFs in the operational regime of the heat engine. Then, we consider the specific case of second-order nonlinearities and expand the interaction up to the fourth order in the coupling. Having fixed the nonlinearity order, here we can perform the optimization of the average work and of the RFs over the frequencies of the bosonic modes and the temperatures of the reservoirs. Finally, we discuss the thermodynamic uncertainty relations (TURs) for these processes in relation with the order of the expansion of the nonlinear interaction.

[1] G. Chesi et al., Quantum Sci. Technol. 10, 035012 (2025). [2] M. Campisi et al., Rev. Mod. Phys. 83, 771 (2011).

Quantum Technologies Uni-Catania: highlights

- Author: Giuliano Chiriacò & Giuseppe Falci — Poster code: **39B**
- Affiliation: University of Catania

Recent results of the QuCaT-Quantum Technologies @ UniCT will be rewieved on the following topics: 1) Non-linear dynamics of artificial atoms Ultrafast communication between distant QPUs [1], Thermodynamic Limit in the Two-qubit Quantum Rabi Model with Spin-Spin Coupling [2], Selective decoupling in multi-level q-systems by the SU(2) sign [3].

2) Open Quantum Systems 1/f noise in quantum nanoscience [4] Quantum 1/f Noise Induced Relaxation in the Spin-Boson Model [5] ; Open-loop quantum control of small-size networks for

high-order cumulants and cross-correlations sensing [6] 3)Quantum Condensed Matter & Materials Local analysis of a single impurity on a graphene Josephson Junction [7] Dissipation and non-thermal states in cryogenic cavities [8]; Current phase relation in a planar graphene Josephson junction with spin-orbit coupling[9]

4) Artificial Intelligence for Quantum Noise Classification in Three-Level Quantum Networks by Machine Learning [10] Quantum sensing of noise correlations by Machine Learning [11] Machine Learning-aided Optimal Control of a noisy qubit [12]

[1] 2507.12020 [2] Phys. Rev. Research 6, 043298 (2024) [3] arXiv:2507.12056 [4] Encyclopedia of Condensed Matter Physics, 2e, vol. 1, pp. 1003-1017 (2024). [5]arXiv:2507.14329 [6] Scientific Reports 14 (1), 16681 (2024) [7] Phys. Rev. Research 7, 013189 (2025) [8] arXiv:2504.00591 [9] 2504.17517 [10] Machine Learning: Science and Technology 5, 045049 (2024) [11] Preprint 2025 [12] arXiv:2507.14085

Synthetic fractional flux quanta in a ring of superconducting qubits

- Author: Luca Chirolli Poster code: **37B**
- Affiliation: Department of Physics, University of Florence

A ring of capacitively-coupled transmons threaded by a synthetic magnetic field is studied as a realization of a strongly interacting bosonic system. The synthetic flux is imparted through a specific Floquet modulation scheme based on a suitable periodic sequence of Lorentzian pulses that are known as 'Levitons'. Such scheme has the advantage to preserve the translation invariance of the system and to work at the qubits sweet spots. We employ this system to demonstrate the concept of fractional values of flux quanta. Although such fractionalization phenomenon was originally predicted for bright solitons in cold atoms, it may be in fact challenging to access with that platform. Here, we show how fractional flux quanta can be read-out in the absorption spectrum of a suitable 'scattering experiment' in which the qubit ring is driven by microwaves.

Inferring quantum network topologies using genetic optimisation of indirect measurements

- Author: Diana A. Chisholm Poster code: **1A**
- Affiliation: University of Palermo

The characterisation of quantum networks is fundamental to understanding how energy and information propagates through complex systems, with applications in control, communication, error mitigation and energy transfer. We explore the use of external probes to infer the network topology in the context of continuous-time quantum walks, where a single excitation traverses the network with a pattern strongly influenced by its topology. The probes act as decay channels for the excitation, and can be interpreted as performing an indirect measurement on the network dynamics. By making use of a Genetic Optimisation algorithm, we demonstrate that the data collected by the probes can be used to successfully reconstruct the topology of any quantum network with high success rates, where performance is limited only by computational resources for large network sizes. Moreover, we show that increasing the number of probes significantly simplifies the reconstruction task, revealing a tradeoff between the number of probes and the required computational power.

Optimal control of an open micromaser quantum battery in the ultra-strong coupling regime

- Author: Maristella Crotti Poster code: **7A**
- Affiliation: University of Insubria

Quantum batteries are quantum systems designed for energy storage and transfer, where genuinely quantum features can be harnessed for enhanced performance beyond classical limits. We study micromaser-based quantum batteries within the framework of collision models, where a stream of qubits (charger) sequentially interacts with a single-mode electromagnetic cavity (battery). The goal is to achieve a high-energy, steady state of the battery with significant ergotropy, i.e., stored energy that is unitarily extractable as useful work. We focus on the ultrastrong coupling regime, where counter-rotating terms in the qubit-cavity interaction, while enabling faster charging, can also destabilize the system. Dissipation, acting as a crucial stabilizing mechanism, counteracts these detrimental effects, enabling the system to settle into a steady state characterized by finite energy and non-zero ergotropy. Specifically, we model dissipation during each qubit-cavity interaction using a Lindblad approach based on transitions between the eigenstates of the joint qubit-cavity system. Furthermore, we employ optimal control techniques to enhance the charging process. By optimizing, e.g, the qubit preparation and the duration of the qubit-cavity interaction, we maximize the stored ergotropy, thereby significantly improving the battery's capability to efficiently retain extractable work.

Trained Quantum Neural Networks are Gaussian Processes

- Author: Giacomo De Palma Poster code: **14A**
- Affiliation: University of Bologna

We study quantum neural networks made by parametric one-qubit gates and fixed two-qubit gates in the limit of infinite width, where the generated function is the expectation value of the sum of single-qubit observables over all the qubits. First, we prove that the probability distribution of the function generated by the untrained network with randomly initialized parameters converges in distribution to a Gaussian process whenever each measured qubit is correlated only with few other measured qubits. Then, we analytically characterize the training of the network via gradient descent with square loss on supervised learning problems. We prove that, as long as the network is not affected by barren plateaus, the trained network can perfectly fit the training set and that the probability distribution of the function generated after training still converges in distribution to a Gaussian process. Finally, we consider the statistical noise of the measurement at the output of the network and prove that a polynomial number of measurements is sufficient for all the previous results to hold and that the network can always be trained in polynomial time.

Based on Girardi, F., De Palma, G. Trained Quantum Neural Networks are Gaussian Processes. Commun. Math. Phys. 406, 92 (2025). https://doi.org/10.1007/s00220-025-05238-0

Securing the Quantum Future: A performance analysis framework for Quantum Key Distribution protocols

- Author: Ryan Debono, Christian Galea, André Xuereb & Johann A.Briffa Poster code: **10A**
- Affiliation: University of Malta

Quantum Key Distribution (QKD) tackles the problem of establishing a secure key between two parties (Alice and Bob) connected by a quantum channel and an authenticated classical channel. A QKD protocol is a formulated stepwise procedure that determines how a key is generated and synchronised between the parties. For a generated key to be considered secure, the algorithm that a QKD protocol follows needs to be shown to be provably secure. While the theoretical security of QKD has been extensively studied, we argue that a robust performance comparison of QKD protocols at different operating conditions is still an open problem. In this work, we provide a framework within which the performance of the BB84 protocol is analysed within the context of an intercept-and-resend attack. We argue that the best metric for measuring performance is the key rate, allowing for direct comparison between different QKD protocols under the same conditions. We provide a generalised model for the BB84 protocol that considers the probability of a successful eavesdropping attack, an unrestricted choice of basis for the eavesdropper, mismatch in the measurement bases between the trusted parties, and different channel models. The general approach proposed in this work also allows for flexibility in the information reconciliation process, specifically the error correcting code used. We show that when taking into consideration the amount of information leaked to the eavesdropper due to error correction and privacy amplification, the quantum bit error rate (QBER) threshold for successful key establishment is less than the 11% value often quoted in the literature.

Quantum Natural Gradient optimizer on noisy platforms: QAOA as a case study

- Author: Federico Dell'Anna Poster code: **25A**
- Affiliation: University of Bologna

We investigate the performance of the Quantum Natural Gradient (QNG) optimizer in the presence of noise. Specifically, we evaluate the efficacy of QNG within the Quantum Approximate Optimization Algorithm (QAOA) for finding the ground state of the Transverse Field Ising Model (TFIM). Its performance is benchmarked against the Vanilla Gradient Descent optimizer across two prominent quantum computing platforms: Rydberg atoms and superconducting circuits. Our analysis includes simulations under both idealized noise-free conditions and realistic noisy environments based on calibration data from actual devices. Results demonstrate that QNG consistently outperforms Vanilla Gradient Descent, exhibiting faster convergence on average and greater robustness against random initializations of parameters. This robustness is attributed to the distance regularization in parameter space inherent to QNG. Additionally, QNG achieves a higher convergence rate to the solution, effectively avoiding certain local minima. These findings highlight QNG as a promising tool for optimizing variational quantum algorithms in noisy intermediate-scale quantum (NISQ) devices.

