*Presented in alphabetical order*

**Janet Anders, University of Exeter, UK**

On-line presentation

***Quantum Brownian Motion for Magnets***

**Abstract**: In this talk we will discuss how a 3D system+bath Hamiltonian, can be used to derive a general spin dynamics equation [1]. In the Ohmic limit, it reduces to the Landau Lifshitz Gilbert equation, a phenomenological equation widely used in magnetism. Beyond the Ohmic limit, we demonstrate how Lorentzian couplings can be used as a general tool for the systematic comparison of non-Markovian and Markovian dynamics, and present numerical results of a classical spin's dynamics under classical and quantum noise.

In the second part of the talk we will explore long time steady states. The dynamical convergence to the Gibbs state is a standard assumption across much of classical and quantum thermodynamics. However, for nanoscale and quantum systems the interaction with their environment becomes non-negligible.  Is the system steady state then still the Gibbs state? And if not, how exactly does it depend on the interaction details? I will briefly outline several aspects   [2, 3, 4] of this timely topic.

**Konrad Banaszek, Centre for Quantum Optical Technologies, University of Warsaw, Poland**

***Secure optical communication under restricted eavesdropping scenarios***

Authors: Konrad Banaszek, Michal Jachura (University of Warsaw), Piotr Kolenderski, Mikolaj Lasota (Nicolaus Copernicus University in Torun)

**Abstract:**While the ambition of the QKD technology is to make key distribution secure even against the most sophisticated physical attacks permitted by quantum theory, it usually requires highly elaborate hardware and offers relatively low effective key rates. It is therefore worthwhile to consider alternative key distribution protocols which are secure against a restricted class of attacks. A relevant model in free-space optical communication is passive eavesdropping where an unauthorized third party collects passively a fraction of the signal that escapes detection by the legitimate recipient. Here we describe and analyze theoretically the performance of an optical key distribution (OKD) protocol relying on intensity modulation/direct detection of the optical carrier, where the security is ensured by the presence of the shot noise that inevitably accompanies eavesdropper’s attempt to detect the collected signal.

**Mohamed Bourennane, Stockholm University, Sweden**

***Stronger correlations than dense coding with elementary quantum resources***

**Abstract:** Dense coding is the seminal example of how entanglement can boost quantum communication. By sharing an Einstein-Podolsky-Rosen (EPR) pair, dense coding allows one to transmit two bits of classical information while sending only one qubit. In this talk I show in both theory and experiment that qubit communication assisted by a shared EPR pair is strictly more powerfull than two classical bits in more general communication tasks, and that this advantage persists even when the Bell basis measurement, which is essential for dense coding, is replaced by more elementary measurements such as partial Bell state analysers or even product measurements. Our results reveal that the power of entanglement in enhancing quantum communications qualitatively goes beyond boosting channel capacities and that it can be harvested in simpler and scalable experiments.

**Adam Burchardt,** **QuSoft, University of Amsterdam, The Netherlands;**

**Suhail Ahmad Rather, IndianInstitute of Technology Madras, India** (on-line presentation)

Joint presentation

***Thirty-six entangled officers of Euler: Quantum solution to a classically impossible problem***

**Abstract**: The negative solution to the famous problem of 36 officers of Euler implies that there are no two orthogonal Latin squares of order six. We show that the problem has a solution, provided the officers are entangled, and construct orthogonal quantum Latin squares of this size. As a consequence, we find an example of the long-elusive Absolutely Maximally Entangled state AME(4,6) of four subsystems with six levels each, equivalently a 2-unitary matrix of size 36, which maximizes the entangling power among all bipartite unitary gates of this dimension, or a perfect tensor with four indices, each running from one to six. This special state deserves the appellation golden AME state as the golden ratio appears prominently in its elements. This result allows us to construct a pure nonadditive quhex quantum error detection code ((3,6,2))\_6, which saturates the Singleton bound and allows one to encode a 6-level state into a triplet of such states.

