Presented in alphabetical order

Karol Bartkiewicz, **Adam Mickiewicz University in Poznań, Poland**

Quantum exceptional points of non-Hermitian systems via quantum process tomography

Abstract: Hamiltonian exceptional points (HEPs) are degeneracies of non-Hermitian Hamiltonians for classical and semiclassical systems, which exhibit usually both dissipation and amplification. However, this definition ignores the effect of quantum jumps on the evolution of quantum systems. Quantum EPs (QEPs), defined as degeneracies of quantum Liouvillians, are natural generalizations of the standard semiclassical EPs by including the effect of quantum jumps [Minganti et al., Phys. Rev. A 100, 062131 (2019)]. Here we explicitly describe how standard quantum process tomography, which is a popular method to reveal the dynamics of a quantum system (a black box), can be readily applied for revealing and characterizing QEPs of non-Hermitian systems. We analyze prototype models to show how to tune their system parameters to observe QEPs. Specifically, we study these models experimentally by implementing them as driven dissipative superconducting qubits. Thus, we show how to reveal QEPs and HEPs experimentally.

Mohamed Bourennane, **Stockholm University, Sweden**

Weak entanglement improves quantum communication using only passive linear optics

Abstract: We show that noisy entangled states, that cannot violate any Bell inequality, can be used to improve quantum communication when measurements are limited to being compatible with standard, ancilla-free, linear optics. We introduce a communication task inspired by the cryptographic primitive known as secret sharing and show that entanglement that is too weak to permit possible Einstein-Podolsky-Rosen steering can still enhance the success rate when using only standard partial Bell state analyzers for decoding. We then go further and show that even the simplest type of decoding, namely product measurements, which require no optical interference at all, can still lead to an advantage when the entanglement is steerable but still Bell-local. We demonstrate the former advantage by preparing polarization qubits in an unsteerable entangled state and by using only beam-splitters and phase-shifters observing a boost in the success rate of beyond the best entanglement-unassisted qubit protocol.

Piotr Dulian, **Centre of Theoretical Physics, Polish Academy of Sciences, Poland**

Haar random approximate t-designs and Gaussian ensembles

Abstract: For a Haar random set $S \subset U(d)$ of quantum gates we consider the uniform measure whose support is given by S. This measure can be regarded as a $\delta(S, t)$-approximate t-design, where t is a non-negative integer. We propose a random matrix model that aims to describe the probability distribution of $\delta(S, t)$ for any t. Our model is given by a block diagonal matrix whose blocks are independent, given by Gaussian or Ginibre ensembles, and their number, size and type is determined by t. We prove that, the operator norm of this matrix, $\delta(t)$, is the random variable to which $\sqrt{|S|}\delta(S, t)$ converges in distribution when the number of elements in S grows to infinity. Moreover, we characterize our model giving explicit bounds on the tail probabilities $P(\delta(t) > 2 + \varepsilon)$, for any $\varepsilon > 0$. We also show that our model satisfies the so-called spectral gap

conjecture, i.e. we prove that with the probability 1 there is finite t such that for all non-negative integers k we have $\delta(k) \leq \delta(t)$. Numerical simulations give convincing evidence that the proposed model is actually almost exact for any cardinality of S. The heuristic explanation of this phenomenon, that we provide, leads us to conjecture that the tail probabilities $P(\sqrt{|S|}\delta(S, t) > 2 + \varepsilon)$ are bounded from above by the tail probabilities $P(\delta(t) > 2 + \varepsilon)$ of our random matrix model. In particular our conjecture implies that a Haar random set $S \subset U(d)$ satisfies the spectral gap conjecture with the probability 1.

Paweł Caban, Jakub Rembieliński, University of Łódź. Poland

Spin correlations of vector bosons from the Higgs decay

Abstract: Recently, the possibility of observing quantum entanglement and violation of Bell-type inequalities in high energy physics processes has been put forward. In particular, the Higgs boson decays, H->ZZ or H->W+W- are considered in this context. In our contribution we discuss spin correlations of relativistic vector bosons that can be used in the description of these decays.

