Presented in alphabetical order

Robert Alicki, University of Gdańsk, Poland

A quantum theory of triboelectricity

Abstract: A microscopic, dynamical model of the triboelectric effect by which friction causes charge separation across the interface of two rough solid surfaces in contact is proposed. Surface electrons are treated as an open quantum system coupled to two baths corresponding to the bulk materials. The baths' relative motion can induce population inversion for certain modes of the surface electrons, which in turn can produce a tribocurrent between the bulk materials. This model is consistent with the basic phenomenology of triboelectricity and triboluminescence.

Marcus Aspelmeyer, University of Vienna, Austria

Towards witnessing system-observer entanglement of a massive object

Abstract: Continuous observation can lead to stationary entanglement between the observer and the observed object. I introduce a scenario, originally proposed by Schroedinger in a letter to Sommerfeld in 1931, in which light is used to probe position and momentum of several modes of a massive mechanical oscillator. In the regime of strong cooperativity, i.e. strong backaction, the observation leads to genuine multipartite entanglement between the observed mechanical motion and the observing radiation field. I discuss possible methods to witness this entanglement.

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

Beating the Rayleigh limit using two-photon interference

Abstract: A promising strategy to determine properties of a composite light source with resolution beating the Rayleigh limit is to measure the emitted radiation in a carefully chosen basis of spatial modes. In contrast to direct imaging, this technique takes advantage of partial spatial coherence of light detected in the image plane, but requires knowledge of other characteristics of the source, in particular its centroid. Such a problem can be viewed from the quantum metrology perspective as a multiparameter estimation task. In general, simultaneous determination of multiple parameters requires implementation of a collective measurement on many copies of the quantum system. We have demonstrated, theoretically and experimentally, that two-photon interference combined with spatially resolved detection of interfered photons provides means to determine simultaneously the centroid and the separation between two point sources avoiding the Rayleigh curse.

Artur Barasiński, University of Wrocław, Poland

Role of multipartite entanglement in quantum teleportation

Abstract: Quantum teleportation is considered as one of the major protocols in quantum information science. Although quantum teleportation is a typically bipartite process, it can be extended to multipartite quantum protocols. An important example of such extension is known as the controlled quantum teleportation which forms a backbone of quantum teleportation network, a prelude for a genuine quantum Internet. It is commonly believed that controlled teleportation (and quantum teleportation network) is a clear manifestation of multipartite entanglement and both protocols involve pre-sharing a genuine multipartite entangled resource. In my presentation, I will discuss the role of multipartite entanglement in controlled quantum teleportation. In particular, I shall present a counterintuitive result of successful controlled teleportation performed without multipartite entanglement what disproves the current misconception.

Fabio Benatti, University of Trieste, Italy

Dynamical monotones and information back-flow

Abstract: I will present a simple qubit non-Markovian dynamics whose P-divisibility does not extend to the tensor product of the dynamics with itself and discuss it from the point of view of the back-flow of information.

Fernando Brandao, Caltech, CA, USA

Applications of near-term quantum computers

Abstract: I will discuss applications of early quantum computers, which might be available in the next decade already. In particular, I will discuss how one might show quantum speed ups for solving (some particular) semidefinite programs.

Caslav Brukner, University of Vienna, Austria

The covariance of physical laws in quantum reference frames

Abstract: Every observation in physics is made with respect to a frame of reference. In practise, we use real physical systems as reference frames, and as such they obey quantum mechanical laws. I will introduce a general method to quantise reference frame transformations, which generalises the usual reference frame transformation to a "superposition of coordinate transformations". I will describe how states, measurements, and dynamical evolutions transform between different quantum reference frames. While entanglement and superposition will be shown to be frame-dependent features, the form of the dynamical physical laws (e.g. the Schrödinger equation) remain the same in all frames, which generalises the notion of covariance of physical laws to quantum reference frames. I will end with two applications of our results: a definition of the rest frame for a quantum particle in a superposition of velocities, and a resolution of an old problem of identifying the qubit for a relativistic spin particle.