**Paweł Caban, University of Łódź, Poland**

***Nonlinear extension of the quantum dynamical semigroup***

**Abstract**: We consider deterministic nonlinear time evolutions satisfying so called convex quasi-linearity condition. Such evolutions preserve the equivalence of ensembles and therefore are free from problems with signaling. We show that if family of linear non-trace-preserving maps satisfies the semigroup property then the generated family of convex quasi-linear operations also possesses the semigroup property. Next we generalize the Gorini--Kossakowski--Sudarshan--Lindblad type equation for the considered evolution. As examples we discuss the general qubit evolution in our model as well as an extension of the Jaynes--Cummings model.

**Lucas Céleri, Federal University of Goiás, Brazil**

***Gauge theory approach to quantum thermodynamics***

**Abstract:** Universality of classical thermodynamics rests on the central limit theorem, due to which, measurements of thermal fluctuations are unable to reveal detailed information regarding the microscopic structure of a macroscopic body. When small systems are considered and fluctuations become important, thermodynamic quantities can be understood in the context of classical stochastic mechanics. A fundamental assumption behind thermodynamics is therefore that of coarse-graning, which stems from a substantial lack of control over all degrees of freedom. However, when quantum systems are concerned, one claims a high level of control. As a consequence, information theory plays a major role in the identification of thermodynamic functions. Here, drawing from the concept of gauge symmetry, essential in all modern physical theories, we put forward a new possible, intermediate route. Working within the realm of quantum thermodynamics we explicitly construct physically motivated gauge transformations which encode a gentle variant of coarse-graining behind thermodynamics. As a consequence, we reinterpret quantum work and heat, as well as the role of quantum coherence.

**Dariusz Chruściński, Nicolaus Copernicus University in Toruń, Poland**

***Universal Constraint for Relaxation Rates for Quantum Dynamical Semigroup***

**Abstract:** general property of relaxation rates in open quantum systems is discussed. I propose a constraint for relaxation rates that universally holds in fairly large classes of quantum dynamics, e.g., weakcoupling regimes, as well as for entropy nondecreasing evolutions. It is conjectured that this constraint isuniversal, i.e., it is valid for all quantum dynamical semigroups. The conjecture is supported by numerical analysis and may be considered as  the physical characterization of complete positivity. Some implications of this conjecture are also discussed.

**Marek Czachor** **Gdańsk University of Technology, Poland**

***Cosmic-time Quantum Mechanics***

**Abstract:** I present an outline of a formalism for relativistic quantum mechanics where the time parameter is counted out since the origin of the universe. Asymptotically, for large cosmic times, the formalism reconstructs quantum mechanics formulated on a proper-time hyperbolic space in 1+3 dimensions. However, for earlier times the hyperbolic space has some timelike thickness, so effectively the notion of "now" is smeared out. The resulting dynamics is not, as in the usual formalisms, statics in space-time. The time here really "flows" and the past disappears in the deepest ontological sense, while future does not yet exist. The universe plays here a role analogous to a reservoir, and what we know as the Schrodinger picture is, effectively an interaction picture, where the free dynamics represents an evolution of an empty universe. There are interesting formal links to Penrose's conformally invariant formulation of relativistic dynamics. The conformal factor turns ot to be related to the wave function of an empty universe. The work is in progress.

**Michele Dall’Arno, Kyoto University, Japan**

On-line presentation

***Guesswork of a quantum ensemble***

Michele Dall’Arno1,2, Francesco Buscemi3, Takeshi Koshiba2

1 Kyoto University, 2 Waseda University, 3 Nagoya University

**Abstract:** The guesswork of a quantum ensemble quantifies the minimum number of queries needed in average to correctly guess the state of the ensemble, when only one state can be queried at a time. It has been conjectured that analytical solutions of the guesswork problem do not exists except for ensembles of two states, where guesswork and state discrimination coincide and therefore Helstrom’s theory applies. Therefore, even for symmetric qubit ensembles the problem has been so far approached with approximated numerical techniques only.

In our contribution, based on Refs. [1], [2], we disprove such a conjecture by presenting a closed-form analytical solution of the guesswork problem subject to a finite set of conditions, that are for instance satisfied by any qubit ensemble with uniform probability distribution, thus conclusively settling the problem in that case. As an application, we replace the numerical approximated values of the guesswork of symmetric qubit ensembles, that represented the state of the art so far, with a unified closed-form analytical formula.