High-dimensional photonic circuits using liquid-crystal

metasurfaces

- Author: Sneha Dey — Poster code: **11A**
- Affiliation: University of Naples, Federico II

An essential component of quantum information processing is the ability to encode information in on quantum states and perform unitary transformations. Photonic states are a promising candidate for this and, in particular, states encoded in high-dimensional degrees of freedom of photons have received attention in recent years due to their potential for higher information capacity and resistance to noise and decoherence. One promising technique for performing unitaries on photonic states is Multi-Plane Light Conversion (MPLC), which acts on spatial modes of light through alternating free-space propagation and phase modulations. MPLC offers a powerful approach for achieving arbitrary unitary operations in high-dimensional spatial mode bases. Traditionally, MPLC systems rely on spatial light modulators (SLMs) or refractive optics (1, 2), but these approaches face scalability challenges e.g. due to losses and inherent reflective geometries. In this work, we explore an alternative implementation using liquid crystal metasurfaces (LCMSs) and structured light modes, specifically the transverse spatial modes i.e. position and momentum. Essentially, LCMSs are a thin layer of liquid crystals whose optic axis can be arbitrarily patterned in the transverse plan allowing for complex phase and polarisation control (3). They enable transmissive operation, reduce optical losses, and enhance stability, making them ideal for scalable quantum photonic circuits. We fabricate these devices and investigate the MPLC technique in transmission, aiming to develop quantum circuits capable of performing unitary transformations in greater than 25 spatial modes, surpassing the current state-of-the-art (4). As a proof of concept, we will demonstrate the implementation of a high-dimensional Hadamard transformation - an essential operation for many techniques in quantum computing, quantum key distribution (QKD), and state tomography - with a limited set of transverse spatial modes (d=4). To do this, we have developed an optimisation approach based on the typically-used wavefront matching algorithm to generate the required phase modulations of our plates. Using this numerical optimisation, we found the ideal experimental parameters, allowing us to move towards a practical demonstration of our novel liquid-crystal-based MPLC. Following this, we plan to scale our approach to a higher number of spatial modes and to incorporate polarization, which will double the size of the Hilbert to which we have access. Such advancements pave the way for a wide range of quantum information applications, such as QKD, photonic quantum computing, quantum state measurement, and more. References: 1. N. K. Fontaine et al., Nat. Commun. 10, 1865 (2019). 2. F. Brandt, M. Hiekkamäki, F. Bouchard, M. Huber, R. Fickler, Optica. 7, 98–107 (2020). 3. A. Rubano, F. Cardano, B. Piccirillo, L. Marrucci, JOSA B. 36, D70–D87 (2019). 4. O. Lib, Y. Bromberg, Nat. Photonics. 18, 1218–1224 (2024).

Emergent cavity-QED dynamics along the edge of a photonic lattice

- Author: Enrico Di Benedetto — Poster code: **17A**
- Affiliation: University of Palermo

Two-dimensional photonic lattices with non-trivial topology support chiral edge modes that appear within bandgaps and enable irreversible decay of quantum emitters into a 1D continuum (a chiral waveguide). However, this paradigm has not been explored in systems with dispersionless edge modes. In this talk, we study light-matter interactions at the edge of a photonic honeycomb lattice (photonic graphene), where dispersionless edge modes arise for specific edge geometries. For qubits tuned near Dirac points, the dynamics is reproduced through an open cavity-QED model, in which each emitter couples to effective cavity modes while also decaying into bulk modes. These emergent cavity modes decay as a power law from the emitter and remain normalizable in the thermodynamic limit. This enables the engineering of exotic resonant and dispersive qubit-qubit interactions—unlike anything found in standard 1D photonic baths. The interaction strength and range can be tuned introducing anisotropy in the system. Finally, we discuss possible experimental realizations in superconducting circuits.

A telecom compatible quantum memortiy based on single-atom

- Author: Emanuele Distante — Poster code: **34A**
- Affiliation: University of Florence

Enabling communication between quantum devices, such as clocks, computers, and simulators has the potential to significantly enhance the capabilities of their applications, such as quantum sensing and computing.The key to achieving this lies in establishing efficient communication channels among these quantum devices even over a long distance, which involves the exchange of qubits encoded in light at telecom wavelengths through optical fibers. In this context, I will present an overview of the new experiment that we are building in Florence, which focuses on interfacing single photons at telecom wavelengths with individual neutral ytterbium atoms trapped in optical tweezers. By leveraging the unique properties of the ytterbium clock state and its telecom transitions, our objective is to interface a long-lived "matter" qubit and resonant light, including atom-resonant heralded single photons or photons forming entangled pairs. I will discuss the first developments, the motivation for exploring this research line and its impact as a crucial foundation for distributing entanglement between light and matter.

Exploring noise-induced Fano coherence in a hot vapor atomic gas

- Author: Ludovica Donati — Poster code: **35A**
- Affiliation: CNR-INO

In multi-level quantum systems, coherent superposition states can unexpectedly arise from interactions with the continuum of modes associated with incoherent processes, such as spontaneous emission and incoherent pumping. This type of coherence, known as noise-induced Fano coherence, tend to disappear when the incoherent source vanishes. The formation of Fano coherence between internal states generated by "noisy" conditions has particular significance for systems in contact with thermal reservoirs, as photovoltaic devices, photodetectors or quantum heat engines, since their performance could see improvements. We propose a V-type three-level quantum system realized in the hyperfine structure of hot 87Rb atoms. The objective is the detection of spatial anisotropy in the fluorescence spectrum of the atomic system driven by an incoherent field, thereby confirming the existence of noise-induced Fano coherences, as explained by Dodin et al. This will offer the first observation and new insights into quantum coherence phenomena arising from non-coherent excitation in a multi-level atomic system, potentially paving the way for the development of novel high-efficiency devices.

From Metrology to Thermodynamics: Relating QFI and Ergotropy in Moving Quantum Batteries

- Author: Samira Ebrahimi AslMamaghani Poster code: **18B**
- Affiliation: University of Palermo

Abstract: The main goal of this study is to explore the relationship between Quantum Fisher Information (QFI) and ergotropy in a dynamical context with quantum batteries. QFI is an important measure in quantum metrology, while ergotropy measures the maximum work that can be extracted from a quantum system. Understanding this connection is important for improving the design and performance of quantum technologies in relativistic scenarios or noisy environments.

First, we analyze a single two-level quantum battery moving along a spatial path in Minkowski spacetime, interacting with a massless scalar field. We look at its behavior across different velocity ranges: non-relativistic, relativistic, and ultra-relativistic. Next, we expand our analysis to a two-qubit quantum battery model, where each qubit interacts with its own local environment as a separate charger, without any direct interaction between the qubits.

Our results show that, under relativistic acceleration, QFI and ergotropy change in qualitatively similar ways over time. This suggests a possible connection between the amount of information and the energy capacity of quantum systems. These findings might provide new opportunities for optimizing quantum batteries and improving accuracy in relativistic quantum metrology.

Loss tolerant states for long range quantum communication

- Author: Tommaso Feri Poster code: **36A**
- Affiliation: University of Trieste

One of the main challenges in achieving long-range quantum communication is overcoming photon loss. Even in the best available optical fibre, losses are exponential in the length of the channel, leading to a rapid degradation of the transmitted message. In this talk, I will present how encoding information in tree-cluster states, a particular type of entangled state, can enable fast and reliable long-range quantum communication through a chain of repeater stations. We will also discuss how asymmetric geometries can improve the loss tolerance of tree-cluster states, and how such states can be efficiently generated using a single deterministic quantum emitter. Building on these results, I will present a minimal and efficient architecture for an all-optical quantum repeater. This design, which relies on a single deterministic quantum emitter per station, offers a compelling alternative to conventional memory-based repeaters.

Local Dephasing versus Spatial Overlap of identical

bosons through a microscopically derived Master Equation

- Author: Alberto Ferrara Poster code: **22A**
- Affiliation: University of Palermo

We study the dynamics of quantum resources in a system of identical bosons under noisy spatial deformation within the sLOCC framework. We consider two initially uncorrelated, spatially separated particles with distinct spatial and spin degrees of freedom, evolving in a double-well potential. Spatial overlap is modeled via a tunneling Hamiltonian, whose interplay with the action of local dephasing baths is analyzed. We present an analytical microscopical derivation of the corrisponding Lindblad master equation, taking into account the system-environment evolution and checking its validity compared to the numerical solution of the full system and we explore how noise affects known indistinguishability-based scenarios, such as Hong-Ou-Mandel interference, entanglement generation and distillation. Additionally, we compare dephasing effects at different stages of the spatial deformation (before, during, after), showing that simultaneous deformation and noise can produce rich, nontrivial dynamics, including shifts in bunching behavior and noise-induced quantum correlations. These findings emphasize the critical role of noise timing and engineering for robust quantum information processing with controlled identical particles.

