Book of Abstracts - Talks

8th International Conference for Young Quantum Information Scientists (YQIS25)

Organizing Committee

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Contents

Talks

1 - Introduction to semidefinite programs in quantum information theory

Armin Tavakoli – Lund University

This tutorial is an introduction to semidefinite programs (SDPs) and their relevance to quantum information science. I discuss SDP on their own merit, why they have become important in quantum information and I give an overview of some of their applications. Towards the end, I review some more contemporary methods for computing properties of quantum correlations via SDP relaxations. The talk is aimed at non-specialists interested in understanding SDP methods.

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2 - Quantum mechanics based on real numbers: A consistent description

Pedro Barrios – Heinrich Heine University Düsseldorf

Complex numbers play a crucial role in quantum mechanics. However, their necessity remains debated: whether they are fundamental or merely convenient. Recently, it was claimed that quantum mechanics based on real numbers can be experimentally falsified in the sense that any real-number formulation of quantum mechanics either becomes inconsistent with multipartite experiments or violates certain postulates. We show that a physically motivated postulate about composite quantum systems allows to construct quantum mechanics based on real numbers that reproduces predictions for all multipartite quantum experiments. Thus, we argue that real-valued quantum mechanics cannot be falsified, and therefore the use of complex numbers is a matter of convenience.

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3 - Was quantum theory based on real numbers experimentally falsified?

Timothée Hoffreumon – Mathematical Institute of the Slovak Academy of Sciences

Renou et al. (2021) argued that quantum theory based on real Hilbert spaces cannot reproduce all predictions of complex quantum theory, identifying a testable discrepancy via a Bell inequality in the bilocal (entanglement-swapping) scenario. While this result suggested real quantum theory is falsifiable, it has since faced criticism, with several groups questioning its assumptions. In this talk, we first present our critique, then situate it within broader discussions by other groups. Our analysis traces the discrepancy to assuming the Kronecker product as the universal tensor product, despite its bilinearity depending on the chosen number field. We propose two consistent alternatives: 1) relaxing the state postulate, or 2) adopting a non-Kronecker tensor product, both of which recover standard quantum predictions. The latter connects to generalized composition rules in Operational Probabilistic Theories and interpretations in terms of Quantum Reference Frames and time-reversal symmetry. Since Renou et al.'s experiment relies on assuming, rather than certifying, the Kronecker representation of the tensor product, we raise the question: has real quantum theory truly been falsified?

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4 - How entangled is a bound entangled state?

Jordi Romero-Pallejà – Universitat Autònoma de Barcelona

We investigate the maximum entanglement that a positive partial transpose (PPT) entangled state can achieve, using the Schmidt number as an entanglement indicator. In our work, we approach the problem of bounding the Schmidt Number through the theory of quantum maps, specifically, by extending the Choi decomposition of K-positive maps within the framework of SN witnesses. This is based on a technique called trivial lifting, which extends a map to a higher-dimension input space while maintaining its main properties, i.e., its k-positivity and (un)decomposability. This allows us to give sufficient criteria for bounding the SN by finding one trivial lifting corresponding to an undecomposable map that does not detect a given PPT state. We then apply these techniques to the symmetric states in bipartite C^4 states, even though our approach is completely general and can be used in any bipartite quantum state. This allows us to give analytical supplemented by numerical evidence that show that all reported cases of Symmetric PPT-Bound entangled states corresponding to these systems do not have maximal SN. Lastly, we comment on the extension of our results to higher-dimensional systems.

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5 - Bell, Wigner, causal reasoning, and interpretations

Andrea Di Biagio – IQOQI Vienna

Bell's theorem and Bell inequality violations are one of the most iconic results in quantum physics. While certainly further from experimental realisation, experiments involving quantum control of observers—the so-called Extended Wigner's friend scenarios—pose an even stronger challenge to our understanding of quantum theory. In this talk, after a review of the implications of Bell and Local Friendliness no-go theorems on the interpretations of quantum mechanics, I will present a recent result about the failure of causal reasoning in dealing with the predictions of quantum mechanics in extended Wigner's friend scenarios: not just classical causal reasoning, but causal reasoning using generalised probabilistic theories fails to faithfully account for the predictions of QM.

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6 - Toy Model Challenging Prevailing Definitions of Classicality

Irene Valladares Duque – University of Manchester

Everyday reality is governed by the laws of classical physics, yet the behaviour of the very atoms that constitute our bodies is ultimately dictated by the principles of quantum mechanics. The transition between these two fundamentally distinct realms remains a subject of debate in the scientific community, not only for its intrinsic philosophical interest but also for its applications to quantum technologies. In this talk, I will discuss the emergence of classicality from the most general dynamics of non-Markovian open quantum systems (OQS). Over the years, several frameworks have proposed various criteria to obtain the most classically behaving states of the OQS, called "pointer states". Our work demonstrates that the presence of memory effects makes the dynamics of said pointer states extremely fragile to external operations, which inhibits the emergence of stable, classical behaviour. To address this issue, we propose a refined definition of pointer states that takes into account operational probing sequences, denoting a pointer state as one in which the OQS is indistinguishable from a dephased state independently of which control operations have been applied to the system

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7 - Quantitative Nonclassicality of Mediated Interactions

Ekta Panwar – Slovak Academy of Sciences

In a plethora of physical situations, one can distinguish a mediator—a system that couples other, noninteracting, systems. Often, the mediator itself is not directly accessible to experimentation, yet it is interesting and sometimes crucial to understand if it admits nonclassical properties. An example of this sort that has recently been enjoying considerable attention is that of two quantum masses coupled via a gravitational field. It has been argued that the gain of quantum entanglement between the masses indicates nonclassicality of the states of the whole tripartite system. Here, we focus on the nonclassical properties of the involved interactions rather than the states. We derive inequalities, the violation of which indicates noncommutativity and nondecomposability of interactions through the mediators. We show that the amount of violation places a lower bound on a suitably defined degree of nondecomposability. This makes the methods quantitative and, at the same time, experiment-ready. We give applications of these techniques in two different fields: for detecting the nonclassicality of gravitational interaction and in bounding the Trotter error in quantum simulations.