Maciej Demianowicz, Gdańsk University of Technology, Poland

Entangled subspaces

Abstract: Entangled subspaces are an important concept in quantum information science, holding both theoretical and practical significance. A specific class of such spaces that has recently garnered considerable attention is genuinely entangled subspaces (GESs). These are subspaces that support only genuinely multipartite entangled (GME) states. In this talk, I will discuss several topics related to these subspaces, including their construction and detection. Moreover, I will demonstrate how tools initially developed for studying GESs can be applied to the analysis of a different type of entangled subspaces.

Khrystyna. P. Gnatenko, Ivan Franko National University of Lviv, Ukraine

Relation of characteristics of quantum graph states with graph properties and their detection on a quantum computer

Abstract: We consider quantum states of spin systems generated by the operator of evolution with Ising Hamiltonian. The states can be associated with graphs and are known as quantum graph states. Geometric characteristics of the states, namely the velocity of quantum evolution, the curvature, and the torsion are calculated on the basis of their relationship with fluctuations of energy presented in [1]. We find that the geometric characteristics of the quantum graph states are related to the total number of edges, triangles, and squares in the corresponding graph [2]. As a result, we propose a quantum algorithm for the detection of the geometric properties of the evolutionary graph states and quantifying the total number of edges, triangles, and squares in graphs.
The algorithm is realized on IBM's quantum computer ibmq-manila [3] for particular cases of quantum graph states corresponding to a chain, a triangle, and a square. The results of quantum calculations are in good agreement with the theoretical ones [2]. We hope that quantum

supremacy will be achieved with the proposed algorithm with the development of a multi-qubit quantum computer.

We also study the geometric measure of entanglement of the quantum graph states [4,5]. For the studies, the relation of the entanglement with the mean spin obtained in [6] is used. Â We find that the entanglement of a spin with other spins in a quantum graph state is related with the degree of vertex representing it in the corresponding graph. Graph states corresponding to a chain, Â a claw, and a complete graph are examined. Quantum protocols for quantifying of the geometric measure of entanglement of the Â states are constructed and realized on IBM's quantum computers [4,5]. The results of the quantum calculations are in agreement with the theoretical ones.

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Marcus Grassl, International Centre for Theory of Quantum Technology, University of Gdańsk, Poland

SIC-POVMS: Construction and Implementation

Abstract: SIC-POVMs are generalised quantum measurements which are of particular interest in the context of quantum state tomography and quantum key distribution. Alternatively, they can be described by d^2 normalised vectors in the d-dimensional complex vector space such that the inner product between any pair of vectors has constant modulus.
It has been conjectured that SIC-POVMs exist for all dimensions and that they can be constructed as orbits of a so-called fiducial vector under the Weyl-Heisenberg group. Despite a lot of effort, numerical or exact fiducial vectors are still only known for a finite, though growing list of dimensions.
The talk will give a brief overview of the current state of the conjecture. It will also be discussed how symmetries help to implement SIC-POVMs using projective measurements.
The talk includes recent results obtained in collaboration with Marcus Appleby, Ingemar Bengtsson, Michael Harrison, and Gary McConnell.

Richard Jozsa, **University of Cambridge, The United Kingdom**

On validating high complexity performance of quantum computers

Abstract: With the ever-growing promise of a quantum computer that can perform tasks beyond the capabilities of classical computing technology, an important issue is to develop methods for gaining confidence in the correctness its outputs when operating in the classically inaccessible 'high complexity' regime.
We consider decision problems (i.e. having a single bit output). The most straightforward and direct method for validating quantum computations is to perform classical simulations and compare results. But the manageable (efficient) application of this method *ipso facto* excludes precisely the high complexity regime that we wish to address. Nevertheless we will describe a class of quantum processes that suffice to efficiently perform universal quantum computation for decision problems while, perhaps somewhat paradoxically, also being classically efficiently simulable. These features will not imply that BQP = BPP, but our perspective does suggest avenues for validating high complexity performance of a quantum computer.