Paweł Caban, University of Łódź, Poland

Nonlinear evolution and nonsignaling

Abstract: There is a common opinion that a deterministic nonlinear evolution in quantum mechanics always leads to an instantenous communication. We give an example of evolution contradicting this belief.
Co-author: Jakub Rembieliński

Ignacio Cirac, Max Planck Institute of Quantum Optics, Germany

Symmetries, entanglement, and state transformations with tensor networks

Abstract: Tensor networks offer efficient ways of describing and dealing with certain multipartite quantum states. The one-dimensional version, so-called matrix product state (MPS) appear very naturally in the context of systems in thermal equilibrium, and also describe many of the features that appear in quantum optical systems. Despite their high description power, they are relatively simple to analyze and characterize. In this talk, after describing the basic mathematical facts of translationally invariant MPS, we analyze their entanglement and symmetry properties. We give a criterion to determine when two states can be transformed into each other by SLOCC transformations, a central question in entanglement theory. We use that criterion to determine SLOCC classes, and explicitly carry out this classification for the simplest, non-trivial MPS. We also characterize all symmetries of MPS, both global and local (inhomogeneous). We illustrate our results with examples of states that are relevant in different physical contexts.

Bob Coecke, University of Oxford, UK

Diagrams in practical quantum computing

For some 15 years now, we developed an entirely diagrammatic formalism for quantum theory [1], and it was recently shown that graphical reasoning can reproduce all equational reasoning in Hilbert space [2, 3]. At the present, experiments are also being setup aimed at establishing the age at which children could effectively learn quantum theory in this manner. The next challenge was to outperform standard methods for practical quantum computational tasks, and this has recently been achieved by Kissinger et al. in the case of circuit optimisation [arXiv:1903.10477, arXiv:1904.00633], by means of the dedicated AI software PyZX [arXiv:1904.04735]. Another area concerns Quantum NLP, where the diagrammatic language, exploiting our compositional distributional model of natural language [4], gave rise to the 1st algorithm in the area [5]. QNLP is moreover a leading candidate for NISQ implementation.

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[2] E. Jeandel, S. Perdrix & R. Vilmart (2017) A Complete Axiomatisation of the ZX-Calculus for Clifford+T Quantum Mechanics. arXiv:1705.11151
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[5] W. Zeng & BC (2016) Quantum Algorithms for Compositional Natural Language Processing. arXiv:1608.01406

Marek Czachor, Gdańsk University of Technology, Poland

Time travel in a space-time ring resonator

Abstract: A ring resonator can be treated as a universal model of a looped dynamics in a Hilbert space. A particular example of a loop occurs in the problem of time travel in space-times whose topologies allow for closed timelike curves (CTCs). I generalize the ring-cavity formalism to an abstract Hilbert-space level. I show that it automatically removes logical inconsistencies associated with chronology protection, provided all input-output relations are given by unitary maps. Examples of elementary loops and a two-loop time machine illustrate the construction. The general formulas, when applied optical ring resonators, reconstruct the quantum optical results and thus agree with experiment. However, the resulting treatment of CTCs is not equivalent to the one proposed by Deutsch in his classic paper. https://arxiv.org/abs/1805.12129

Alessandro Ferraro, Queen's University Belfast, UK

Resource theory of quantum non-Gaussianity and Wigner negativity

Abstract: In this talk, I will introduce a resource theory for infinite-dimensional (continuous-variable) quantum systems, grounded on operations routinely available within current technologies. In particular, the set of free operations is convex and includes quadratic transformations and conditional coarse-grained measurements. The present theory lends itself to quantify both quantum non-Gaussianity and Wigner negativity as resources. After showing that the theory admits no maximally resourceful state, I will define a computable resource monotone --- the Wigner logarithmic negativity. The latter allows to assess the resource content of experimentally relevant states and to find optimal working points of some resource concentration protocols. This framework finds immediate application in continuous-variable quantum computation, where the ability to implement non-Gaussian operations is crucial to obtain universal control.

Mark Hillery, City University of New York/Hunter College, NY, USA

Wave particle duality relations: coherence and group asymmetry

Abstract: Wave-particle duality relations traditionally relate the amount of information one has about the path of a particle in an interferometer to the visibility of the resulting interference pattern. The path information is encoded in states of detectors. These relations have recently been extended by replacing the visibility with measures of coherence that came out of quantum resource theories. Here we extend them further by making use of the resource theory of group asymmetry. We show that there is a relation between one's ability to determine which member of a group representation has been applied to a quantum particle and which invariant subspace, corresponding to an irreducible representation, the particle is in. The wave-particle duality relation for coherence is a special case of the one for group asymmetry.