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8 - Efficient characterization of coherent and correlated noise in layers of gates

Marianna Crupi – Max Planck Institute of Quantum Optics

Operations in current quantum devices are affected by various errors, making efficient and accurate noise characterization essential for advancing quantum technologies. Existing methods can only efficiently compute specific process features, leaving out potentially important information. To resolve this issue we propose a noise model for which the complete process tomography is efficient by construction. Under the assumption that the errors in the device are well represented by a low-Pauli weight channel, our protocol is efficient in time and sample complexity and exhibits a scaling of O(poly(n)). Our proposed tomography method is based on a randomized product state preparation and measurement scheme and can be applied even for noise characterization of a whole layer of two-qubit Clifford gates. The scheme is independent of the specific physical implementation and can be readily applied to characterize correlated and coherent errors in 2D architectures of current quantum computers.

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9 - Device-independent cryptography

Peter Brown – Telecom Paris

In many cryptographic systems, we assume that the hardware and software are working exactly as intended. However, in practice devices may be imperfectly modeled, faulty, or even maliciously prepared. Device-independent protocols take a different approach: if two or more devices are observed to violate a Bell inequality, then certain properties of the underlying hardware can be inferred, regardless of how the devices were built. For example, any violation implies that the devices are capable of sharing entanglement. But how far can this paradigm be pushed, and can it be made practically useful? In this tutorial, we will provide an accessible introduction to the main ideas of device independence through the lens of random number generation. We will discuss the foundations of security in this setting, examine the practical challenges that arise, and conclude with an overview of current directions in the field.

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10 - Certification of quantum correlations and DIQKD at arbitrary distances through routed Bell tests

Edwin Peter Lobo – Université Libre de Bruxelles

Transmission loss represents a major obstacle to the device-independent certification of quantum correlations over long distances, limiting applications such as device-independent quantum key distribution (DIQKD). In this work, we investigate the recently proposed concept of routed Bell experiments, in which a particle sent to one side can be measured either near or far from the source. We prove that routed Bell tests involving only entangled qubits can certify quantum correlations even in the presence of arbitrary loss on the channel to the distant device. This is achieved by adapting concepts from self-testing and quantum steering to the routed Bell test framework. Finally, as a natural extension of our approach, we outline a DIQKD protocol that, in principle, is secure over arbitrary distances.

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11 - Experimental Implementation of Quantum Oblivious Transfer from One-Way Functions

Adriano Innocenzi – Sorbonne Université

Oblivious transfer (OT) is a fundamental primitive in cryptography, allowing the construction of general multi-party computation. Recent results have proved the possibility of quantum protocols from one-way functions, which is expected to be weaker than the assumptions needed in OT in the classical setting. In particular, a recent result by Diamanti et al. provided a quantum protocol for OT considering practical aspects of the protocol, while maintaining its composable security.

In this work, we provide the first experimental implementation of a composable oblivious transfer protocol from OWF. The setup implements a weak coherent pulses BB84 states source in polarization encoding, whose experimental parameters are employed to optimize the theoretical security bounds. The obtained security parameters are then used to perform a secure execution of the protocol, whose performances are profiled and compared with the literature benchmark.

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12 - Quantitative quantum soundness for bipartite compiled Bell games via the sequential NPA hierarchy

Xiangling Xu – Inria Saclay

Compiling Bell games under cryptographic assumptions removes the need for physical separation, enabling tests of nonlocality with a single untrusted device. Beyond preserving quantum advantage, prior results established quantum soundness—no cheating quantum device can beat the original Bell score—quantitatively only for specific bipartite games; later work proved a general but qualitative version under infinitely secured compilation. However, the more practically relevant case of finitely secured compilation remained open.

In this talk, we resolve this problem. Specifically, for every bipartite compiled Bell game with a finite-dimensional optimal strategy, we give the first quantitative soundness bounds: any polynomial-time prover's score is negligibly close to the game's ideal quantum value. More generally, for all bipartite games we upper-bound compiled scores via a newly formalized, convergent sequential Navascués–Pironio–Acín (NPA) hierarchy, which we fully characterize, including comparisons to the standard NPA and the flatness condition.

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13 - Bounding the asymptotic quantum value of all multipartite compiled non-local games

Matilde Baroni – LIP6, Sorbonne University

Non-local games are a powerful tool to distinguish between correlations possible in classical and quantum worlds. Kalai et al. proposed a compiler that converts multipartite non-local games into interactive protocols with a single prover, relying on cryptographic tools to remove the assumption of physical separation of the players. While quantum completeness and classical soundness of the construction have been established for all multipartite games, quantum soundness is known only in the case of bipartite games. In this paper, we prove that the Kalai et al.'s compiler indeed achieves quantum soundness for all multipartite compiled non-local games, by showing that any correlations that can be generated in the asymptotic case correspond to quantum commuting strategies. Our proof uses techniques from the theory of operator algebras, and relies on a characterisation of sequential operationally no-signalling strategies as quantum commuting operator strategies in the multipartite case. On the way, we construct universal C*-algebras of sequential PVMs and prove a new chain rule for Radon-Nikodym derivatives of completely positive maps on C*-algebras which may be of independent interest.