We consider a communication scenario involving two parties, Alice and Bob. An ensemble ρ of quantum states with labels in a set M is given and known to both parties. At each round, Alice picks a label m in M with probability Tr[ρ(m)] and hands state ρ(m)/Tr[ρ(m)] over to Bob. Bob aims at correctly guessing label m being allowed to query one element of M at a time, until his query is correct, at which point the round is over. The cost function incurred by Bob is the average number of guesses, or guesswork, until he correctly guesses m. Bob’s most general strategy consists of performing a quantum measurement π outputing an element n from the set of numberings of M and querying the elements of M in the order specified by n. Hence, the guesswork is given by the occurence of label m in numbering n, averaged over all numberings.

The guesswork has been extensively studied for classical ensembles, but only very recently tackled for quantum ensembles [3], [4]. In particular, in Ref. [3] the following conjecture was formulated:

*“Closed-form result or optimal measurement* [for the quantum state discrimination problem] *is only known for some special quantum systems, e.g., the case with exactly two states, equiprobable symmetric states, or multiply symmetric states. We believe that it is also the case for minimum guesswork discrimination, because of the analogy between these two problems”.*

Accordingly, the numerically approximated values of the guesswork were recently obtained in Ref. [4] for the square qubit ensemble:

*“... the SDP... can be solved numerically... providing a matching numerical lower bound... showing agreement to 200 digits”*,

as well as for the trine qubit ensemble:

*“The SDP... is solved for this example as well, and the numerical result shows agreement with the analytic upper bound up to a relative tolerance of at least 10-7”*.

Our main result disproves the aforementioned conjecture of Ref. [3] by providing the analytical solution of the guesswork problem subject to a finite set of conditions. In particular, we provide the analytical solution for any qubit ensemble with uniform probability distribution. As an application of our results, we replace the aforementioned numerical approximations of the guesswork of the trine and square qubit ensembles from Ref. [4] with a unified analytic closed-form formula valid for any regular polygonal and polyhedral qubit ensemble, as a function of the number of vertices only.

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**Rafał Demkowicz-Dobrzański, University of Warsaw, Poland**

*Fundamental Limits in Mutiparameter**Quantum Metrology*

Rafał Demkowicz-Dobrzański1, Francesco Albarelli1,2, Wojciech Górecki1

1Faculty of Physics, University of Warsaw, Warszawa, Poland  
2Department of Physics, University of Warwick, Coventry, United Kingdom

**Abstract:** We derive fundamental bounds on the maximal achievable precision in multiparameter **noisy** quantum channel estimation, valid under the most general entanglement assisted adaptive strategy, which are tighter than the bounds obtained by a direct use of single-parameter bounds. We also show operationally meaningful Heisenberg scaling precision limits for the multiple phase interferometry in the **absence of noise** and show that the advantage of the optimal simultaneous estimation scheme amounts to a constant factor improvement when compared with schemes where each phase is estimated separately.

**Berthold-Georg Englert, CQT National University of Singapore, Singapore**

***Sequentially constrained Monte Carlo sampler for quantum states***

**Abstract:** A random sample of quantum states with specific properties is useful for various applications. Since the quantum state space has highly complicated boundaries in high dimension due to the positivity constraint, it is challenging to incorporate the specific properties into the sampling algorithm. The Sequentially Constraint Monte Carlo (SCMC) algorithm is a powerful method for sampling quantum states in accordance with any desired properties that can be described by inequalities. For illustration, we apply this method to the sampling of quantum states with bound entanglement, high-dimensional quantum states with a desired target distribution, and uniformly distributed quantum states in regions bounded by values of the problem-specific target distribution. These examples demonstrate that the SCMC sampler is not only efficient and reliable, it also overcomes the curse of dimensionality.