Michał Karpiński, University of Warsaw, Faculty of Physics, Poland

Phase-only temporal mode transformations

Jerzy Szuniewicz, Filip Sośnicki, Michał Karpiński

Abstract: Spectral-temporal modes of quantum light have been recognized as a promising platform for quantum information processing (QIP) and metrology. However, a simple general tool for efficient conversion between spectral-temporal modes is still missing. A phase-only, i.e. in-principle lossless, approach is required for quantum light. We show that transformations between spectral-temporal modes can be realized by a single application of arbitrary temporal phase modulation and a single application of arbitrary spectral phase modulation. The required arbitrary phases can be found by means of the well-known phase retrieval algorithm, such as the Gerchberg-Saxton algorithm. We show numerical examples and discuss the prospects of experimental implementation using wide-bandwidth electro-optic phase modulation.

Ryszard Kukulski, Institute of Theoretical and Applied Informatics, Polish Academy of Sciences, Poland

Probabilistic quantum error correction

Abstract: Probabilistic quantum error correction is an error-correcting procedure which uses postselection to determine if the encoded information was successfully restored. In this talk we analyze the probabilistic version of the channel-adapted error-correcting procedure for general noise. We provide several constructions of probabilistic, channel-adapted codes and discuss the probability of success, which can be achieved. In addition to the theoretical results, we will present numerical results for random quantum noise channels.

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Marek Kuś, **Centre of Theoretical Physics, Polish Academy of Sciences, Poland**

Entanglement of indiscernibles. Some fundamental remarks

Abstract: In my presentation I would like to return to the long-discussed problem of entanglement of indistinguishable particles. My goal is to discuss this problem from a slightly more fundamental level, let's call it Leibnizian, i.e. the “identity of indiscernibles”. Purely formally, at the quantum level, Leibniz's principle does not apply, but it appears at the classical level, and here it is one of the most important metaphysical principles, necessary it seems, e.g., in the discussion of individuals. I would like to show what importance entanglement and the process of measurement play here, in particular, in terms of the "emergence" of this principle when moving from the quantum to the classical level.

Wiesław Leoński, **University of Zielona Góra, Poland**

Quantum correlations and their transfer in two physical models

W. Leoński[1], J. K. Kalaga[1], V. Le Duc[1,2], M. Kostrzewa[1]
[1] Institute of Physics, University of Zielona Góra, Z. Szafrana 4a, 65-516 Zielona Góra, Poland
[2] Tinh Gia 3 high school, Nghi Son, Thanh Hoa, Vietnam

Abstract: The most intriguing topics among those devoted to quantum theory (including those related to quantum information) seem to be those devoted to quantum correlations, their types, stability, and transfer. In this communication, we concentrate on the last aspect mentioned here – the transfer of quantum correlation.

We discuss two main types of physical systems, and they are linear and hexagonal models. In particular, we consider two situations where in the first one, we check how the quantum bipartite entanglement can be transferred from one part of the hexagonal model involving interacting spin qubits to another part of the system. In the second case, we discuss two linear (or nonlinear) oscillator chains. We assume that the oscillators interact with their neighbors inside individual chains, whereas there is no interaction between the chains. For such a model, we concentrate on transferring both entanglement and quantum steering from one end of the chains to the second one. We show that for both models mentioned here, the transfer of the quantum correlations can be achieved with high accuracy.

Gerd Leuchs, **Max Planck Institute for the Science of Light, Germany**

Interfering the bright and the dark - improving the sensitivity of an interferometer using Kerr squeezed light

Gerd Leuchs[1-3]

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2. Physik Department, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen, Germany

3. Nexus for Quantum Technologies, University of Ottawa, Ottawa, K1N 6N5, ON, Canada

Abstract: One of the most promising applications for squeezed light is interferometry beyond the shot-noise limit (SNL). To date, only squeezed light generated by parametric down-conversion has been used to improve interferometer sensitivity. Remarkable results have been achieved with this approach, including applications to large-scale gravitational wave detectors. On the other hand, there exists a potentially more robust way to generate squeezed light, that is, using the optical Kerr effect. It occurs almost for free in optical fibers and requires no phase matching. However, no interferometer sensitivity enhancement has been demonstrated so far using this method. One of the reasons for that is that the uncertainty distribution of a Kerr-squeezed state in phase space is tilted with respect to the amplitude or phase quadratures. Additional obstacles include Raman and guided acoustic wave Brillouin scattering in fibers.