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14 - Classical machine learning for quantum problems

Anna Dawid – Universiteit Leiden

In times of ChatGPT and AlphaFold, no one needs to be convinced of the power of machine learning. But how can these classical tools help us understand and control quantum systems? In this talk I will give an overview of how machine learning is being applied to quantum physics and quantum technologies. I will discuss examples ranging from detecting phases of matter and automatically discovering their order parameters, through learning effective Hamiltonians from experimental data, to guiding quantum circuit design and representing wave functions with neural quantum states. These cases illustrate the promise of how machine learning can turn raw quantum data into physical insight and accelerate progress in building and understanding quantum devices. I will also tell you why we are not there yet!

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15 - Learning interpretable representation of quantum data

Paulin de Schoulepnikoff – Universität Innsbruck

Interpretable machine learning is becoming a crucial tool for analyzing quantum systems. In particular, variational autoencoders (VAEs) have shown promise in extracting hidden physical features without supervision or prior knowledge. However, the ability of VAEs to generate meaningful, interpretable representations relies on their accurate approximation of the underlying probability distribution of their input. For quantum data, VAEs must therefore account for intrinsic randomness and complex correlations. We show that two key modifications enable VAEs to learn physically meaningful latent representations of quantum data: a decoder that faithfully reproduces quantum-state probability distributions, and a probabilistic loss tailored to this task. On benchmark quantum spin models, we identify regimes where standard methods fail while our approach provide meaningful representations. Applied to experimental data from Rydberg atom arrays, the model autonomously uncovers the phase structure without access to prior labels, Hamiltonian details, or knowledge of relevant order parameters, highlighting its potential as an unsupervised and interpretable tool for the study of quantum systems.

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16 - Role of scrambling and noise in temporal information processing with quantum systems

Weijie Xiong – EPFL Lausanne

Scrambling quantum systems have attracted attention as effective substrates for temporal information processing. Here we consider a quantum reservoir processing framework that captures a broad range of physical computing models with quantum systems. We examine the scalability and memory retention of the model with scrambling reservoirs modelled by high-order unitary designs in both noiseless and noisy settings. In the former regime, we show that measurement readouts become exponentially concentrated with increasing reservoir size, yet strikingly do not worsen with the reservoir iterations. Thus, while repeatedly reusing a small scrambling reservoir with quantum data might be viable, scaling up the problem size deteriorates generalization unless one can afford an exponential shot overhead. In contrast, the memory of early inputs and initial states decays exponentially in both reservoir size and reservoir iterations. In the noisy regime, we also prove that memory decays exponentially in time for local noisy channels. These results required us to introduce new proof techniques for bounding concentration in temporal quantum models.

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17 - Sampling Groups of Pauli Operators to Enhance Direct Fidelity Estimation

Júlia Barberà Rodríguez – ICFO

Direct fidelity estimation is a protocol that estimates the fidelity between an experimental quantum state and a target pure state. By measuring the expectation values of Pauli operators selected through importance sampling, the method is exponentially faster than full quantum state tomography. We propose an enhanced direct fidelity estimation protocol that uses fewer copies of the experimental state by grouping Pauli operators before the sampling process. We derive analytical bounds on the measurement cost and estimator variance, showing improvements over the standard method. Numerical simulations validate our approach, demonstrating that for 8-qubit Haar-random states, our method achieves a one-third reduction in the required number of copies and reduces variance by an order of magnitude using only local measurements. These results underscore the potential of our protocol to enhance the efficiency of fidelity estimation in current quantum devices.

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18 - A Random Matrix Theory of Pauli Tomography

Nathan Keenan – Trinity College Dublin

Quantum state tomography (QST), the process of reconstructing some unknown quantum state from repeated measurements on copies of said state, is a foundationally important task in the context of quantum computation and simulation. For this reason, a detailed characterization of the error in a QST reconstruction is of importance to quantum theory and experiment. In this work, we develop a random matrix theory (RMT) treatment of state tomography in informationally-complete bases; and in doing so we reveal connections between QST errors and the Gaussian unitary ensemble (GUE). By exploiting this connection we prove that wide classes of functions of the spectrum of the QST error matrix can be evaluated by substituting appropriate samples of the GUE. This powerful result enables analytic treatments of the statistics of the QST error, which allows us to derive a bound on the QST sample complexity, and subsequently demonstrate that said bound doesn't change under the most widely-used rephysicalization procedure. These results demonstrate the flexibility, strength, and broad applicability of our approach; and lays the foundation for broader studies of RMT treatments of QST in the future.

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19 - Classical Shadows over Symmetric Spaces

Rebecca Chang – MIT

Efficiently learning expectation values of unknown quantum states via classical shadows has become an important primitive in both theoretical and experimental aspects of quantum computation. Typically, classical shadow protocols are considered to be induced by sampling uniformly randomly from a compact group, a situation which is now quite well understood. Here we go beyond this standard assumption, studying the classical shadow protocols induced by sampling uniformly randomly from the so-called compact symmetric spaces. We uncover a unifying theory of such protocols, extending the extent to which the general theory of classical shadows is understood at a mathematical level. Interestingly, we further find that some of them allow for an improvement in sample complexity over known protocols for the estimation of observables sampled from certain distributions, and may therefore find experimental applications.

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20 - Shedding light on classical shadows: a classical shadow protocol for photonic

Hugo Thomas – Quandela, LIP6, DIENS

Efficient learning of quantum state properties is both a fundamental and practical problem in quantum information theory. Classical shadows have emerged as an efficient method for estimating properties of unknown quantum states, with rigorous statistical guarantees, by performing randomized measurement on a moderated number of copies. With the advent of photonic technologies, formulating efficient learning algorithms for such platforms comes out as a natural problem. We introduce a classical shadow protocol for Fock input states via randomized passive linear optical transformations and photon-number measurement. We show that the sample complexity and running time of the classical post-processing scale with the degree of the observable, and that both are efficient in many interesting cases. We experimentally demonstrate our findings on a twelve-mode photonic integrated quantum processing unit. Our protocol allows for scalable learning of a wide range of Fock state properties and paves the way to applying the already rich variety of applications of classical shadows to linear optical platforms.