**Dardo Goyeneche, University of Antofagasta, Chile**

On-line presentation

***The classical value of Bell inequalities: an old problem in mathematics***

**Abstract:** In this talk, it is shown that the problem of calculating the classical value of bipartite Bell inequalities is equivalent to a problem posed by mathematicians in 1973, and deeply studied since 1977. We translate many of those results to a simple language and derive some new ones. As a consequence, we provide analytical expressions of the classical value for continuous families of Bell inequalities in any bipartite escenario, without requiring optimization procedures. Also, we obtain a non-trivial upper bound for the classical value, i.e. sometimes it is strictly smaller than known upper bounds for the quantum value. Finally, we find a series of tight bipartite Bell inequalities for two outcomes and a large number of measurement settings, and conjecture that infinitely many Bell inequalities based on Hadamard matrices are tight, for an unbounded number of measurement settings.

**Beatrix C. Hiesmayr, University of Vienna, Austria**

***About bound entanglement***

Abstract: Already for quantum systems that can give more than two answers, one finds a new type of entanglement, which cannot be distilled. So far no general method is known to construct the set of bound entangled states. This talk gives an overview over the recent progresses on bound entanglement.

**Mark Hillery, Hunter College, NY, USA**

On-line presentation

***Quantum walks and path finding***

**Abstract**: Quantum walks are quantum versions of random walks.  The simplest ones take place on a line, but they can also take place on a general graph.  There are several different kinds of quantum walk, and in this talk we will focus on the scattering walk in which the walker sits on an edge and is scattered when it goes through a vertex.  These walks can form the basis for search algorithms, being able to find special vertices or structures, such as extra edges, that break the symmetry of a graph, and do so with a quantum speedup.  Recently it has been shown that they can, in some cases, find paths between distinguished vertices as well.  This can be thought of as using quantum mechanics to find your way through a maze.

**Felix Huber,** **Jagiellonian University in Kraków, Poland**

***Dimension-free entanglement detection in multipartite Werner states***

(https://arxiv.org/abs/2108.08720)

**Abstract:** Werner states are multipartite quantum states that are invariant under the diagonal conjugate action of the unitary group. This paper gives a complete characterization of their entanglement that is independent of the underlying local Hilbert space: for every entangled Werner state there exists a dimension-free entanglement witness. The construction of such a witness is formulated as an optimization problem. To solve it, two semidefinite programming

hierarchies are introduced. The first one is derived using real algebraic geometry applied to positive polynomials in the entries of a Gram matrix, and is complete in the sense that for every entangled Werner state it converges to a witness. The second one is based on a sum-of-squares certificate for the positivity of trace polynomials in noncommuting variables, and is a relaxation that involves smaller semidefinite constraints.

**Ajehandro Jenkins, ICTQT, University of Gdańsk, Poland**

***Quantum thermodynamics of coronal heating***

**Abstract**: How heat is persistently transported from the Sun’s photosphere (at about 6,000 K) to the much hotter corona (at about 10^6 K) is a longstanding puzzle in astrophysics. Using the quantum Markovian master equation, we show that convection in the stellar photosphere generates plasma waves by an irreversible process akin to Zeldovich superradiance. In the Sun, this mechanism is most efficient in quiet regions with small magnetic fields. Energy is mostly carried by megahertz Alfven waves that scatter elastically until they reach a height at which they can dissipate via mode conversion. This model gives the right power flux for coronal heating and may account for 'chromospheric evaporation' leading to impulsive heat transport into the corona*.*

**Yeong-Cherng Liang, National Cheng Kung University, Taiwan**

***Naturally restricted subsets of nonsignaling correlations: how different are they?***

**Abstract:** It is well-known that in a Bell experiment, the observed correlation between measurement outcomes—as predicted by quantum theory—can be stronger than that allowed by local causality, yet not fully constrained by the principle of relativistic causality. In practice, the characterization of the set Q of quantum correlations is often carried out through a converging hierarchy of outer approximations. On the other hand, some subsets of Q arising from additional constraints [e.g., originating from quantum states having positive-partial-transposition (PPT) or being finite-dimensional maximally entangled (MES)] turn out to be also amenable to similar numerical characterizations. How then, at a quantitative level, are all these naturally restricted subsets of nonsignaling correlations different? Here, we consider several bipartite Bell scenarios and numerically estimate their volume relative to that of the set of nonsignaling correlations. Among others, our findings strongly suggest the following (1) for a given number of inputs n_s(outputs n_o), the relative volume of the Bell-local set rapidly increases (decreases) with increasing n_o (n_s) (2) for given n_s (n_o), the relative volume of Q increases (decreases) with increasing n_o(n_s) (3) the so-called macroscopically local set Q1 can be a very poor approximation of the quantum set when n_s > n_o(4) the difference between Q and the set of correlations originating from MES is most significant when n_o = 2, whereas (5) the difference between the Bell-local set and the PPT set becomes more significant with increasing n_o.