Graph Representation Learning of Quantum Circuits

- Author: Maurizio Ferrari Dacrema & Riccardo Pellini Poster code: **39A**
- Affiliation: Polytechnic University of Milan

Quantum circuits can represent the same unitary operator through structurally different gate sequences. Verifying whether two quantum circuits implement the same unitary operator is however computationally intractable for large systems, since the size of an operator grows exponentially with respect to the number of qubits. Addressing this challenge may enable more efficient strategies for quantum circuit synthesis and analysis.

In this work, we aim at learning representations of quantum circuits which are both compact and semantically meaningful. We leverage the inherent graph structure of quantum circuits to map them into a low-dimensional space using Graph Neural Networks (GNNs). In such space, representations of equivalent circuits are close to each other. We train our models using a hybrid supervised and unsupervised approach, which involves a classification task and contrastive learning.

Preliminary results show that our learned can be effectively used for downstream tasks such as the classification of unitary operators. These findings suggest new directions for scalable quantum circuit synthesis without explicit unitary computations.

Variational basis optimization for scalable simulations of two-dimensional lattice gauge theories

- Author: Pierpaolo Fontana Poster code: **15B**
- Affiliation: Universitat Autonoma de Barcelona (UAB)

We provide a scalable, resource-efficient scheme for the quantum simulation and computation of lattice gauge theories (LGTs) with continuous gauge groups in the Hamiltonian formulation. We present both Abelian LGTs, considering compact quantum electrodynamics (cQED), and pure non-Abelian SU(2) LGTs in two spatial dimensions. We first reformulate the theory in terms of dual variables and then complement this formulation with the variational choice of the local basis, achieving significant improvements in terms of retained states needed to simulate the theory at arbitrary values of the bare coupling and lattice spacings. Within this approach, we determine the ground state of the theory for small lattices with periodic (for pure gauge) and open (in presence of fermionic matter) boundary conditions, and compute in both cases the expectation value of the plaquette operator. We finally show preliminary results for larger lattices obtained by means of tensor network algorithms. These results indicate that our method is suitable to scale up the system size in quantum simulations and computations architectures without dramatically increasing the number of required resources.

Chiral quantum walks for link prediction in network medicine

- Author: Gaia Forghieri — Poster code: **18A**
- Affiliation: University of Milan

Network medicine is an interdisciplinary field that studies the underlying mechanisms and interconnections between genes, diseases, and more. Protein-protein interaction (PPI) networks, also called interactomes, are at the basis of this study, since they are built through the physical and/or functional interactions between the proteins of an organism. However, despite the advancement made in building such networks, our current knowledge on them only covers an estimated 10% of all interactions in humans. In this context, link prediction is the fundamental task which aims at inferring missing or potential connections between two nodes of a network, based on its existing topology. Of all the classes of link prediction methods, we specifically focus on those based on continuous-time quantum walks (CTQW), which have already proven to be competitive with, and often complementary to, other state-of-the-art biologically motivated methods. Indeed, CTQWs can explore the whole network, and are consequently able to predict edges between nodes that are far away in the network. The aim of our project is to generalize these results by introducing chirality. This concept generalizes the quantum-classical correspondence by adding complex phases into the Hamiltonian generator of the CTQW. Due to the arbitrariness in the choice of such phases, this implies that a single network may correspond to an infinite number of CTQWs. Thus, chirality allows to explore a much larger configurational space, which can then be exploited for a more accurate link prediction. We show how this feature can potentially increase the performance of link prediction when considering the cumulative contribution of multiple chiral configurations. Additionally, we analyse the impact of the network properties on the performance by comparing results on different real-life PPI networks.

Generalized Carnot Theorem

- Author: Anna Gabetti — Poster code: **26B**
- Affiliation: Polyechnic University of Turin

We are currently witnessing the Second Quantum Revolution, and one of the most significant challenges in advancing quantum technologies is the development of efficient, miniaturized thermoelectric devices. These devices must optimize the conversion of heat into electricity minimizing energy dissipation within a finite operation time. This is a crucial and widely studied problem in the field of quantum thermodynamics. Traditional thermodynamic bounds, such as the Carnot efficiency, offer limited insight as they apply only to infinitely slow processes. Moreover, the effect of quantum correlations is still not well understood when quantum systems serve as the working medium in thermal processes. To address these limitations, we have derived a new fundamental bound to the efficiency of thermodynamic cycles through the description of a thermal engine which applies to both classical and quantum systems. This bound provides a more practical and informative constraint than classical thermodynamic limits (which imply knowledge of environment features, i.e. bath temperatures), as it explicitly incorporates controllable physical parameters such as cycle time duration and the system's internal energy. In the case of reversible cycles, the bound is saturated. Additionally, it can enable a deeper understanding of how quantum effects influence the performance of nanoscale engines and devices, with potential applications in emerging quantum technologies. In this presentation, we illustrate the meaning of our results also with examples of specific applications, including a quantum dot engine. Our bound is completely general, applying to transient systems far from thermal equilibrium, regardless of the number of heat baths involved or the nature of their interactions with the system.

Spin squeezing generation in atom-cavity systems: on the effects of adiabatic elimination beyond the leading order

- Author: Stefano Gregorio Giaccari — Poster code: **10B**
- Affiliation: INRiM

Spin-squeezed states are a prototypical example of metrologically useful quantum states where structured entanglement allows for enhanced sensing with respect to the one possible using classically correlated particles. Relevant aspects are both the efficient preparation of spin-squeezed states and the scalability of estimation precision with the number N of probes. Recently, in the context of the generation of spin-squeezed states via coupling of three-level atoms to an optical cavity, it was shown that increasing the atom-cavity coupling can be detrimental to spin-squeezing generation, an effect that is not appreciated in the standard second-order cavity removal approximation [1]. We describe adiabatic elimination techniques to derive an effective Lindblad master equation up to third order for the atomic degrees of freedom. We then show through numerical simulations that the spin-squeezing scalability loss is correctly reproduced by the reduced open system dynamics, pinpointing the relevant role of higher order contributions [2].

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A. Caprotti, M. Barbiero, M.G. Tarallo, M.G. Genoni, G. Bertaina

DOI: 10.1088/2058-9565/ad4584

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[2] "Spin squeezing generation in atom-cavity systems: on the effects of adiabatic elimination beyond the leading order"

Stefano Gregorio Giaccari, Giulia Dellea, Marco Giovanni Genoni, Gianluca Bertaina

e-Print: 2506.22383 [quant-ph]

Quantum plenoptic microscopy

- Author: Davide Giannella Poster code: **31B**
- Affiliation: University of Bari

Correlation plenoptic imaging (CPI) is a volumetric imaging technique retrieving the light-field of a three-dimensional sample exploiting a measurement of intensity correlations between light distributions collected by two high-resolution disjoint detectors. The light-field, in fact, is directly encoded in the second order correlation function and, to be retrieved, it requires the presence of spatio-temporal correlations between the intensities of the collected light: it can thus be decoded by employing either chaotic, or pseudo-chaotic, light or entangled photons/beams. Accessing the light-field enables both enhancing the depth of field (independently of the numerical aperture of the optical system) without sacrificing diffraction limited resolution, and refocusing the acquired images with no need for movable scanning optomechanics; as a consequence, scanning-free reconstruction of high resolution three-dimensional images can also be achieved.

Here we will present the main experimental results of the application of CPI to the microscopy domain by exploiting beams produced by type-II spontaneous parametric down-conversion (SPDC). The experiment aims at investigating the possibility of integrating CPI with sub-shot noise imaging, leveraging on the quantum correlations of SPDC beams in space and momentum, as well as intensity and time; in particular, we focus on the multi-photon regime, where many temporal modes and many photons per pixel are collected by the employed EM-CCD camera.

We shall present the experimental refocusing capability of CPI, the expected resolution limits, as well as the improved signal-to-noise ratio enabled by CPI over ghost imaging.

Integrated platforms for photonic quantum algorithms

- Author: Taira Giordani Poster code: **36B**
- Affiliation: Sapienza University of Rome

Quantum photonic platforms are a leading architecture for quantum information processing, enabling demonstrations of fundamental quantum phenomena and applications in cryptography and computation. Integrated photonic circuits offer efficient processing of multi-photon states and path-encoded evolutions, with promise for Boson Sampling-based quantum algorithms. These devices provide precise control and programmability over quantum photonic states, paving the way for scalable implementations.