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21 - Exponential improvements to the average-case hardness of random circuits

Shaun Datta – Stanford University

How hard are random circuits to simulate? If sampling from random circuits is computationally hard, it would have far-reaching consequences in complexity theory, cryptography, and experimental quantum advantage. Prior works showed that average-case hardness of sampling follows from certain unproven conjectures about the hardness of computing output probabilities, such as the Permanent-of-Gaussians Conjecture (PGC), positing that $e^{-n\log n - n - O(\log n)}$ additive-error estimates to output probabilities of most random BosonSampling experiments are #P-hard.

In this work, we show that $e^{-n\log n - n - O(n^{\delta})}$ additive-error estimates are #P-hard for any $\delta > 0$, exponentially improving on prior results. In the process, we circumvent all the known proof barriers. Moreover, whereas prior results do not imply the hardness of sampling, we prove such a theorem under an anticoncentration conjecture: specifically the impossibility of multiplicative-error sampling with probability $1 - 2^{-\tilde{O}(N^{1/3})}$ for input size N, unless the Polynomial Hierarchy collapses. This raises the prospect of showing the hardness of average-case sampling without ever proving PGC.

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22 - Measurement-based quantum computation in symmetry-enriched topological phases

Paul Herringer – Leibniz Universität Hannover

We present the first examples of topological phases of matter with uniform power for measurement-based quantum computation (MBQC). This is possible thanks to a new framework for analyzing the computational properties of phases of matter that is more general than previous constructions, which were limited to short-range entangled phases in one dimension. We show that ground states of the toric code in an anisotropic magnetic field yield a natural, albeit non-computationally-universal, application of our framework. We then present a new model with topological order whose ground states are universal resources for MBQC. Both topological models are enriched by subsystem symmetries, and these symmetries protect their computational power. Our framework greatly expands the range of physical models that can be analyzed from the computational perspective.

23 - On the ultimate limits of resource testing and the generalised quantum Stein's lemma

Ludovico Lami – Scuola Normale Superiore Pisa

Quantum resource theories provide a unified framework for studying a broad range of quantum resources—such as entanglement, quantum magic, athermality, and coherence—on an equal footing. The central notion is that of free states: a state is free if it contains no resource, and the choice of free states is one of the defining features of the theory. Within this setting, two fundamental tasks emerge: resource manipulation and resource testing. While very distinct on the surface, these two tasks are in fact deeply connected. Resource manipulation concerns the conversion of one form of quantum resource into another—typically, one needs to transform one quantum state into a different one—whereas resource testing aims to discriminate a resourceful state from the set of all free states. The ultimate limits of these two tasks can both be characterised by two key results in quantum resource theories: the generalised Sanov theorem and the generalised quantum Stein's lemma. The latter statement, in particular, reveals a profound structural feature of the theory: in the asymptotic regime, quantum resources become—in some sense—reversibly interconvertible, with all asymptotic conversion rates governed by a single quantity, the regularised relative entropy of resource. This establishes a unified asymptotic picture of quantum resources, reminiscent of the role of entropy in thermodynamics. If time permits, I will also outline some ideas from the recent proofs of these results in [Lami/Berta/Regula, arXiv:2408.07067, 2024] and [Lami, IEEE Trans. Inf. Theory, 71(6), 2025].

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24 - Quantum Correlations Cannot Be Reproduced with a Finite Number of Measurements in Any No-Signaling Theory

Lucas Tendick – Inria Paris-Saclay

We show, for any finite $n \geq 2$, that there exist quantum correlations obtained from performing dichotomic quantum measurements in a bipartite Bell scenario, which cannot be reproduced by mixtures of measurement devices with at most (n-1) incompatible measurements across different partitions in any no-signaling theory. That is, it requires for any no-signaling theory an unbounded number of measurements to reproduce the predictions of quantum theory. We prove our results by showing that there exist linear Bell inequalities that have to be obeyed by any no-signaling theory involving only (n-1)-wise incompatible measurements and show explicitly how these can be violated in quantum theory. Finally, we discuss the relation of our work to previous works ruling out alternatives to quantum theory with some kind of bounded degree of freedom and consider the experimental verifiability of our results.

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25 - Quantum Circuits for Absolutely Maximally Entangled States

Berta Casas – Barcelona Supercomputing Center

Absolutely maximally entangled (AME) states of multipartite quantum systems exhibit maximal entanglement across all possible bipartitions. These states lead to teleportation protocols that surpass standard teleportation schemes, determine quantum error correction codes and can be used to test performance of current term quantum processors. Several AME states can be constructed from graph states using minimal quantum resources. However, there exist other constructions that depart from the stabilizer formalism. In this work, we present explicit quantum circuits to generate exemplary non-stabilizer AME states of four subsystems with four, six, and eight levels each and analyze their capabilities to perform quantum information tasks.

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26 - Bosonic error correction with concatenated codes of multimode inner GKP qubits

Florian Cottier – EPFL, ENS, INRIA

Bosonic codes based on continuous-variable systems have raised much interest in the community. Gottesman-Kitaev-Preskill codes are among the leading candidates, showing great noise resilience capacities at an interesting decoding cost when concatenated. GKP codes embed a logical qubit into one or several bosonic modes by creating an equal superposition of position-eigenstate grid peaks in phase space. This work presents a new class of codes showing promises of surpassing the previous state-of-the-art performance of Concatenated GKP codes. The key idea is to start the concatenation from single qubits encoded each in several modes, as opposed to one qubit per mode. This shows noticeable performance improvements in simple cases but also requires generalising several steps of ordinary error correction procedures, as well as introducing a novel method for estimating the optimal correction.