**Adam Miranowicz, Adam Mickiewicz University in Poznań, Poland**

***Non-Hermitian quantum mechanics: No-go theorems and quantum exceptional points***Coauthors: Fabrizio Minganti, Chia-Yi Ju, Guang-Yin Chen, Ravindra Chhajlany, and Franco Nori  
  
**Abstract**: I will discuss two topics of non-Hermitian quantum mechanics:  
(1) Quantum exceptional points (EPs): When a quantum system is isolated from its environment, it is described by a Hermitian Hamiltonian. Its eigenvalues characterize the resonances frequency, while its eigenvectors describe the form of those resonances. If, however, the system interacts with its environment, some particles will leak, while others will enter. For semiclassical systems, this loss and gain can be captured by a non-Hermitian Hamiltonian, whose eigenvalues represent both the resonance frequencies and lifetime. The presence of the environment can cause two different resonances to become the same, forcing the frequency and the lifetime to match. In this case, we speak of EPs, which are considered as the basis for enhanced sensing measures and are relevant to describe dynamical phase transitions and characterize topological phases of matter. Many exotic phenomena, such as parity-time symmetry breaking and unidirectional propagation, have been observed in the proximity of EPs. The vast majority of the studies on EPs, however, have focused on semiclassical models. To properly describe open quantum systems, quantum jumps, representing the instantaneous switching between the energy levels of the system, must be included. Using Liouvillian quantum jumps, we defined quantum EPs, and showed how, and if, they could correspond to semiclassical EPs. Recent experiments and numerous theoretical studies of various groups confirm the usefulness of the quantum EPs proposed by us.  
(2) No-go theorems in quantum information based on non-Hermitian systems:  
Recently, apparent nonphysical implications of Bender's non-Hermitian quantum mechanics have been discussed in the literature. In particular, the apparent violation of the no-signaling theorem, discrimination of nonorthogonal states, and the increase of quantum entanglement by local operations were reported, and therefore the Bender theory was not considered to be fundamental. I will show that these and other no-go principles (including the no-cloning and no-deleting theorems) of conventional quantum mechanics still hold in finite-dimensional non-Hermitian quantum systems, including parity-time symmetric and pseudo-Hermitian cases, if its formalism is properly applied.

**Kavan Modi, Monash University Melbourne, Australia**

On-line presentation

***Linking many-body physics to many-time physics: Characterising micro and macro features of non-Markovian quantum processes***

**Abstract:** A classical stochastic process is a joint probability distribution of a random variable over time. Its quantum generalisation then turns out to be a multipartite density matrix. We refer to the studies of this density matrix as many-time physics in analogy to the well-founded field of many-body physics. Here, we report a set of tools that allows us to characterise both the detailed features of a quantum process, as well as its coarse structures. The former, we show, could be used to tame correlated noise due to a quantum stochastic process. The latter, on the other hand, allows us to explore exotic features such as genuine multipartite entanglement in time. All of these tools are well-tested and shown to be highly effective on NISQ devices with real noise. Importantly, these tools have direct application for noise reduction for NISQ devices and studying facets of complex quantum processes.

**Marek Mozrzymas, University of Wrocław, Poland**

***Square-root measurement and the degradation of the resource state in the deterministic port-based teleportation scheme***.