This talk presents a photonic platform designed for quantum information processing, combining various single-photon sources and multi-port interferometers in integrated optics. We first demonstrate experiments using a universal and fully reprogrammable femtosecond-laser-written integrated circuit, beginning with a universal 6-mode interferometer interfaced with a parametric down-conversion source [1]. We then explore a high-performance platform incorporating a bright semiconductor quantum dot source, which offers on-demand single-photon generation and a high level of photon indistinguishability, and an 8-mode universal circuit.

We provide an overview of recent results in implementing quantum photonic algorithms, including a randomness manipulation protocol, known as Quantum Bernoulli Factory, realized in two distinct

3-photon setups: one using path-encoded qubits [2] and another leveraging a quantum dot source with polarization qubits, and fiber interferometers [3]. Finally, we discuss prospects in the context of further applications in variational quantum circuits and quantum machine learning.

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Time correlations from steady-state expectation values

- Author: Wojciech Gorecki Poster code: **17B**
- Affiliation: Freie Universitat Berlin, Germany

Second-order correlation functions, such as photon-number autocorrelations, capture essential dynamical features of quantum systems but are often experimentally challenging to access. In this talk, I will present a method to bound such correlation times using only steady-state expectation values and their parametric derivatives [1]. This offers a practical route to infer relaxation or coherence times without time-resolved measurements or full dynamical solutions.

These bounds are rooted in a general quantum metrological framework linking estimation precision to physical resources like time and energy [2]. By connecting correlation times to quantum Fisher information, we derive rigorous constraints that apply broadly to dissipative systems.

We previously applied this framework to analyze critical sensing protocols, showing their robustness and optimal scaling in noisy environments [3]. Building on those insights, we now extend the theory to the domain of dynamical correlations. As an application, I will discuss the infinite-range Ising model, where our method yields nontrivial bounds despite the absence of accessible dynamics.

[1] Time correlations from steady-state expectation values, W Górecki, S Felicetti, L Maccone, R Di Candia, to appear on arXiv (2025). [2] Interplay between time and energy in bosonic noisy quantum metrology, W Górecki, F Albarelli, S Felicetti, R Di Candia, L Maccone, PRX Quantum 6 (2), 020351 (2025) [3] Optimality and noise resilience of critical quantum sensing, U Alushi, W Górecki, S Felicetti, R Di Candia, Physical Review Letters 133 (4), 040801 (2024)

Exact model reduction for quantum systems.

- Author: Tommaso Grigoletto Poster code: **4B**
- Affiliation: University of Padova

The task of finding computationally more tractable descriptions of quantum dynamical systems is of paramount importance for tasks ranging from many-body quantum simulation to control. In this talk, I will present a recently proposed method to construct reduced-order models that exactly reproduce the evolution of selected observables or initial states of a Markovian quantum system of interest. The proposed framework leverages results from control-systems theory as well as classical and quantum probability and is strongly tied to symmetry notions in quantum dynamical systems. This framework is very general and has been applied to the reduction of both discrete- and continuous- time quantum dynamics and quantum trajectories. Notably, for systems evolving under Lindblad dynamics, our approach yields a reduced quantum-dynamical generator that is still in Lindblad form. Examples will be presented, including decoherence dynamics in central-spin systems coupled to structured environments and continuously monitored spin chains.

Non-Gaussian rank as an operational measure of non-Gaussianity

- Author: Rivu Gupta — Poster code: **27A**
- Affiliation: Sate University of Milan

We introduce the non-Gaussian rank as an operational measure of genuine quantum non-Gaussianity, defined as the minimum number of non-Gaussian gates required to generate a target quantum state, when supplemented with intermediate Gaussian operations. We propose two variants of this measure—the absolute and the average non-Gaussian rank—and demonstrate that both are monotonic under Gaussian operations. In addition, the absolute rank is shown to be a monotone under probabilistic Gaussian transformations, while the average rank exhibits robustness against small perturbations. We discuss the relevance of these measures in characterizing and constraining state transformations. To enable practical evaluation, we define the ϵ-approximate generalization of the non-Gaussian rank, quantifying the minimum number of applications of a given non-Gaussian gate needed to generate a target state within a fixed fidelity threshold. As illustrative examples, we consider experimentally accessible non-Gaussian gates—including the cubic-phase gate and the SNAP gate—and compute their ϵ-approximate ranks for key non-Gaussian states such as the CAT, Binomial, and GKP states, all of which play essential roles in quantum error correction. The proposed measure provides a direct connection between the resources required for universal quantum computation over bosonic systems and the hardness of implementing them in practical setups.

Entanglement and Stabilizer entropies of random bipartite pure quantum states

- Author: Daniele Iannotti — Poster code: **24A**
- Affiliation: Scuola Superiore Meridionale

The interplay between non-stabilizerness and entanglement in random states is a very rich arena of study for the understanding of quantum advantage and complexity. In this work, we tackle the problem of such interplay in random pure quantum states. We show that while there is a strong dependence between entanglement and magic, they are, surprisingly, perfectly uncorrelated. We compute the expectation value of non-stabilizerness given the Schmidt spectrum (and thus entanglement). At a first approximation, entanglement determines the average magic on the Schmidt orbit. However, there is a finer structure in the average magic distinguishing different orbits where the flatness of entanglement spectrum is involved.

Resource efficiency of quantum linear regression and shadow tomography for state estimation

- Author: Luca Innocenti Poster code: **16A**
- Affiliation: University of Palermo

We show that a number of paradigms of quantum metrology and quantum machine learning, such as quantum reservoir computing, quantum extreme learning machines, quantum kernels, and shadow tomography, can be understood as different aspects of a unifying formalism, and reveal from this perspective as extremely close in their resource cost and performances, differing only in different kinds of assumed knowledge on the part of the user. We show in particular how to relate the performance of shadow tomography in general measurement scenarios to that of quantum extreme learning machines, and how to fit quantum kernels in this picture. This answers a number of open questions regarding efficiency cost and relations between different approaches to state estimation and quantum machine learning.

Stabilizer Entropy and entanglement complexity in the Sachdev-Ye-Kitaev model

- Author: Barbara Jasser Poster code: **16B**
- Affiliation: Scuola Superiore Meridionale

The Sachdev-Ye-Kitaev (SYK) model is of paramount importance for the understanding of both strange metals and a microscopic theory of two-dimensional gravity. We study the interplay between Stabilizer Rényi Entropy (SRE) and entanglement entropy in both the ground state and highly excited states of the SYK4+SYK2 model interpolating the highly chaotic four-body interactions model with the integrable two-body interactions one. The interplay between these quantities is assessed also through universal statistics of the entanglement spectrum and its anti-flatness. We find that SYK4 is indeed characterized by a complex pattern of both entanglement and non-stabilizer resources while SYK2 is non-universal and not complex. We discuss the fragility and robustness of these features depending on the interpolation parameter.

Long-range nonstabilizerness and phases of matter

- Author: David Korbany Poster code: **40A**
- Affiliation: University of Bologna

Long-range nonstabilizerness can be defined as the amount of nonstabilizerness which cannot be removed by shallow local quantum circuits. In this work, 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.

Unveiling the role of magic and scrambling in quantum extreme learning

- Author: Gabriele Lo Monaco   Poster code: **41B**
- Affiliation: University of Palermo

Efficient estimation of expectation values is crucial for many quantum algorithms. Shadow tomography enables reconstruction of expectation values for low-rank observables via randomized measurements but suffers from noise-induced bias, often requiring error correction. Quantum Extreme Learning Machine (QELM) provides a noise-resilient alternative: the target state interacts with a fixed, uncalibrated quantum reservoir, which is measured in the computational basis. A weight matrix, trained on known states, maps measure outcomes to observable estimates.

A natural question, however, concerns the limits of QELM performance: How does the nature of the reservoir dynamics affect estimation accuracy, and what quantum resources are truly necessary for universal reconstruction? In this talk, we address these questions through two complementary perspectives.

First, we investigate the relation between QELM performance and quantum information scrambling—the process by which local quantum information becomes delocalized through many-body interactions. We show that, contrary to intuition, accurate state reconstruction via QELM remains possible even well beyond the scrambling time. While out-of-time-ordered correlators (OTOCs) saturate and nonlocal correlations dominate, sufficient local information persists to allow high-fidelity estimation. This reveals that scrambling, per se, does not hinder QELM effectiveness; rather, the key requirement is sufficient information spreading across the reservoir.

We then shift perspective, focusing on the role of non-classicality with particular reference to non-stabilizerness (magic). While Clifford dynamics can generate significant entanglement, we rigorously show they are insufficient for universal reconstruction in QELM, using the formalism of measurement frames. We also show that at least 2n T-gates are required to construct informationally complete measurements for n-qubit inputs. However, reaching this threshold is not sufficient in practice—most minimally doped circuits fail to reconstruct arbitrary observables. We study the scaling with the doping of the probability to sampling reconstructing circuits; we find that although the success probability increases exponentially, it does so with a subpolynomial exponent. Interestingly, T-gates can be applied in parallel, enabling a trade-off between circuit depth and reservoir size.