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27 - Informational Nonequilibrium Concentration

Benjamin Stratton – The University of Bristol

Informational contributions to thermodynamics can be studied in isolation by considering systems with fully degenerate Hamiltonians. In this regime, being in nonequilibrium (termed informational nonequilibrium) provides thermodynamic resources, such as extractable work, solely from the information content. The usefulness of informational nonequilibrium creates an incentive to obtain more of it, motivating the question of how to concentrate it: can we increase the local informational nonequilibrium of a product state $\rho \otimes \rho$ under a global closed system (unitary) evolution? We fully solve this problem analytically, showing that it is impossible for two-qubits, and it is always possible to find states achieving this in higher dimensions. Specifically for two-qutrits, we find that there is a single unitary achieving optimal concentration for every state, for which we uncover a Mpemba-like effect. We further discuss the notion of bound resources in this framework, initial global correlations' ability to activate concentration, and applications to concentrating purity and intrinsic randomness.

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28 - An information-theoretic proof of the Planckian bound for thermalization

Alberto Rolandi – TU Wien

We demonstrate that quantum mechanics entails a fundamental lower bound on the thermalization time τ of any system. At finite temperature, we show that τ is bounded by half the Planckian dissipation time, $\tau \geq \tau_{\mathrm{Pl}}/2 \quad \text{with} \quad \tau_{\mathrm{Pl}} = \hbar/(k_B T)$. In the low-temperature regime, our bound takes the form $\tau \geq \hbar/\Delta$, with Δ the spectral gap, in close connection with the quantum adiabatic theorem. These bounds, rooted in Hamiltonian estimation, hold for arbitrary quantum processes that output states close to the corresponding thermal ensemble for a nontrivial class of Hamiltonians.

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29 - Thermodynamic Signatures of Gaussian Entanglement Beyond Entropy

Bea Polo – ICFO

Whereas correlations in quantum systems are often studied from an information perspective, Quantum Thermodynamics offers an energetic framework to assess the role of correlations and to certify entanglement via work extraction. We analyze the link between separability and ergotropic gap in Continuous-Variable systems, showing that the gap quantifies entanglement in pure states. For mixed states, differences with the DV case arise from the infinite-dimensional Hilbert space. We derive bounds on the relative ergotropic gap (REG) for Gaussian states, making it a valid entanglement witness, and prove coincidence of upper and lower bounds for a wide parametric family, giving a necessary and sufficient criterion. We also extend the analysis to certain non-Gaussian states, observing similar energy-based signatures. Beyond its foundational value in unifying information and thermodynamics, our approach suggests new, less resource-intensive schemes for entanglement detection, relevant for optimizing heat transfer, work extraction, and thermal machine performance.

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30 - Dynamical Landauer Principle

Chung-Yun Hsieh – University of Bristol

Energy transfer and information transmission are two fundamental aspects of nature. They are seemingly unrelated, while recent findings suggest that a deep connection between them is to be discovered. This amounts to asking: Can we phrase the processes of transmitting classical bits equivalently as specific energy-transmitting tasks, thereby uncovering foundational links between them? We answer this question positively by showing that, for a broad class of classical communication tasks, a quantum dynamics' ability to transmit n bits of classical information is equivalent to its ability to transmit n units of energy in a thermodynamic task. This finding not only provides an analytical correspondence between information transmission and energy extraction tasks, but also quantifies classical communication by thermodynamics. Furthermore, our findings uncover the dynamical version of Landauer's principle, showing the strong link between transmitting information and energy. In the asymptotic regime, our results further provide thermodynamic meanings for the well-known Holevo-Schumacher-Westmoreland theorem in quantum communication theory.

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31 - Random Exclusion Codes: Quantum Advantages of Single-Shot Communication

Andrés Damián Muñoz Moller – University of Jyväskylä

The utility of quantum information technologies can be found by identifying tasks for which quantum resources outperform their classical counterparts. In this work, we introduce a two-party communication primitive, Random Exclusion Code (REC), which is a single-shot prepare-and-measure protocol where a sender encodes a random message into a shorter sequence and a receiver attempts to exclude a randomly chosen letter in the original message. We present quantum advantages in RECs in two ways: probability and dimension. We show that RECs with quantum resources achieve higher success probabilities than classical strategies. We verify that the quantum resources required to describe detection events of RECs have a smaller dimension than classical ones.

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32 - Codes for entanglement-assisted classical communication

Tushita Prasad – ICTQT, University of Gdansk

Entanglement-assisted classical communication (EACC) aims to enhance communication systems using entanglement as an additional resource. However, there is a scarcity of explicit protocols designed for finite transmission scenarios, which presents a challenge for real-world implementation. In response, we introduce a new EACC scheme capable of correcting a fixed number of erasures/errors. It can be adjusted to the available amount of entanglement and sends classical information over a quantum channel. We establish a general framework to accomplish such a task by reducing it to a classical problem. Comparing with specific bounds, we identify optimal parameter ranges. The scheme requires only the implementation of super-dense coding which has been demonstrated successfully in experiments. Furthermore, our results show that an adaptable entanglement use confers a communication advantage. Overall, our work sheds light on how entanglement can elevate various finite-length communication protocols, opening new avenues for exploration in the field.