One way to work with Kerr-squeezed states is to produce a polarization-squeezed state. We developed a novel setup for the generation of polarization squeezed states via the Kerr effect in optical fibers [1], which greatly improves stability and robustness. In a setup based on this novel approach, we demonstrate that it is possible to enhance interferometric sensitivity beyond the SNL using Kerr-squeezed states. With the use of a squeezed state, the signal-to-noise ratio is demonstrated to improve by 4 dB beyond the SNL.

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Karol Łukanowski, University of Warsaw, Poland

Upper bounds on key rates in device-independent quantum key distribution

Abstract: Device-independent quantum key distribution (DIQKD) is a paradigm of quantum cryptography that achieves the highest degree of secret communication security by placing no assumptions on the implementation of a cryptographic protocol. Instead, all claims about security have to be made solely on the basis of the actual data recovered by the honest users. DIQKD protocols that are proven to be secure are then automatically immune to hacking attacks based on implementation flaws or even malicious interference of the device manufacturers themselves. On the other hand, the certification of device-independent security constitutes a great theoretical challenge with a lot of research activity put into deriving bounds on the rate of secret key distillation in such protocols. In this thesis, I introduce the convex-combination (CC) attack, a technique that can be used by an adversary to eavesdrop on the communication of the honest users. I show how considering the attack allows one to efficiently calculate tight upper bounds on DIQKD key rates which translate to constraints on the allowed degree of experimental imperfections in cryptographic protocols. In particular, I apply the technique to state-of-the-art DIQKD protocols constructed around the violation of the CHSH Bell inequality and show that the current predictions on their robustness to noise are already very close to the ultimate tolerable thresholds.

Florian Mintert, Imperial College London, The United Kingdom

Quantum control with quantum invariants

Abstract: Most control problems in quantum information are concerned with qubit degrees of freedom, but many practical realizations require dynamics outside qubit subspaces.

Moving trapped ions in real space, for example, can help to make trapped ion technologies scalable.Quantum invariants can be very helpful to find solutions for such control problems.
I will discuss shuttling protocols derived from quantum invariants and extensions that can be used for control of interacting spin chains.

Adam Miranowicz, Adam Mickiewicz University in Poznań, Poland

Novel methods and applications of parametric amplification

Authors: Levgen I. Arkhipov, Wei Qin, Adam Miranowicz, Fabrizio Minganti, Şahin K. Özdemir, Franco Nori

Abstract: Squeezed states of light generated via parametric amplification form a fundamental building block in modern quantum technologies ranging from quantum metrology, including advanced LIGO experiments, to quantum information processing by demonstrating quantum advantage via, e.g., boson sampling of squeezed modes.
We will discuss other recently developed methods and applications of parametric amplification which enable, in particular: exponential amplification of light-matter interactions and that of spin squeezing, as well as squeezing-based quantum nondemolition measurements [1] and new types of doubly-degenerated exceptional points [2].

References:
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Gláucia Murta, University of Dusseldorf, Germany

Self-testing with dishonest parties and entanglement certification in quantum networks

Abstract: Multipartite entanglement is a crucial resource for network cryptographic tasks, such as secret sharing and anonymous quantum communication. Here, we consider the task of entanglement verification of the state distributed in a quantum network. The goal is to certify entanglement properties of the distributed state even when some of the parties (an unknown subset of parties in the network) may act maliciously. We present a device-independent protocol that can certify the presence of genuine multipartite entanglement among the honest parties and the set of (unknown) dishonest parties. Moreover we introduce the paradigm of self-testing with dishonest parties and self-test the GHZ state in this framework. We also extend our results to provide robust self-testing statements.

Jonathan Oppenheim, University College London, The United Kingdom

Decoherence vs diffusion: testing the quantum nature of gravity

Abstract: We consider two interacting systems when one is treated classically while the other remains quantum. Despite several famous no-go arguments, consistent dynamics of this coupling exist, and its most general form can be derived. We discuss the application of these dynamics to the foundations of quantum theory, and to the problem of understanding gravity when space-time is treated classically, while matter has a quantum nature. If any system is treated as fundamentally classical, the dynamics necessarily results in decoherence of quantum systems, and a breakdown in predictability in classical phase space. We prove that a trade-off between the rate of decoherence and the degree of diffusion induced in the classical system is a general feature of all classical-quantum dynamics. Applying the trade-off to gravity provides an experimental signature of theories in which gravity is fundamentally classical. Bounds on decoherence rates arising from current interferometry experiments, combined with precision measurements of mass, place significant restrictions on theories where Einstein's classical theory of gravity interacts with quantum matter.