**Abstract:** Port-based teleportation (PBT) is a quantum teleportation protocol in which the parties exploit joint measurements performed on $N$ shared $d$-dimensional maximally entangled pairs (the resource) and the state to be teleported, with the addition of the one-way classical communication. The lack of correction in the last step is an essential feature distinguishing PBT from standard quantum teleportation. It was shown that in the asymptotic limit of $N$ one can faithfully teleport single qubit state and, in general a qudit using PBT. The question arises, how well one can teleport multiple states by the means of PBT. In my talk I shall consider the idea of entanglement recycling, i.e. the repeated use of the same resource for multiple rounds, which is one of possible solutions to the problem. In particular, I shall show how the resource degrades after one or multiple uses. To answer it we analyse the structure of the measurement employed in the protocol (the square-root-measurement, to be precise), which enables us to obtain the explicit formula for the recycling fidelity involving only group-theoretic parameters describing irreducible representations of the symmetric group $S(n)$. Additionally, the analysis of the resource degradation in the optimal PBT are provided.

**Michał Oszmaniec***,* **Center for Theoretical Physics, Polish Academy of Sciences, Poland**

***Saturation and recurrence of quantum complexity in random quantum circuits***

**Abstract:** Quantum complexity is a measure of the minimal number of elementary operations required to approximately prepare a given state or unitary channel. Recently this concept has found applications beyond quantum computing---in the classification of topological phases of matter and in the description of chaotic many-body systems. Furthermore, within the context of the AdS/CFT correspondence, it has been postulated that the complexity of a specific time-evolved many-body quantum state is sensitive to the long-time properties of AdS-black hole interiors. Recently Brown and Susskind conjectured that the complexity of a chaotic quantum system grows linearly in time up to times exponential in the system size, saturating at a maximal value, and remaining maximally complex until undergoing recurrences at the doubly-exponential times. In this work we prove the saturation and recurrence of complexity of quantum states and unitaries in a model of chaotic time-evolution based on local random quantum circuits, in which a local random unitary transformation is applied to the system at every time step. Importantly, our findings do not depend on details of the model of random circuits, such as geometry of interactions between the qubits.  Our results advance an understanding of the long-time behaviour of chaotic quantum systems and could shed light on the physics of black hole interiors.  From a technical perspective our results are based on establishing new quantitative connections between the Haar measure and high-degree approximate designs, as well as the fact that random quantum circuits of sufficiently high depth converge to approximate designs.

**Massimo Palma**, **University of Palermo, Italy**

On-line presentation

***Non-locality breaks the relations between measures of quantum objectivity***

Dario A. Chisholm, Luca Innocenti, and G. Massimo Palma

**Abstract:** A quantum system is said to be objective if different observers agree on its state. Such agreement, or consensus, is in turn defined as redundant encoding of the information about the system into the environment. Different notions of “quantum objectivity” are all based on the same principle, but use different ways to quantify the redundancy of the encoded information. Here, we consider how these types of quantum objectivity fare when the information encoding into the environment is non-local. We find that such non-local encoding into the environment hinders the observers’ ability to recover the state of the system, and thus reduces the objectivity of the overall state, even in the case of high redundancy of the information spread into the environment. Considering non-local information encoding highlights the need to more carefully distinguish between the notions of “consensus” and “redundancy” in the context of quantum objectivity, and that special care ought to be taken when considering the relations between the different notions of quantum objectivity.

**Tomasz Placek, Jagiellonian University in Kraków, Poland**

***Chance and choice: On experimenters' free choice and deterministic hidden-variable models***

Tomasz Placek (Jagiellonian University, Philosophy) and Thomas Müller (University of Konstanz, Philosophy)

A proof of a Bell-type theorem typically invokes a premise about the independent selections of the setting of the measurement apparatuses. Recently, real time data from human choices were used to provide independent selections of settings in Bell-type experiments (Abellan et al, Nature 557, 2018 ). In contrast, deterministic hidden-variable models aim to remove indeterminism of measurement results. We attempt an analysis of deterministic hidden-variable models for GHZ-type experiments, which exhibit this combination of „retain choice but remove chance”.

We study a structure that has indeterminism induced by agents as well as indeterminism produced by Nature, and in which there are non-local perfect correlations. To remove the non-local correlations harbored by Nature-given choice points (outcomes of measurements), while retaining the freedom of experimenters, we extend the structure appropriately.

We apply this structure extension to analyze the GHZ experiment. We prove that:

(1) global super-determinism (removal of all experimenters' choices) is always an option.

(2) An extended structure for GHZ with non-contextual instruction sets involves the removal of some choices of experimenters.