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33 - Certifying high-dimensional quantum channels

Sophie Egelhaaf – University of Geneva

The use of high-dimensional systems for quantum communication opens interesting perspectives, such as increased information capacity and noise resilience. In this context, it is crucial to certify that a given quantum channel can reliably transmit high-dimensional quantum information. Here we develop efficient methods for the characterization of high-dimensional quantum channels. We first present a notion of dimensionality of quantum channels, and develop efficient certification methods for this quantity. We consider a simple prepare-and-measure setup, and provide witnesses for both a fully and a partially trusted scenario. In turn we apply these methods to a photonic experiment and certify dimensionalities up to 59 for a commercial graded-index multimode optical fiber. Moreover, we present extensive numerical simulations of the experiment, providing an accurate noise model for the fiber and exploring the potential of more sophisticated witnesses. Our work demonstrates the efficient characterization of high-dimensional quantum channels, a key ingredient for future quantum communication technologies.

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34 - Percolation thresholds and connectivity in quantum networks

Andrea De Girolamo – University of Padova

We study entanglement percolation in qubit-based planar quantum network models of arbitrary topology, where neighboring nodes are initially connected by pure states with quenched disorder in their entanglement. We develop a physics-informed heuristic algorithm designed to find a sequence of entanglement swapping and distillation operations to connect pairs of distant nodes. The algorithm combines locally optimal percolation strategies between nodes at a maximum distance of one swapping operation. If this fails to produce a maximally entangled state, it looks for alternative paths surrounding intermediate states within the process. We analytically find and numerically verify thresholds in quantum percolation, which depend on the initial network configuration and entanglement, and are associated with specific percolation strategies. We classify strategies based on the connectivity, a quantity that relates the final state entanglement to the level of integrity of the network at the end of the process. We find distinct regimes of quantum percolation, which are clearly separated by the percolation thresholds of the employed strategies and vastly vary according to the network topology.

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35 - Bell nonlocality in quantum networks with unreliable sources: Loophole-free postelection via self-testing

Sadra Boreiri – University of Geneva

We discuss Bell nonlocality in quantum networks with unreliable sources. Our main result is a condition on the observed data which ensures that inconclusive events can be safely discarded, without introducing any loophole. More formally, we characterize the fair-sampling property for measurements in a network. When all measurements are fair-sampling, we show that the post-selection of conclusive outcomes does not compromise the assumption of source independence, hence avoiding the detection loophole. Furthermore, we show that in some cases, the fair-sampling property can in fact be guaranteed based only on observed data. To show this, we prove that saturation of the Finner inequality provides a self-test of the underlying quantum model. We illustrate the relevance of our results by demonstrating an improvement in device-independent randomness generation for a photonic Bell test with a probabilistic source and for the triangle network.

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36 - Nonlinear Quantum Sensing with a Frustrated Kitaev Trimer

Anubhav Kumar Srivastava – ICFO, Spain

We investigate the response of a Ramsey interferometric quantum sensor based on a frustrated, three-spin system (a Kitaev trimer) to a classical time-dependent field (signal). The system eigenspectrum is symmetric about a critical point, $|b| = 0$, with four of the spectral components varying approximately linearly with the magnetic field and four exhibiting a nonlinear dependence. Under the adiabatic approximation and for appropriate initial states, we show that the sensor's response to a zero-mean signal is such that below a threshold, $|b| < b_{th}$, the sensor does not respond to the signal, whereas above the threshold, the sensor acts as a detector that the signal has occurred. This thresholded response is approximately omnidirectional. Moreover, when deployed in an entangled multisensor configuration, the sensor achieves sensitivity at the Heisenberg limit. Such detectors could be useful both as standalone units for signal detection above a noise threshold and in two- or three-dimensional arrays, analogous to a quantum bubble chamber, for applications such as particle track detection and long-baseline telescopy.

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37 - Measuring Entanglement of Continuous variable state with free running local oscillator

Benjamin Lundgren Larsen – Technical University of Denmark

Entangled CV states are often verified using the Simon-Duan (SD) criterion which states that for any separable state the bound holds, while a Guassian entangled state will violate the bound. The criterion requires measurements of orthogonal quadratures, which is often done with a feedback system employed to lock the phase between the LO and the signal in homodyne or heterodyne detectors. In this work we employ a technique for verifying entanglement of a continuous variable TMSV state, with a free running local oscillator (LO). The method employed in this experiment does not requires feedback to lock the LO phase, measurements are performed with free-running local LO on RF-heterodyne detectors. By mixing a strong pilot tone the frequency of the signal and rotations in channel can be recovered and correct in post. We show that the method can be used to violate the SD bound.

38 - Tensor Networks: What, How and Why?

Patrick Emonts – Ulm University

Tensor networks provide a powerful tool to represent and simulate complex quantum systems, bridging ideas from physics, mathematics, and computer science. In this tutorial, we introduce the basics of tensor networks, highlighting both computational and analytical perspectives. In the first part, we focus on the construction and the numerical side of tensor networks. How do tensor networks encode quantum states efficiently, and how do we optimize states like matrix product states and projected entangled pair states? In the second part, we shift to analytical considerations, showing how tensor networks states can be understood as the unique ground state of gapped, local Hamiltonians, so-called parent Hamiltonians. This second viewpoint will lead us to a recent application of tensor network: parent Hamiltonians can be used to optimize the adiabatic state preparation of tensor networks state of near-term quantum devices.