Based on joint work with Carlo Sparaciari, Barbara Šoda & Zachary Weller-Davies
https://arxiv.org/abs/1811.03116
https://arxiv.org/abs/2203.01982

Eugen Polzik, **Niels Bohr Institute, Copenhagen University, Denmark**

Quantum state engineering of a macroscopic object

Abstract: Recent ideas and technological developments have made possible studies of macroscopic objects deep in the quantum regime. An entangled Einstein-Podolsky-Rosen (EPR) state has been generated between distant mechanical and atomic oscillators [1]. Such entanglement allows to measure disturbances in the position and the momentum of an oscillator simultaneously, the trait which may seem counterintuitive. Using this entangled state, the trajectory of motion of the oscillator in phase space can be traced with, in principle, unlimited accuracy. Those ideas can be employed in gravitational wave detectors [2] following the proposals [3,4].

Another challenge within quantum physics of macroscopic objects is generation of single quantum excitations of an oscillator and quantum superpositions of those. A question, how large an object can exist in a quantum superposition state has been always at the forefront of quantum physics. Starting with the ground state of a drum mode of a millimeter-sized membrane oscillator, we write a single quantum of motion to it. Following a programmable time delay, we read out the motional quanta by converting it into a photon. We observe nonclassical correlations between the write and read photons and demonstrate the single phonon-photon character of the process [5].

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Hanna Wojewódka-Ściążko, Institute of Theoretical and Applied Informatics IITiS, Polish Academy of Sciences, Poland

Resource engines

Zbigniew Puchała, Hanna Wojewódka-Ściążko, Kamil Korzekwa

Abstract: In this talk, we aim to advance the analogy between thermodynamics and quantum resource theories by extending previous inspirations. While previous studies focused on scenarios with a single heat bath, neglecting heat engines operating between two baths at different temperatures, we investigate the performance of resource engines. These engines replace access to two heat baths with two arbitrary constraints on state transformations. We propose a two-stroke heat engine analogy, where the system is sent to two agents, Alice and Bob, who can transform it using their constrained sets of free operations. We address questions such as whether a resource engine can generate a full set of quantum operations or all possible state transformations, and how many strokes are needed for that. We also explore how the resource engine framework enables the fusion of different resource theories, exemplified by combining thermodynamics and coherence resource theories with respect to distinct bases.

Ana Predojević, Stockholm University, Sweden

Quantum light sources: entanglement generation and characterization

Abstract: Single quantum dots are established emitters of single photons and entangled photon pairs. However, the achievable degree of entanglement and the source readiness to be deployed in quantum communication protocols depend on additional functionalities, including high photon collection efficiency. I will present engineered photonic systems that allow for entangled photon pair sources to be more efficient. Also, I will introduce a novel method to achieve potentially scalable photonic sources that can be accomplished without need for costly and complex deterministic nanofabrication and lithography techniques.

Grzegorz Rajchel-Mieldzioć, Centre of Theoretical Physics, Polish Academy of Sciences, Poland

Certifying the metrological usefulness of quantum statistics: a semidefinite programming approach

Abstract: The usefulness of quantum states for metrology is bounded by the quantum Fisher information (QFI). However, estimating QFI might require full tomography of a state, which is unfeasible even for a small number of qubits. To avoid this problem, we find a state of minimal QFI that is compatible with a small number of expectation values using semidefinite programming. As we show in examples, this approach allows us to reliably certify QFI in a way that scales linearly or quadratically with a number of qubits, outperforming previous bounds [PRL 122, 090503 (2019)].

Ravishankar Ramanathan, **University of Hong-Kong, China** **(on-line)**

Device-independent randomness amplification of public weak seeds with finite devices

Abstract: The extraction of randomness from weak random seeds is a problem of central importance with multiple applications in cryptography. In this talk, we will first present a device-independent (DI) protocol for amplification of randomness from public weak Santha-Vazirani (SV) sources that uses a device consisting of two separated components and is secure against no-signaling adversaries. Specifically, under the assumption that the device behavior is as prescribed by quantum mechanics, the scheme allows for amplification of arbitrarily weak public SV sources. Secondly, we will tackle the problem of finite-device randomness amplification of more general min-entropy sources and present a DI protocol for randomness extraction from a single min-entropy source (consisting of two blocks of sufficiently high min-entropy) secure against quantum adversaries.