(3) An extended structure for GHZ with contextual instructions does not remove all non-local correlations given by Nature.

**Katarzyna Roszak, University of Wroclaw, Poland**

***A measure of qubit environment entanglement for pure dephasing evolutions***

**Abstract:** Decoherence of a quantum system due to the interaction with an environment can either be the outcome of a process which leads to entanglement generation between the system and the environment, or one which does not. Distinguishing between the two situations is an involved problem. Contrarily to entanglement between two qubits, the theoretical means for the study of such entanglement are very limited unless the joint system state is pure. The only available measure which can be calculated from the density matrix is Negativity [1,2] , the calculation of which requires diagonalization of a matrix of the same dimension as the joint Hilbert space of the two parties, which must be and has been done numerically. This limits the range of general conclusions which can be reached about the creation and behavior of entanglement.

The problem is that the question of entanglement between qubits and their environment becomes important when more complicated procedures and quantum algorithms are performed. This is because the presence of entanglement, although its manifestation is limited when straightforward qubit decoherence is of interest [3,4], can significantly change the effect that the environment has on the system, especially post measurement.

Although the general question of qubit-environment entanglement cannot be simplified, it is possible to do so when the class of systems under study is restricted. I propose a qubit-environment entanglement measure which is tailored for evolutions that lead to pure dephasing of the qubit, such as are abundant in solid state scenarios. The measure fulfills the requirements for an entanglement measure [5] within the bounds of its applicability, as it allows to unambiguously determine separability, reduces to a known entanglement measure for pure states, and behaves appropriately under the set of allowed separable operations. In contrast to all other measures of mixed state entanglement, the measure has a straightforward physical interpretation, directly linking information about the qubit state which is contained in the environment to entanglement. This means that the pure state interpretation of entanglement for pure dephasing evolutions can bedirectly extended to mixed states, even though the link between entanglement and decoherence cannot.

The measure can be calculated directly from the joint system-environment state, since it actually only requires the knowledge of the initial qubit state and the evolution of the environment conditional on qubit pointer states (hence diagonalization of matrices half the dimension of the joint system-environment state in the worst case scenario) and does not require any sort of minimization. In the situation when there are no correlations between different components of the conditional environmental density matrices (such as spins, bosons,etc.), the numerical problem reduces to diagonalization of matrices the dimension of each component separately, which allows to find the evolution of the measure for extremely large environments. The measure therefore has strong computational advantages.

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**Ana Belén Sainz,** **ICTQT University of Gdańsk, Poland**

***Steering: a modern perspective on this fundamental puzzle***

**Abstract**: In this talk we will discuss the phenomenon of Steering - that which puzzled Einstein, Podolsky, Rosen, and Schroedinger back in the 1930’s. We will see the similarities and differences between Bell and steering experiments, and notice hence other aspects in which quantum systems can behave non-classically. We will also take a step further into the realm of post-quantumness: we will discuss how an analogue of the PR-box can be constructed in steering scenarios, and pin down some particular insights on quantum foundations that we can only draw from studying steering.

**Michail Skoteiniotis**, **UAB Barcelona, Spain**

***Certifying topological states of matter***

**Abstract:** Topological phases of matter are paradegmatic materials with important applications in material science and quantum computing.  The characterization and classification of topological states of matter is not yet fully understood as such states fall outside the paradigm of standard Landau theory.  Hitherto, such a characterization has focused mainly on the difficulty of preparing topological states via quantum circuits, or required knowledge of the ground space of the parent Hamiltonian.

In this talk, I propose an alternative method for certifying the presence of topological order from the quantum state itself, by exploiting the connection between topological quantum states and quantum error correction.  I provide evidence  that the coherent information of a quantum error correcting code can be used to answer affirmatively whether a given multi-partite quantum state possesses topological properties or not.

This work is in collaboration with Alonso Viladomat (TU Munich), and Ricardo Costa de Almeida and Philipp Hauke (University of Trento).