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39 - Estimating entanglement monotones in spin systems using symmetries

Julia Mathé – TU Wien, Atominstitut

We present general methods to estimate entanglement monotones in complex many-body spin systems by deriving lower and upper bounds to distance-like measures using entanglement witnesses and separable ansatz states. Leveraging system symmetries, we significantly simplify the problem and demonstrate applications to spin models on fully connected graphs at finite temperature. Focusing on spin-squeezing inequalities, we obtain tight lower bounds at zero temperature and at the threshold where entanglement vanishes, capturing these regimes precisely. Our results reveal that entanglement can emerge at nonzero temperature near quantum phase transitions, indicating that first excited states may be highly entangled even when the ground state is separable – an effect with experimental signatures. Extending this framework, we investigate translationally invariant spin chains, whose richer phase diagrams pose additional challenges and insights. Here, we focus on optimal entanglement detection from covariance matrices and on how these optimal witnesses connect to thermodynamic quantities and may be used as potential order parameters for classifying complex phases of matter.

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40 - Quantum simulation of lattice gauge theories with qudit systems

Pavel Popov – ICFO

In this talk we will explore the use of qudit-based quantum systems for the simulation of Abelian and non-Abelian lattice gauge theories. Unlike conventional qubit platforms, qudits (quantum systems with d>2 levels) naturally accommodate the local degrees of freedom arising in gauge theories, enabling more efficient encodings. We utilize strategies for effective Hamiltonian formulations beyond (1+1)-dimensional settings, enabling local qudit encodings. Our approach towards quantum simulation of LGTs includes variational algorithms that can be realized on platforms such as trapped ions with native qudit gates. We demonstrate a path towards real-time dynamics and ground-state preparation for (2+1)-D Abelian U(1) models and ground-state preparation of non-Abelian D_4 lattice gauge theories. Furthermore, we investigate topological and fracton signatures in multiflavour Schwinger models, showing how vacuum physics is affected by the presence of gauge fields with fractional topological charge. Notably, these effects are detectable even in highly truncated qudit systems, highlighting their relevance for near-term quantum simulation of gauge theories.

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41 - Orbit dimensions in linear and Gaussian quantum optics

Eliott Mamon – LIP6, Sorbonne Université

In sub-universal quantum platforms such as linear or Gaussian optics, quantum states can behave as different resources, in regard to the extent of their accessible state space (called their orbit) under the action of the restricted unitary group. We propose to study the dimension of a quantum state's orbit (as a manifold in the Hilbert space), a simple yet nontrivial topological property that can quantify "how many" states it can reach. As natural invariants under the group, these structural properties of orbits alone can reveal fundamental impossibilities of enacting certain unitary transformations deterministically. We showcase a general way to compute orbit dimensions for states of finite support in the Fock basis, by leveraging the group's Lie algebra. We study genericity and robustness of orbit dimensions, and we propose several ways to efficiently evaluate them experimentally. We also highlight their role as a non-Gaussianity witness, which we expect to be universal for multimode pure states. While proven in the DV setting (i.e. passive linear optics with an energy cutoff), the validity of our work in the CV setting rests on a technical conjecture which we do not prove.

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42 - Optimal interferometer for benchmarking genuine n-photon indistinguishability

Rodrigo Martínez Sanz – Universitat Politècnica de València

Photon indistinguishability is a fundamental requirement for quantum interference, which underpins photonic quantum algorithms. Reliable benchmarking techniques are therefore essential for developing high-quality photon sources and scalable quantum technologies. Existing protocols, such as the cyclic interferometer, rely on exponentially rare post-selection events, severely limiting efficiency. We introduce a new protocol leveraging the Quantum Fourier Transform (QFT), its zero-transmission laws, and novel number-theoretic and symmetry-based results derived in this work. This framework yields an exponential speedup in estimating genuine n-photon indistinguishability: in the optimal cases requiring only O(1) samples, and at worst scaling sub-polynomially. We implement the protocol on Quandela's photonic QPU, demonstrating experimentally that it outperforms state-of-the-art methods by delivering higher precision and efficiency within comparable acquisition times.

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43 - Mode-selective generation of non-Gaussian states in multimode quantum states

Leonardo Rincon – Sorbonne Université

The rapid advancement of quantum technologies has emphasized the need for the generation of robust and reliable quantum states capable of achieving quantum advantage. Employing continuous variable (CV) encoding of quantum information, it is possible to harness the inherent properties of light fields to generate tailored quantum states on demand. In this paradigm, CV multimode light presents itself as a remarkable platform for quantum technologies: a large number of modes -spectral and spatial degrees of freedom– can be used to encode large amounts of information, while the modes can straightforwardly be entangled and measured to process the information.

At the Multimode quantum optics group at LKB (MQO-LKB), we specialise in generating CV-multimode quantum states by using frequency combs and second-order nonlinear interactions. I will present our experimental implementation for the generation of non-Gaussian states, essential resources for achieving quantum advantage. We employ a Synchronously Pumped-OPO (SPOPO) to produce multimode quantum states, which are then directed into a mode-selective photon subtraction scheme. Furthermore, we derived experimental witnesses such as Wigner negativity and stellar rank, which provide a reliable operational characterization of the non-Gaussian properties, eliminating the need for a full state tomography.

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44 - Experimental Memory Control in Continuous Variable Optical Quantum Reservoir Computing

Iris Paparelle – Laboratoire Kastler Brossel

Photonics quantum networks play a crucial role in quantum information processing by enabling efficient distribution and manipulation of quantum states of light. Femtosecond pulses, when combined with nonlinear interactions, generate entangled multimode outputs, which can be enhanced through mode-selective homodyne detection, forming quantum cluster states. These naturally arising nonlinearities and correlations, integrated with optical or electronic feedback, serve as a foundation for quantum reservoir computing (QRC). We present a scalable, room-temperature approach to quantum computing without single-photon sources or detectors. We report a proof-of-principle experimental realization of QRC using pump phase encoding with electronic feedback, with ongoing efforts focused on optimizing implementations through pulse shaping. Additionally, we explore a novel measurement-based QRC protocol using cluster states and teleportation, where measurements drive input encoding, processing, and time series monitoring.