Unsupervised machine learning for cat-state characterization

- Author: Adriano Macarone Palmieri
- Affiliation: University of Palermo

Poster code: **22B**

The characterization of continuous-variable (CV) quantum states stands as a pivotal cornerstone in the advancement of quantum technologies. This understanding unlocks precise control and verification of these intricate states. CV states, like the squeezed or entangled light, can carry information with unparalleled potential and, for this reason, their characterization through sophisticated methods like covariance matrices or Wigner functions, is the linchpin that ensures the security of quantum key distribution (QKD), or fidelity in quantum teleportation..

The "cat states" stand as a special type of CV states. These states are of high interest for circuit QED platforms because they allow for error correction without full syndrome measurement, therefore improving scalability. For this reason there is high interest in characterizing their quantum properties.

In this work, we opt for re-analyzing the problem from scratch, without resorting to Wigner or Radon transformations, looking directly into the structure of the sampled data obtained from the homodyne detection. Basically, we run our considerations on the structure of the distribution they elicit. Firstly, as a kickstarter, we re-sketch the tomography problem as a clustering problem, by using density estimation method to infer the number of clusters, and clustering algorithm to pinpoint the underlying true value. Then, we tackle a discrimination task between quantum and classical states. We observe that for non-classical states, interference fringes can arise when we perform homodyne measurements on the cat, and not a mixed one. Taking advantage of this fact, we show that, in machine learning terms, the problem can be tackled as a kernel density estimation one. In doing so, when a quantum state enters, we can detect the fringes as an increased number of distributions peaks – in other words, the measurements data densify in a different fashion according to their properties.

Breaking local symmetries with locality-preserving operations

- Author: Michele Mazzoni
- Affiliation: University of Bologna

Poster code: **19A**

In the general framework of quantum resource theories, one typically only distinguishes between operations that can or cannot generate the resource of interest. In many-body settings, one can further characterize quantum operations based on underlying geometrical constraints and a natural question is to understand the power of resource-generating operations that preserve locality. In this work, we address this question within the resource theory of asymmetry, which has recently found applications in the study of many-body symmetry-breaking and symmetry-restoration phenomena. We consider symmetries corresponding to both abelian and non-abelian compact groups with a homogeneous local action on the space of N qubits, focusing on the prototypical examples of $U(1)$ and $SU(2)$. We study the so-called G-asymmetry ΔS_N^G, and present two main results. First, we derive a general bound on the asymmetry that can be generated by locality-preserving operations acting on symmetric (mixed) product states, proving that $\Delta S_N^G \leq (1/2)\Delta S_N^{G,\max} + c$, where $\Delta S_N^{G,\max}$ is the maximum value of the G-asymmetry in the full many-body Hilbert space, while c is a N-independent constant. Second, we show that locality-preserving operations can generate maximal asymmetry $\Delta S_N^G \sim \Delta S_N^{G,\max}$ 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.

Nonequilibrium steady states in multi-bath quantum collision models

- Author: Ronan McElvogue Poster code: **20B**
- Affiliation: University College Dublin

We compare and contrast the dynamics and steady-states for a two-level quantum system whose open system dynamics are described using different collision model approaches. As a benchmark, in the first approach we adopt the typical setting by assuming each constituent of the collisional environment is initialised in an identical thermal state. The second approach involves modelling the environment using two collisional baths, with the system-bath interactions dictated by the initial environmental constituent's energy. While these approaches formally give rise to an identical system dynamics for a Markovian setting in the limit of vanishing system-environment interaction time, we demonstrate that at the microscopic level they describe fundamentally different physical processes. In particular, we show that the two-collisional bath setting invariably drives the system to a non-equilibrium steady state for any finite collision duration. We further investigate the impact that non-Markovian dynamics has on the resulting steady state properties by introducing intra-environment interactions. We show that while both settings exhibit a comparable degree of non-Markovianity, the two-bath non-Markovian dynamics drives the system further from the expected equilibrium state. We establish that it is the creation of strong system-environment and inter-environment correlations in the two-bath setting that enhances the non-equilibrium character of the resulting steady state. Finally, we consider how the stochastic heat current can be recovered in the second setting via a two-point measurement scheme applied to the auxilliary units.

Mean-field limit from general mixtures of experts to quantum neural networks

- Author: Anderson Melchor Hernandez Poster code: **28B**
- Affiliation: University of Bologna

In this talk, we investigate the asymptotic behavior of Mixture of Experts (MoE) models trained via gradient flow on supervised learning tasks. Our main result establishes a propagation of chaos phenomenon as the number of experts tends to infinity. Specifically, we show that the empirical distribution of the experts' parameters converges to a deterministic probability measure governed by a nonlinear continuity equation. Furthermore, we derive an explicit convergence rate that depends only on the number of experts. Finally, we illustrate our theoretical findings by applying them to a MoE architecture implemented with a quantum neural network. This is based on joint work with G. De Palma and D. Pastorello.

Generating Positive but Non-Decomposable Maps Using Semidefinite Programming

- Author: Angela Rosy Morgillo Poster code: **30B**
- Affiliation: University of Pavia

Positive but non-decomposable maps play a central role in quantum information theory, particularly in the detection of entanglement that eludes the Peres-Horodecki criterion. However, despite their importance, the landscape of such maps in low dimensions remains poorly understood. In particular, for d=3, the Choi map remains one of the few known explicit examples. In this work, we address the open problem of characterizing and systematically generating positive non-decomposable maps. We design a novel optimization framework based on semidefinite programming (SDP), where positivity is guaranteed by testing the Choi matrix against symmetric Positive Partial Transpose (PPT)-extendible states, and non-decomposability is promoted by minimizing its expectation value over the set of PPT states. Our method successfully constructs new instances of positive maps that are not expressible as a sum of completely positive and completely co-positive maps.

Daemonic work extraction via non-ideal QND-energy measurement

- Author: Daniele Morrone Poster code: **5B**
- Affiliation: University of Palermo

Work extraction from a quantum battery is theoretically optimal under thermal operations which are, however, difficult to implement at the experimental level. Unitary operation are more feasible, but extracting work through them is known to underperform thermal operation, as the ergotropy is known to lower bound the classical work definition. The gap in extracted work between the two operations can be bridged through quantum measurements, which can enhance the amount of extracted work. To perform the measurement, however, an energy cost must be payed in agreement with Landauer's principle. Even when accounting for this energy cost, a favorable net gain in terms of ergotropy can be demonstrated to exist, oppositely to the case with thermal operations which are bound by energy-conservation (the total amount of work gained cannot exceeds the cost payed). This result proves that work extraction with unitary operations benefits more from measurements compared with work extraction with thermal operations. We provide a rigorous accounting of the extracted net work via a quantum nondemolition (QND) energy measurement scheme. Our analysis reveals that when the measurement efficiency is sufficiently high, the performance gap between thermal and unitary work extraction asymptotically reaches zero. To showcase our results, we apply our protocol to the simple case of a qubit quantum battery initially prepared in an active state, and we evaluate the work extracted through different protocols, both with and without our measurement scheme. Our results demonstrate that optimal work extraction can be achieved without thermal operations whenever efficient measurements can be implemented.

Programmable Quantum Photonic Processing via Temporal Photonic Lattices

- Author: Farzam Nosrati Poster code: **34B**
- Affiliation: University of Palermo

We experimentally design a dynamically programmable quantum photonic platform that leverages synthetic temporal photonic lattices, implemented in a fiber-based coupled-loop architecture, to enable the preparation, manipulation, and detection of high-dimensional time-bin-entangled photon pairs. By mapping the synthetic temporal photonic lattices onto the discrete-time quantum walk model, we gain control over the walker's evolution and the quantum interference between two photons, allowing for the precise engineering of quantum operations. Notably, we demonstrate that interference measurements can be optimized through dynamic control over both time and synthetic position, enabling post-selection-free measurements and enhanced detection efficiency. The fiber-based implementation operates entirely within the telecom band, ensuring compatibility with existing optical infrastructure. This compatibility paves the way for practical deployment for quantum information tasks, including high-dimensional entanglement distribution, Boson sampling, quantum phase estimation, and secure key generation in quantum cryptography.