Oliver Reardon-Smith, **Jagiellonian University**, **Poland**

Improved simulation of quantum circuits dominated by free Fermionic operations

Abstract: We present a classical algorithm capable of estimating Born rule probabilities of quantum circuits consisting of matchgate/Fermionic linear optical (FLO) unitaries and non-FLO controlled-phase gates with arbitrary phases. Our algorithm has asymptotic runtime linear in an (in general) exponentially large quantity we have named the "FLO-extent", and is at most polynomial all other parameters. The FLO-extent is defined in a similar way to the stabilizer extent known from the literature on quantum simulation using stabilizer decompositions. The FLO extent is sub-multiplicative, and the multiplicative upper bound leads to a runtime for our algorithm which doubles for each swap gate, or controlled-Z gate added to the circuit. Controlled-phase gates with different phases have lower extent, smoothly interpolating between 1 and 2. These numbers can be compared with the prior state of-the-art for this task, the runtime of which is multiplied by a factor 9 for each CZ-gate. This dramatic difference in performance is due to our use of methods we have developed to perform tasks in the FLO subtheory in a phase-sensitive way, allowing us to decompose the relevant "magic states" at the level of statevectors rather than density operators. Our results are formulated for quantum circuits, directly extending the class of quantum computations that can be simulated using current classical computers. However, the FLO subtheory also naturally represents the evolution of non-interacting Fermions, while the addition of non-FLO unitaries to the circuit can represent interactions between Fermions. We therefore expect that our results will be applicable to classical simulations of weakly interacting Fermions, with potential applications in condensed matter and quantum chemistry research. In addition to practical simulation our work is part of the ongoing effort to understand the differences between the computational power of classical and that of quantum mechanics. By extending classical simulation methods to new areas we can focus attention on those features of quantum computations which are necessary for meaningful "quantum advantage".

Anna Sanpera Trigueros, University of Barcelona, Spain

Convex set geometry, copositive matrices, and local-Hamiltonians

Abstract: The theory of entanglement has an elegant geometric formulation in terms of convex sets, positive maps and geometrical structures such as: measures, volumes, witnesses, transformations. For symmetric quantum states, we have found that the theory of entanglement and the theory of copositive matrices are intimately related concepts, and a correspondence between exceptional (non-exceptional) copositive matrices and non-decomposable (decomposable) entanglement witnesses applies. Surprisingly, such geometrical approach might also be used to analyze local-Hamiltonians describing interacting quantum many-body systems of condensed matter, high energy physics, quantum chemistry...Such approach should allow to assess the entanglement capability of local Hamiltonians and, from it, the properties of their relevant eigenstates.

Gniewomir Sarbicki, Nicolaus Copernicus University in Toruń, Poland

New families of optimal entanglement witnesses

Abstract: We provide new families of entanglement witnesses and show their optimality. The families generalise known families of entanglement witnesses. Some of them arises in a non-trivial optimisation procedure. Proofs of optimality are obtained using the spanning criterion, but some entanglement witnesses are proven to be optimal, without satisfying the spanning criterion.

Michał Studziński, University of Gdańsk, Poland

When the symmetric group meets partial transposition: new tools for studying quantum systems

Joint work with:
M. Horodecki, International Centre for Theory of Quantum Technologies, University of Gdańsk, Poland,
P. Kopszak, Institute for Theoretical Physics, University of Wrocław, Poland,
M. Mozrzymas,Institute for Theoretical Physics, University of Wrocław, Poland,
S. Strelchuk , DAMTP, Centre for Mathematical Sciences, University of Cambridge, UK.