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45 - Pauli and Majorana Propagation methods for classically simulating quantum circuits

Zoë Holmes – EPFL Lausanne

Simulating quantum circuits classically is in general a hard task. However, certain families of quantum circuits may be practically or even provably efficiently simulable by use of specialized classical algorithms. In this talk, we will cover "Pauli propagation" which has recently been shown to enable efficient classical simulation of expectation values in quantum circuits and a wide range of noise-free quantum circuits. Appreciating the strengths and weaknesses of this simulation method, and how it can be efficiently combined with other classical and quantum subroutines, will help point towards promising applications of quantum devices. We will end by discussing a generalization of this approach to Fermionic systems opening up new applications in quantum chemistry and material science. This talk will give an overview of the following works: arxiv:2308.09109, arXiv:2408.12739, arXiv:2409.01706, arXiv:2411.19896, arXiv:2501.13101, arXiv:2503.18939.

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46 - A unifying account of warm start guarantees for patches of quantum landscapes

Ricard Puig – EPFL Lausanne

Barren plateaus are fundamentally a statement about quantum loss landscapes on average but there can, and generally will, exist patches of barren plateau landscapes with substantial gradients. Previous work has studied certain classes of parameterized quantum circuits and found example regions where gradients vanish at worst polynomially in system size. Here we present a general bound that unifies all these previous cases and that can tackle physically-motivated ansätze that could not be analyzed previously. Concretely, we analytically prove a lower-bound on the variance of the loss that can be used to show that in a non-exponentially narrow region around a point with curvature the loss variance cannot decay exponentially fast. This result is complemented by numerics and an upper-bound that suggest that any loss function with a barren plateau will have exponentially vanishing gradients in any constant radius subregion. Our work thus suggests that while there are hopes to be able to warm-start variational quantum algorithms, any initialization strategy that cannot get increasingly close to the region of attraction with increasing problem size is likely inadequate.

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47 - One for All: Universal Quantum Conic Programming Framework for Hard-Constrained Combinatorial Optimization Problems

Lennart Binkowski – Leibniz Universität Hannover

We present a unified quantum-classical framework for addressing NP-complete constrained combinatorial optimization problems, generalizing the recently proposed Quantum Conic Programming (QCP) approach. It inherits many favorable properties of the original proposal such as mitigation of the effects of barren plateaus and avoidance of NP-hard parameter optimization. By collecting the entire classical feasibility structure in a single constraint, we enlarge QCP's scope to arbitrary constrained problems. Yet, we prove that the additional restriction is mild enough to still allow for an efficient parameter optimization via the formulation of a generalized eigenvalue problem (GEP) of adaptable dimension. Our proof further fills some gaps in prior derivations of GEPs from parameter optimization problems. We further detail a measurement protocol for formulating the classical parameter optimization that does not require us to implement any (time evolution with a) problem-specific objective Hamiltonian or a quantum feasibility oracle. Lastly, we prove that, even under the influence of noise, QCP's parameterized ansatz class always captures the optimum attainable within its generated subcone.

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48 - Quantum Machine Learning in Phase-Space

Timothy Heightman – ICFO

Quantum machine learning (QML) seeks to exploit the intrinsic properties of quantum mechanical systems, including superposition, coherence, and quantum entanglement for classical data processing. However, due to the exponential growth of the Hilbert space, QML faces practical limits in classical simulations with the state-vector representation of quantum system. On the other hand, phase-space methods offer an alternative by encoding quantum states as quasi-probability functions. Building on prior work in qubit phase-space and the Stratonovich-Weyl (SW) correspondence, we construct a closed, composable dynamical formalism for one- and many-qubit systems in phase-space. This formalism replaces the operator algebra of the Pauli group with function dynamics on symplectic manifolds, and recasts the curse of dimensionality in terms of harmonic support on a domain that scales linearly with the number of qubits. It opens a new route for QML based on variational modelling over phase-space.

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49 - Sound and SPAM-agnostic certification of Quantum Computers

Jan Nöller – TU Darmstadt

The rapid advancement of quantum hardware calls for the development of reliable methods to certify its correct functioning. However, existing certification tests often fall short: they either rely on known state preparation and measurement, or lack soundness guarantees, i.e. they cannot rule out all incorrect implementations of a target gate set. We introduce a method for the certification of quantum gates, where a classical user tests the results of quantum computations for specifically tailored input instructions. Importantly, our approach does not require trusted state preparation and measurement and is thus inherently free from associated systematic errors. For several relevant gate sets, we prove our certification protocol to be sound, assuming a bound on the total memory. A major technical challenge to solve in this setup is to establish the local addressability within a multi-qubit system. For the simplest case of a single-qubit phase gate, we also prove that the gate infidelity is up to a constant upper bounded by the failing probability of the protocol. Our protocol is platform-agnostic, therefore introducing a new paradigm for benchmarking diverse quantum architectures.

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50 - Benchmarking quantum devices beyond classical capabilities

Rafał Bistroń – Jagiellonian University

Rapid development of quantum computing technology has led to a wide variety of sophisticated quantum devices. Benchmarking these systems becomes crucial for understanding their capabilities and paving the way for future advancements. The Quantum Volume (QV) test is one of the most widely used benchmarks for evaluating quantum computer performance due to its architecture independence. However, as the number of qubits in a quantum device grows, the test faces a significant limitation: classical simulation of the quantum circuit, which is indispensable for evaluating QV, becomes computationally impractical. In this talk I present modifications of the QV test that allow for direct determination of the most probable outcomes (heavy output subspace) of a quantum circuit, eliminating the need for expensive classical simulations. This approach resolves the scalability problem of the Quantum Volume test beyond classical computational capabilities, while still examining universal quantum computing.