Generation of nonclassical light in doubly resonant linearly uncoupled integrated resonators

- Author: Matteo Piccolini Poster code: **23B**
- Affiliation: University of Pavia

The generation of nonclassical light, such as squeezed states or entangled photons, is a critical resource for quantum technologies, including quantum key distribution (QKD) and quantum computing. These states enable secure communication, enhanced measurement precision, and facilitate fundamental tests of quantum mechanics. The ability to generate high-quality nonclassical light is, therefore, a key requirement for advancing quantum information science and enabling real-world applications.Among the various sources of nonclassical light, spontaneous parametric down-conversion (SPDC) stands out as an efficient and widely-used method. Currently, most SPDC sources are bulk-based. However, there have been proposed integrated approaches to miniaturize the source and allow for scalability and integration into photonic circuits, unlocking new potential for quantum devices. Yet, despite these advances, there remain significant challenges such as operating across a wide frequency range, phase matching, and source tunability. Managing all these aspects simultaneously while ensuring low-loss propagation is essential for achieving high-efficiency photon-pair generation and preserving the desired quantum properties of the output light.Recent advances in material science have introduced new platforms like aluminum nitride (AlN) and lithium niobate (LiNbO3), which can help integrating SPDC sources ensuring fabrication quality and taking advantage of wide transparency windows. In particular, AlN, known for being a CMOS-compatible material with a large second-order nonlinearity and a wide bandgap (6.2 eV) is emerging as a promising material for realizing efficient SPDC sources.In this work, we propose a novel device featuring resonant elements at both the pump and generation frequencies. These resonances can be tuned independently, providing great flexibility in managing the nonlinear interaction. This further allows to decouple the nonlinear process from the linear one, optimizing performance at both high and low frequencies. We demonstrate that this structure can generate photon pairs via SPDC across a broad spectral range and that we can precisely control their quantum correlations. Our results show that the proposed integrated structure offers a powerful platform for efficient, scalable nonclassical light generation, with promising applications in quantum technologies.

Non-Markovian dynamics of a qubit due to accelerated light in a lattice

- Author: Marcel Pinto Poster code: **25B**
- Affiliation: University of Palermo

We investigate the emission of a qubit weakly coupled to a one-band coupled-cavity array where, due to an engineered gradient in the cavity frequencies, photons are effectively accelerated by a synthetic force F . For strong F , a reversible emission described by an effective Jaynes-Cummings model occurs, causing a chiral time-periodic excitation of an extensive region of the array, either to the right or to left of the qubit depending on its frequency. For weak values of F instead, a complex non-Markovian decay with revivals shows up. This is reminiscent of dynamics induced by mirrors in standard waveguides, despite the absence of actual mirrors, and can be attributed to the finite width of the energy band which confine the motion of the emitted photon. In a suitable regime, the decay is well described by a delay differential equation formally analogous to the one governing the decay of an atom in a multi-mode cavity where the cavity length and time taken by a photon to travel between the two mirrors are now embodied by the amplitude and period of Bloch oscillations, respectively.

Emergence of the FFLO State in 2D Spin-Imbalanced Fermi Gases

- Author: Francesco Pirolo Poster code: **32A**
- Affiliation: University of Bologna

In this work, we explore the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state in two-dimensional spin-imbalanced Fermi gases using a T-matrix framework. The FFLO phase—characterized by finite-momentum pairing—is a paradigmatic example of unconventional superconducting order. In our inquiry, we construct the phase diagram of the spin-imbalanced Fermi mixture and examine its quantum critical behavior by analyzing the scaling of fermionic self-energies in the proximity of the critical point. Our approach builds on a non-self-consistent T-matrix (NSC) resummation of the Dyson series, which we enhance with a Hartree-like shift. This modification proves essential for correcting the shortcomings of the NSC theory alone. Ultracold atomic gases, with their high tunability and controllable imbalance, provide an ideal platform to explore such exotic pairing phenomena.

Classification of qubit cellular automata on hypercubic lattices

- Author: Andrea Pizzamiglio Poster code: **33B**
- Affiliation: University of Pavia

In this talk, I will introduce digital quantum dynamics known as Quantum Cellular Automata (QCA) and the problem of their classification, focusing on recent results that fully characterize nearest-neighbor, translation-invariant quantum cellular automata acting on hypercubic lattices of qubits. These results answer key questions: What is the set of unitary maps abiding such locality and symmetry constraints?

How much entanglement can they generate? Which can be realized by constant-depth quantum circuits? And how are these dynamics connected to the classification of topological phases of matter? This talk is based on joint work with Paolo Perinotti and Alessandro Bisio (Phys. Rev. Lett. 134, 240601).

Quantum State Routing using Chiral Quantum Walks

- Author: Giovanni Ragazzi — Poster code: **13A**
- Affiliation: University of Modena and Reggio Emilia

Quantum Walks offer a versatile framework for characterizing the quantum evolution of particles or excitations within a discrete network, represented as a graph. Beyond their intrinsic scientific appeal, Quantum Walks serve as a useful tool for describing, designing, and optimizing energy transport in both artificial and biological systems. Notably, Continuous-Time Quantum Walks on graphs are typically regarded as a quantum version of classical Continuous-Time Random Walks, achieved by promoting the classical transfer matrix, i.e., the graph Laplacian, to a Hamiltonian. Nonetheless, this specific approach severely restricts the permissibles Hamiltonians that can be associated with a given graph and proves inefficient for directional transport due to inherent symmetries. In this presentation, I demonstrate that the transport capabilities of a system are considerably enhanced by incorporating complex phases into the Hamiltonian and utilizing what literature terms as Chiral Quantum Walks. Specifically, we tackle the problem of routing quantum information, initially encoded in a superposition state across two graph nodes, to a selected target state among many possible destinations. The router's effectiveness is measured by evaluating the quantum fidelity between the time-evolved initial state and the target state, which can achieve a value of 1 by configuring appropriate phases and weights within the Hamiltonian. Furthermore, our findings indicate that perfect quantum information routing can be attained in a time frame that remains constant regardless of the input signal and the number of outputs, positioning our method as a possible efficient and scalable approach.

Quantum algorithms for equational reasoning

- Author: Davide Rattacaso — Poster code: **A37**
- Affiliation: University of Padova

Verifying whether two quantum or classical circuits are functionally equivalent—and optimizing them accordingly—is a central problem in quantum science and technology. This task requires navigating the space of circuits that implement the same unitary, a problem that can be formalized using term rewriting systems. These systems, traditionally used in automated reasoning and formal logic, operate by applying equivalence rules to transform symbolic expressions and have found diverse applications in areas such as circuit optimization, computational group theory, formal language theory, and even biomolecular modeling. In this work, we introduce quantum algorithms to address fundamental problems in equational reasoning, with a focus on the word problem: deciding whether two expressions can be transformed into one another using a set of rewriting rules. We show that this problem can be formulated as a quantum optimization task by encoding it into a sparse Hamiltonian whose structure directly reflects the rewriting rules. Leveraging Tensor Network simulations, we solve the word problem in equivalence classes containing up to $10^2$8 equivalent expressions. Finally, we illustrate how these methods can be applied to perform optimal compilation of quantum circuits directly on quantum computers.

Reliable quantum advantage in quantum battery charging

- Author: Davide Rinaldi Poster code: **29A**
- Affiliation: University of Pavia

One of the most crucial requirements for competitive and efficient quantum technologies is the possibility to be both miniaturized and scaled effectively. However, devices operating at the nanoscale necessitate the management of extremely small quantities of energy. This requirement gives rise to a fundamental question: how can fluctuations be properly accounted for? Indeed, the smaller the amount of energy involved, the more significant the relative impact of energy fluctuations becomes. Consequently, it is essential to suppress such fluctuations in order to minimize noise in any practical application of quantum technologies, such as in the implementation of efficient quantum computation. Moreover, a comprehensive understanding of the mechanisms underlying fluctuations during a given process enables the identification of protocols characterized by a reduced variance in the results, thereby suggesting a more favorable path toward the development of high-precision quantum devices and the optimization of quantum technologies.

Within this context, quantum batteries play a distinctive role. These are systems capable of storing energy upon being charged and subsequently delivering it on demand. They can be analyzed from a thermodynamic perspective, particularly through the study of energy exchanges and fluctuations. As such, they serve as well-suited models for proof-of-principle investigations of the thermodynamic efficiency of quantum devices. Exploring the field of quantum batteries and their practical implementation may prove valuable in enhancing control over the processes necessary for the deployment of quantum technologies.

In our work, we investigate a Jaynes–Cummings quantum battery, namely a device composed of a flying qubit interacting with an optical resonator. By employing the Full Counting Statistics technique, we analytically demonstrate that the charging performance of the battery can be enhanced by preparing the single-mode resonator in a genuinely quantum, non-Gaussian state. Specifically, when the cavity mode is initialized in a Fock state, the charging process proves to be more efficient than in alternative protocols - such as those involving a cavity prepared in a "classical" coherent state or in a Gaussian (yet quantum) squeezed state. We substantiate this advantage of the Fock-state protocol by evaluating the signal-to-noise ratio (SNR), which quantifies the quality of the signal (i.e., the average energy injected into the battery) comparing it to its fluctuations (i.e., the variance). This advantage is shown to be reliable, as it accounts for the dynamical energy fluctuations that arise during the process.