**Jan Sperling**, **Paderborn University (Germany)**

***Many colors of entanglement***

**Abstract.** In this presentation, different aspects of entanglement theory are discussed together with their experimental application in photonic systems. We begin with analyzing quantum correlations in multipartite settings, including the various ways of decomposing composite systems to harness distinct kinds of entanglement and even extending to macroscopic limits. Other concepts, such as negative joint probabilities and quantum correlations for real and complex numbers, are discussed in theory and explored in experiments. We specifically focus on entanglement in bosonic systems, being essential for quantum optics and applications in quantum communication. For example, the difference between the entanglement of individual light particles, photons, and between multiple optical modes is studied, also encompassing recent notions of mode-independent entanglement. Finally, the evolution of entanglement is explored on the basis of novel equations of motions that are derived from the stationary-action principle.

**Armin Tavakoli,** **University of Geneva, Switzerland**

***Informational restrictions in quantum correlations***

**Abstract:** We investigate the relationship between quantum correlations and the communication of quantum bits of information. We go beyond standard qubits and instead consider a more general notion of informational restriction which makes no reference to the dimension of Hilbert space. We show how to characterise such informationally restricted quantum correlations and how they qualitatively go beyond standard qubits. Then, we discuss how this concept provides both an alternative perspective and a solution to natural problems in quantum contextuality and entanglement-assisted communications

**Volodymyr Tkachuk, Ivan Franko National University of Lviv, Ukraine**On-line presentation

***Spin system energy levels detection on a quantum computer***

**Abstract:** Time dependence of the mean value of a physical quantity is related to the transition energies of a quantum system. We show that in the case when the operator of a physical quantity anticommutes with the Hamiltonian the mean value of this quantity is related to the energy levels of a quantum system. On the basis of the result, we propose a method for determining the energy levels of physical systems on a quantum computer [1]. Note that this method is restricted to the Hamiltonians for which anticommuting operators exist and the energy spectrum of which is symmetric with respect to inversion of energy. We also generalize this method to the case of an arbitrary spin system, adding to the system one probe (ancilla) spin [2]. Studies of the evolution of this probe spin allow determining energy levels of the system. On the basis of the proposed method, the energy levels of various spin systems are found on IBM’s quantum computer. The results of quantum calculations are in good agreement with the theoretical ones. The method is efficient for estimating the energy levels of spin systems and opens a possibility to achieve quantum supremacy in solving the eigenvalue problem with the development of multi-qubit quantum computers.

**References:**  
[1]  Kh. P. Gnatenko, H. P. Laba, V. M. Tkachuk, Phys. Lett. A 424, 127843 (2022).  
[2] Kh. P. Gnatenko, H. P. Laba, V. M. Tkachuk, Eur. Phys. J. Plus  137, 522 (2022).

**Lorenza Viola,** **Dartmouth College, USA**

On-line presentation

***Restoring superclassical precision scaling in quantum frequency estimation under spatiotemporally correlated quantum noise***

**Abstract**: Realizing the full potential of quantum metrology demands that the impact of realistic noise sources be accounted for. I will focus on entanglement-assisted frequency estimation in the presence of temporally correlated ("non-Markovian") dephasing noise that is also spatially correlated and non-classical. In a collective coupling regime, this kind of noise is known to preclude superclassical precision scaling due to uncontrolled entanglement and squeezing among the qubit probes, mediated by the environment. Breaking collectivity provide a means for effectively tuning the impact of spatial noise correlations. In particular, I will show how metrological advantage can be restored by suitably randomizing the probes’ locations, or, if detailed knowledge about the noise is available, how nearly-Heisenberg precision scaling may be achievable by suitably tailoring the sensing system’s geometry.

**Marek Żukowski,**  **ICTQT, University of Gdańsk, Poland**

***On absurdity of some interpretations of Wigner's Friend gedanken-experiment***

**Abstract:** An extension of the Wigner's Friend experiment of the kind proposed by Deutsch, and later used e.g. by Frauchiger and Renner, is shown to be inherently inconsistent. This fact has consequences for the measurement theory and invalidates some interpretations of quantum mechanics. In contradistinction with "local friendliness" no go results, the proof does not rest on the assumptions of locality and free-will of observers. The talk is based on Phys. Rev. Lett. 126, 130402 (2021) (with Marcin Markiewicz), and our current discussions with Jay Lawrence.