Abstract: In this talk we give an overview of the recent developments in representation theory of the symmetric group and its deformation by partial transposition. Motivated by the famous Schur-Weyl duality we construct irreducible matrix basis for the deformed algebra allowing for reducing the complexity of analytical and numerical computations for various problems appearing not only in the quantum information theory. We show that developed tools have universal character in the sense that they allow us for effective studies of many complex systems since the considered deformed symmetries appear naturally in many aspects of physics, applied and pure mathematics. From the point of view of physics we explain how considered symmetries arise in many-body physics, quantum teleportation, theory of higher-order operations or particular aspects of gravity theories. We show by presenting particular examples how our tools lead from general complicated statement to final closed expression for quantities under interest. From the side of the applied and pure mathematics, we explain how our results meets complexity reduction in semi-definite programming and novel approach to the representation theory of the symmetric group called the Vershik-Okounkov approach.

Piotr Surówka, Wroclaw University of Science and Technology, Poland

Fractons: entanglement and renormalization

Abstract: In the quest of searching robust self-correcting quantum memories a new phase of matter was discovered, the so-called fracton phase of matter. Fracton systems exhibit certain similarities to traditional topologically ordered phases, namely topological ground state degeneracy on a torus and robustness to local perturbations. At the same time, fracton phases are quite unusual in that the topological degeneracy depends exponentially on the system size and on the presence of topologically non-trivial lattice defects, such as disclinations. In order to have a detailed understanding of these phases we need to understand their entanglement structure, renormalization properties and the corresponding universality classes. I will review the state-of-the-art in this endeavor and present several models that have been studied. Finally I will focus on the plaquette-dimer height model with fractonic behavior. This model will be studied by means of the renormalization group approach. I will present a Berezinskii-Kosterlitz-Thouless transition of the fracton type and elucidate its universality class.

Géza Tóth, University of the Basque Country, Spain

Activation of metrologically useful genuine multipartite entanglement

Abstract: We consider quantum metrology with several copies of bipartite and multipartite quantum states. We characterize the metrological usefulness by determining how much the state outperforms separable states. We identify a large class of entangled states that become maximally useful for metrology in the limit of large number of copies, even if the state is weakly entangled and not even more useful than separable states. This way we activate metrologically useful genuine multipartite entanglement. Remarkably, not only that the maximally achievable metrological usefulness is attained exponentially fast in the number of copies, but it can be achieved by the measurement of few simple correlation observables. We also make general statements about the usefulness of a single copy of pure entangled states. We surprisingly find that the multiqubit states presented in Hyllus et al. [Phys. Rev. A 82, 012337 (2010)], which are not useful, become useful if we embed the qubits locally in qutrits. We discuss the relation of our scheme to error correction, and its possible use for quantum metrology in a noisy environment.

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Emilia Witkowska, Institute of Physics, Polish Academy of Sciences, Poland

Spin squeezing in Heisenberg spin chains

Abstract: The second Quantum Revolution's main objective lies in multipartite entangled states: their production, storage, certification, and application. Such states, i.e., many-body

entangled and many-body Bell correlated states, are essential resources for quantum-based technologies and quantum-enhancement metrology. As such, a general protocol allowing the controlled generation of such states is an extensive research direction in modern quantum science. Spin squeezing represents such a protocol.
I will discuss methods to obtain spin squeezing in Heisenberg spin chains. Such spin-squeezed chains can be obtained using either bosonic or fermionic ultra-cold atoms in optical lattices. I will show how an addition of spin-flip coupling or inhomogeneous field induces effective interactions among individual spins allowing the production of spin squeezing. The schemes could be directly implemented experimentally with state-of-the-art techniques.

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Adventures with entanglement with Ryszard

Abstract: Over fifty yours ago I was a student at Ryszard's course on mathematical methods of physics.Something like 30 years ago Pawel and later Michał attended my courses, based on my earlier ones in Innsbruck.
At more or less this time Ryszard wrote his first paper on entanglement. We both struggled in an environment hostile toward this topic. Around 25 years ago the topic started to be acceptable, and later even fashionable. In the new century we co-worked in many consortial grants, however working on different scientific problems. This continues till today.

My congratulations for his outstanding achievements concerning entanglement, creation of Horodecki Family super-group, and creation of KCIK (with a little help of his friends). Well, if I have time left, I shall show you an oldish idea of creating non-linear entanglement indicators, based on a simple geometrical intuition. Effectively this is a generalization of the criteria shown by R & P & M Horodeccy in 1996.