Our model may serve as a valuable starting point for designing processes essential to the development of efficient quantum technologies. These processes may include, among others, the preparation of a target quantum state, the lossless storage of minimal energy quantities, and the precise exchange of energy quanta between atomic systems. Moreover, the ability to control multiple resources (for example, by sequentially charging a train of flying qubits) makes it possible to extend the efficiency advantage demonstrated for a single quantum battery to a multibody configuration, thereby generalizing the analysis to more complex systems. This potential advantage is currently being investigated from an experimental perspective as well, specifically through the implementation of the quantum battery on a trapped calcium-ion platform.

A Bethe ansatz approach to the Thirring Quantum Cellular Automaton

- Author: Saverio Rota Poster code: **11B**
- Affiliation: University of Pavia

We investigate the integrability of the 1+1 dimensional massless Thirring Quantum Cellular Automaton, which models the discrete-time evolution of fermionic modes on a lattice through local, number-preserving interactions. These interactions act as a discrete-time analogue of those found in integrable Hamiltonian systems such as the Thirring and Hubbard models. Motivated by this correspondence, we apply the coordinate Bethe ansatz—a well-established method in the study of integrable systems—to analyze the spectrum of the unitary operator governing the automaton's update rule.

Our goal is to construct translationally invariant eigenstates, assuming they can be expressed as plane waves with momenta permuted among particles—an assumption we verify a posteriori by testing the completeness of the resulting solutions. We have obtained explicit solutions for the two- and three-particle sectors and are currently working toward a generalization for arbitrary particle numbers. Ultimately, our aim is to recover the Yang-Baxter equation, which would allow for a recursive construction of the solutions in terms of a representation of the symmetric group.

Our preliminary findings indicate that the periodicity of the quasi-energy—a consequence of the model's discrete-time nature—necessitates a slight modification of the standard Bethe ansatz used in the Hamiltonian setting. In particular, the wavefunction must include additional components in its plane-wave expansion, corresponding to quasi-energies that differ by integer multiples of 2pi.

Vibrating Border for Quantum Light: Multiphoton Entanglement and Bilateral Emission

- Author: Enrico Russo Poster code: **35B**
- Affiliation: University of Palermo

Entanglement plays a crucial role in the development of quantum-enabled devices. One significant objective is the deterministic creation and distribution of entangled states. In this talk I will talk about a particular setting of a cavity resonator containing a two-sided perfect mirror. Although the mirror separates the cavity modes into two independent confined electromagnetic fields, the radiation pressure interaction gives rise to high-order effective interactions across the subsystems. Depending on the chosen resonant conditions, which are also related to the position of the mirror, we consider the entaglement generation of 2n-photon emission and the case of bilateral photon pair production. We provide a pathway to control these phenomena, opening potential applications in quantum technologies. Looking ahead, similar integrated devices could be used to entangle subsystems across vastly different energy scales, such as microwave and optical photons.

Multi-Dimensional Hybrid Quantum Reservoir Computing for Low-Dimensional Turbulence Forecasting

- Author: Luca Salatino Poster code: **9B**
- Affiliation: ICAR-CNR

The prediction of complex dynamics remains an open problem across many domains of physics, where nonlinearities and multiscale interactions severely limit the reliability of conventional forecasting methods. Quantum reservoir computing (QRC) has emerged as a promising paradigm for information processing by harnessing the high-dimensional dynamics of quantum systems. Here, we introduce a hybrid quantum-classical reservoir architecture capable of handling multivariate time series through quantum evolution combined with classical memory enhancement. Our model employs a five-qubit transverse-field Ising Hamiltonian with input-modulated dynamics and temporal multiplexing, enabling a rich encoding of input signals over multiple timescales. Here, we apply this framework to two paradigmatic models of chaotic transitions in fluid dynamics, where multiscale dynamics and nonlinearities play a dominant role: a low-dimensional truncation of the two-dimensional Navier-Stokes equations and the Lorenz-63 system. By systematically scanning the quantum system's parameter space, we identify regions that maximize forecasting performance, as measured by the Valid Prediction Time. The observed robustness and generality across both dynamical systems suggest that this hybrid quantum approach offers a flexible platform for modelling complex nonlinear time series.

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Circuit dynamics of free fermions in disguise

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- Affiliation: University of Bologna

The models known as "free fermions in disguise" are a class of Hamiltonians with very peculiar properties: while they are directly solvable by any Jordan-Wigner (JW) transformation, they display a free-fermionic spectrum. Indeed, the mapping to free fermionic modes involves a complicated non-linear and highly non-local map. Because of this, contrary to standard JW-solvable spin chains, it is a non-trivial and partially open question to compute the dynamics in such models, or whether this can be done efficiently at all. In this poster, I will focus on a family of quantum circuits which are the discrete version of the dynamics of free fermions in disguise and present recent results pertaining to their time evolution. I will discuss the implications of our results for the classical simulability of this class of circuits, and the quantum simulation of "free-fermions in disguise" on a quantum computer.

Generalized uncertainty relations for SU(N) observables and their relation with partition–separability

- Author: Gianluigi Tartaglione Poster code: **12A**

■ Affiliation: University of Salerno

In this work, we derive an exact uncertainty relation for arbitrary quantum states, pure or mixed of multipartite systems. For any fixed k-partition of the system, we show that the total uncertainty associated with all tensor products of SU(N) observables acting on the subsystems depends solely on the purities of the global state and its subsystems. By generalizing the Schrödinger uncertainty relation for a single qubit in a multipartite system for Pauli observables, we demonstrate that the missing term required to saturate the inequality corresponds to the qubit's purity, capturing correlations with the rest of the system. Leveraging this framework, we reformulate, in terms of purities alone, an existing criterion that provides a necessary condition for partition-separability. For a fixed k-partition of a multipartite system, this criterion takes the form of an inequality involving the purity of the global state and those of its subsystems, whose violation guarantees entanglement. This approach offers a physically meaningful tool for entanglement detection, particularly in high-dimensional systems. We analyze the effectiveness of the criterion both numerically and analytically, identifying classes of states for which entanglement is most readily detected. For two-qubit states, we explore its relation to CHSH inequalities and provide a geometric interpretation for Bell-diagonal states. Our approach reveals a link between uncertainty, purity, and entanglement.

Robustness of Magic in the quantum Ising chain via Monte Carlo tomography

■ Author: Hari Timsina

Poster code: **6A**

■ Affiliation: SISSA

We study the behavior of magic as a bipartite correlation in the quantum Ising chain across its quantum phase transition. In order to quantify the magic of partitions rigorously, we formulate a hybrid scheme that combines stochastic sampling of reduced density matrices via Monte Carlo, with state-of-the-art estimators for the robustness of magic - a good measure of magic for mixed states. This allows us to compute the mutual robustness of magic for partitions up to 8 sites, embedded into a much larger system. We show how mutual robustness is directly related to critical behaviors: at the critical point, it displays a power law decay as a function of the distance between partitions, whose exponent is related to the partition size. Once finite temperature is included, mutual magic retains its low temperature value up to an effective critical temperature, whose dependence on size is also algebraic.

Solving MNIST with a globally trained Mixture of Quantum Experts

■ Author: Paolo Alessandro Xavier Tognini

Poster code: **38A**

■ Affiliation: Scuola Normale Superiore, Pisa

We propose a new quantum neural network for image classification, which is able to classify the parity of the MNIST dataset with full resolution with a test accuracy of up to 97.5% without any classical pre-processing or post-processing. Our architecture is based on a mixture of experts whose model function is the sum of the model functions of each expert. We encode the input with amplitude encoding, which allows us to encode full-resolution MNIST images with 10 qubits and to implement

a convolution on the whole image with just a single one-qubit gate. Our training algorithm is based on training all the experts together, which significantly improves trainability with respect to training each expert independently. In fact, in the limit of infinitely many experts, our training algorithm can perfectly fit the training data. Our results demonstrate the potential of our quantum neural network to achieve high-accuracy image classification with minimal quantum resources, paving the way for more scalable and efficient quantum machine learning models.

Renormalisation of Quantum Cellular Automata

- Author: Lorenzo Siro Trezzini

Poster code: **33A**

- Affiliation: University of Pavia

Quantum Cellular Automata (QCA) represent the most general form of discrete-time dynamics for countably many quantum systems. As such, they play a key role in diverse areas including quantum computation, quantum information theory, and condensed matter physics.