Paweł Horodecki, University of Gdańsk/ICTQT, Poland

On relativistic causality and no-signaling

Abstract: The most natural generalization of discrete quantum mechanical statistics were so called no-signaling (NS) boxes [1] that allow to study quantum mechanical correlations „from outside". However it has been pointed that causality does not forbid some faster than light influences as long as they concern correlations and not local statistics [2]. We shall report the results of a systematic analysis of consequences of such influences which leads to a concept of relativistic causal (RC) boxes that goes far beyond that of the original NS ones [3]. The RC boxes may violate of the correlation monogamy relation and their framework entails redefinition of a concept of free will. Both aspects makes natural to pose questions about quantum-based security protocols in RC framework. Independently of the above framework which considers point-like particles in space-time, we have performed the systematic analysis of the evolution of the continuous potential – quantum-based or not – statistics associated with a single particle [4]. The previous formal condition of causal evolution of such potential [5] has been proven here to be fully operational in the sense that its violation always leads to superluminal signaling. It has been accompanied by the complete study of its relation with three other axioms necessary to keep relativistic causality [4]. All the results put limits on any future theory of evolution of a single particle potential statistics or – more general – an evolution of effective potential statistics of klicks on detectors. It also provides a starting point to a possible framework of relativistic causal boxes with continuous variables which will be a subject of future study.

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Marcin Karczewski, Adam Mickiewicz University in Poznań, Poland

Extracting entanglement from the indistinguishability of particles

Abstract: The states of a system of identical particles are required to be symmetric for bosons and antisymmetric for fermions. Are these inherent correlations just a mathematical artifact or can they be treated as a resource? In the talk I will support the latter point of view by showing how operationally accessible entanglement can be extracted from the indistinguishability of particles. I will focus on a recently proposed method[1] based on tailored single-photon subtractions from multiboson states.

[1]Karczewski,Marcin, etal."Sculpting out quantum correlations with bosonic subtraction." arXivpreprintarXiv:1902.08159(2019).

Kamil Korzekwa, University of Sydney, Australia

Avoiding irreversibility: engineering resonant conversions of quantum resources

Abstract: Due to the rapid progress in experimental control of intermediate-scale quantum systems, we may soon witness the emergence of new technologies that will utilize quantum resources to overcome current technological constraints. From a theoretical perspective, it is then crucial to understand the potential and limitations of manipulating and interconverting these resources in realistic scenarios, when only finite amounts of resources are available. In our work we address this pressing issue by developing a rigorous mathematical framework that allows one to investigate resource interconversion of finite-size systems within resource theories of entanglement, coherence and thermodynamics. This allows us to quantitatively analyse the irreversibility (and thus the unavoidable loss) of the conversion process arising from finite-size effects. Although this could potentially prohibit small quantum information processors or thermal machines from achieving their full potential, we show that by carefully engineering the resource interconversion process any such losses can be greatly suppressed. More precisely, we identify and explore the intriguing property of resource resonance that ensures that certain pairs of resources can be interconverted at greatly reduced loss. By analysing its applications within quantum thermodynamics and

entanglement theory, we further explain how the resonance phenomenon can be employed to enhance the performance of intermediate-scale quantum devices and thermal machines developed in the near term. Our results are predicted by higher order expansions of the trade-off between the rate of resource interconversion and the achieved fidelity, and are verified by exact numerical optimizations of the appropriate underlying approximate majorization conditions.

Barbara Kraus, University of Innsbruck, Austria

From Compressible to universal Quantum computation

Abstract: Matchgate (MG) circuits can be compressed into an exponentially smaller universal quantum computer. However, the usage of an additional resource, the so-called magic states, elevates such a computation to universal quantum computation, while maintaining the same gate set. We show that every pure fermionic state which is non-Gaussian, i.e. which cannot be generated by MGs from a computational basis state, is a magic state for MG computations. This result has significance for prospective quantum computing implementation in view of the fact that MG circuit evolutions coincide with the quantum physical evolution of non-interacting fermions.