In this work, we introduce a renormalisation procedure for QCA, aimed at extracting their large-scale degrees of freedom. Our approach builds on the framework developed by Israeli and Goldenfeld for Classical Cellular Automata [N. Israeli and N. Goldenfeld, Phys. Rev. E, 2005]. We define a renormalisation equation, explore its structural features, and derive a necessary and sufficient condition for a QCA to admit a consistent renormalisation. We focus on one-dimensional QCAs that can be implemented as finite-depth quantum circuits, and treat separately the cases in which the renormalised dynamics preserve or break this circuital structure. Within this framework, we show that the renormalisability of the global (infinite) evolution reduces to specific conditions on a finite-dimensional operator.

By leveraging the classification of one-dimensional qubit QCAs by Schumacher and Werner [B. Schumacher and R. F. Werner, quant-ph/0405174], we show that only local evolutions and those diagonal in a separable basis can be consistently coarse-grained. These dynamics are characterised by the absence of information propagation—an apparent consequence of the trivial structure of the qubit observable algebra. We then extend our renormalisation framework to Fermionic Cellular Automata (FCA). Using the recent classification of one-dimensional FCAs with a single fermionic mode per site [L. S. Trezzini, M. Lugli, P. Meda, A. Bisio, P. Perinotti, A. Tosini, arXiv:2501.05349], we fully classify the renormalisable dynamics in this setting. Here, richer phenomena emerge: in particular, we find that certain renormalisable fermionic automata do support information propagation. This observation strengthens the conjecture that the limitations observed in the qubit case stem from the triviality of the underlying observable algebra, rather than from the renormalisation procedure itself.

Multipartite entanglement extraction from fermionic states

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Poster code: **30A**

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Estimation of entanglement in atomistic systems requires a combination of advanced ab initio calculations - to account for the effect of the electron-electron interaction - and rigorous quantum-informational theoretical analyses. This combination is a challenging task that has not been tackled so far to investigate genuine multipartite entanglement (GME) in materials. Here we show that, contrary to conventional wisdom, a high degree of GME can be extracted from closed-shell states - even in the non-interacting limit (single-configuration states). We further demonstrate the possibility of maximizing the GME through localized extraction orbitals in a variety of realistic systems and correlated states. Based on the symmetries of the fermionic state, we finally derive general expressions for the extracted spin states, and characterize them in terms of spin squeezing inequalities.

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Nonequilibrium thermometry via an ensemble of initially correlated qubits

- Author: Enrico Trombetti — Poster code: **12B**
- Affiliation: CNR - INO

We investigate an nonequilibrium quantum thermometry protocol in which an ensemble of qubits, acting as temperature probes, is weakly coupled to a macroscopic thermal bath. The temperature of the bath, the parameter of interest, is encoded in the dissipator of a Markovian thermalization process. For some relevant initial states, we observe a peak in the Quantum Fisher Information (QFI) during the transient of the thermaliziation, indicating enhanced sensitivity in early-time dynamics. This effect becomes more pronounced at higher bath temperatures and is further enhanced when the qubits' initial state has a larger ground-state population. Our analysis shows that both local coherence in the probes' initial state and initial correlations among the probes contribute to the amplification of the peak in the QFI, thus improving the precision of the temperature estimation. The influence of quantum correlations emerges as a central feature of this work. Although the dynamics does not permit superlinear scaling of the QFI with the number of probes, we identify the most effective initial states for designing high-precision quantum sensors within this setting. We also provide concrete guidelines for experimental implementations.

Disentangling signalling and causal influence

- Author: Leonardo Vaglini — Poster code: **2B**
- Affiliation: Aix-Marseille University

The causal effects activated by a quantum interaction are studied, modelling the latter as a bipartite unitary channel. The two parties, say Alice and Bob, can use the channel to exchange messages—i.e. to signal. On the other hand, the most general form of causal influence includes also the possibility for Alice, via a local operation on her system, to modify Bob's correlations and viceversa. The presence or absence of these two effects are equivalent, but when they both occur, they can differ in their magnitude. We define two functions that quantify the amount of signalling and causal influence conveyed by an arbitrary unitary channel. We then show a continuity theorem for causal effects of unitary channels: a channel has small causal influence iff it allows for small signalling. Morover, the functions are proved to be continuous and monotonically increasing with respect to the tensor product of channels. Finally, signalling and causal influence are analytically computed for the quantum SWAP and CNOT gates, in the single use scenario, in the n-parallel uses scenario, and in the asymptotic regime. A finite gap is found between signalling and causal influence for the quantum CNOT, thus proving the existence of extra causal effects that cannot be explained in terms of communication only. However, the gap disappears in the asymptotic limit of an infinite number of parallel uses, leaving room for asymptotic equivalence between signalling and causal influence.

Exoplanetary atmospheres retrieval via a quantum extreme learning machine

- Author: Marco Vetrano Poster code: **28A**
- Affiliation: University of Palermo

We propose a novel framework for the rapid and accurate retrieval of exoplanetary atmospheric parameters using quantum extreme learning machines (QELMs). QELMs are a class of quantum machine learning models that exploit random quantum evolution as a substrate for efficient data processing. While traditional retrieval methods depend on computationally expensive forward modeling across high-dimensional parameter spaces, our approach leverages the expressive power of QELMs to perform this task more efficiently.

We generate a dataset of synthetic spectra using TauREx, a classical retrieval algorithm, and train a QELM to extract key chemical and physical features—such as molecular abundances (CH_4, CO_2, CO, H_2O), planetary mass (M), radius (R), and temperature (T). We demonstrate the faul-tolerance of this method with an experimental implementation on IBM's 156-qubit Fez quantum processor, achieving over 85% accuracy in recovering selected atmospheric parameters.

Our results validate QELMs as a promising, scalable tool for atmospheric retrieval, offering a path toward integrating quantum technologies into next-generation exoplanet characterization pipelines.

Stability of quantum symmetries against perturbations

- Author: Vito Viesti Poster code: **38B**
- Affiliation: University of Bari & INFN

We show that the classification of quantum symmetries can be refined by analyzing their stability against small perturbations of the Hamiltonian. We provide a complete algebraic characterization of the set of symmetries that are robust with respect to a single fixed perturbation, and we use this result to characterize stability with respect to larger sets of perturbations.

Subradiance in random cold atomic clouds: a cooperativeness-induced phase transition

- Author: Viviana Viggiano Poster code: **32B**
- Affiliation: University of Bari & INFN Bari

In a cooperative spontaneous emission process from an atomic cloud, the decay rate is modified compared to that of a single isolated atom, giving rise to subradiance (slower decay) or superradiance (faster decay). We consider a cold cloud of atoms with random positions in three dimensions and analyze the extremely subradiant part of the spectrum of a Euclidean random matrix (ERM) related to the dissipative dynamics of the cloud. We find evidence of a phase transition controlled by the cooperativeness parameter b, which quantifies the number of atoms coherently involved in photon emission, and numerically evaluate the critical value of b following two approaches. First, we determine the critical value of b at which the minimum eigenvalue of the ERM under study (associated with the most subradiant state) becomes compatible with zero, indicating the emergence of a nondecaying mode. Second, we analyze the macroscopic accumulation of vanishing eigenvalues and find the critical value of b at which this condensation transition occurs. Remarkably, the two approaches to characterize the transition provide the same critical value of the cooperativeness parameter, indicating that there is a single transition point above which the lower edge of the spectrum vanishes exhibiting a macroscopic accumulation of eigenvalues. Finally, we corroborate the condensation transition with an analytical argument based on localization perturbation theory. Joint work with R. Bachelard, F. D. Cunden, P. Facchi, R. Kaiser, S. Pascazio, F. V. Pepe, and A. Scardicchio

Probing entanglement in open quantum many-body systems out of equilibrium

- Author: Darvin Wanisch — Poster code: **3B**
- Affiliation: University of Padova

We present a numerical framework based on tree tensor operators that enables large-scale simulation of out-of-equilibrium open quantum many-body systems. By design, it protects density operator positivity and provides direct access to entanglement monotones, such as entanglement of formation and logarithmic negativity. To demonstrate the framework's ability to probe entanglement in open quantum many-body systems and distinguish it from other correlations, we apply it to a range of non-equilibrium open quantum many-body scenarios. Our work opens new avenues for investigating entanglement in the presence of dissipation—an essential step toward the development of scalable quantum technologies.

Quantum state transfer of qubits through repeated use of a quantum channel

- Author: Hayden Zammit — Poster code: **7B**
- Affiliation: University of Malta

The impact of memory effects on quantum state transfer resulting from the repeated use of an XX spin-chain will be presented. Memory effects arise when the channel is not reset in-between uses. The quantum channel is modelled by an XX spin-1/2 linear chain, with several coupling schemes, e.g. fully-engineered couplings or optimal end-couplings [1,2]. Readout timing errors result in a decay of the achievable average fidelity, determining the maximum number of uses the quantum channel can be utilised before dropping below the LOCC limit. Analytical, as well as numerical, results about the capacity of the quantum channel to transfer entangled states will be shown as a function of the length of the chain.

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