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Jan-Åke Larsson, Linköping University, Sweden

Quantum computation and the additional degrees of freedom in a physical system

Abstract: The speed-up of Quantum Computers is the current drive of an entire scientific field with several large research programmes both in industry and academia world-wide. Many of these programmes are intended to build hardware for quantum computers. A related important goal is to understand the reason for quantum computational speed-up; to understand what resources are provided by the quantum system used in quantum computation. Some candidates for such resources include superposition and interference, entanglement, nonlocality, contextuality, and the continuity of state-space. The standard approach to these issues is to restrict quantum mechanics and characterize the resources needed to restore the advantage. Our approach is dual to that, instead extending a classical information processing systems with additional properties in the form of additional degrees of freedom, normally only present in quantum-mechanical systems. In this talk, we will have a look at these additional degrees of freedom and how quantum computers make use of them to achieve the so-called quantum speed up. We will also discuss whether the additional degrees of freedom can be viewed as a ”side channel,” a term often seen in cryptology, and whether quantum parallelism rather should be viewed as computation performed in some additional degree of freedom.

Arul Lakshminarayan, Indian institute of Technology Madras, India

Entangling power of time-evolution operators: from bipartite to many-body systems

Abstract: The entangling power of the time-evolution operator provides a state independent measure of thermalization. We show how in a bipartite setting, sufficiently local random operators play a crucial role in the exponential relaxation of the entangling power to the global Haar average, however small the nonlocality of the interaction maybe. We apply these to Floquet spin chain models and show how in some cases of maximally chaotic systems the entangling power can be analytically well described by such a thermalization.

Felix Leditzky, JILA, University of Colorado, CO, USA

Quantum codes from neural networks

Abstract: We report on the usefulness of using neural networks as a variational state ansatz for many-body quantum systems in the context of quantum information-processing tasks. In the neural network state ansatz, the complex amplitude function of a quantum state is computed by a neural network. The

resulting multipartite entanglement structure captured by this ansatz has proven rich enough to describe the ground states and unitary dynamics of various physical systems of interest.
In the present paper, we supply further evidence for the usefulness of neural network states to describe multipartite entanglement. We demonstrate that neural network states are capable of efficiently representing quantum codes for quantum information transmission and quantum error correction. In particular, we show that a) neural network states yield quantum codes with a high coherent information for two important quantum channels, the depolarizing channel and the dephrasure channel; b) neural network states can be used to represent absolutely maximally entangled states, a special type of quantum error correction codes. In both cases, the neural network state ansatz provides an efficient and versatile means as variational parametrization of these states.
Joint work with Johannes Bausch, based on https://arxiv.org/abs/1806.08781

Piotr Mironowicz, University of Gdańsk, Poland

Symmetries, designs and semidefinite programming

Abstract: "Symmetries are ubiquitous in physical sciences. Whenever one recognizes some new elegant pattern of properties that are invariant with respect to some interesting operations, it usually means a great progress in understanding of the problem. Moreover symmetries are very aesthetically pleasing. In this talk I present benefits from exploiting symmetries in optimization techniques for analysis of themes like quantum designs and quantum games, and surprising connections between them.

Michał Oszmaniec, University of Gdańsk, Poland

Relative power of projective and generalized measurements in quantum information theory

Abstract: Standard projective measurements represent a subset of all possible measurements in quantum physics. In fact, general measurements (POVMs) are relevant for many applications in quantum information theory. However, physical implementation of projective measurements is often much easier as it does not require any control over the additional degrees of freedom.
In this talk I will address the question of what POVMs can be simulated via projective measurements and suitable classical resources: randomization, classical post-processing and postselection. I will first present the general conditions for projective simulability for qubit and qutrit system. Then, I will focus on the scenario in which one is allowed to use postselection in the simulation procedure. There, a more complete picture can be obtained. Specifically, it turns out that in any d dimensional system all generalised measurements can be implemented with the help of projective measurements, randomisation and postselection. However, the success probability of such implementation equals in the worst case 1/d. Interestingly, this gap of the power between projective measurements and POVMs can be captured by many instances of the task unambiguous state discrimination.

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arXiv preprint arXiv:1807.08449 (joint work with Z. Puchała and F. Maciejewski)

Martin Plenio, Ulm University, Germany

Quantifying operations with an application to coherence

Abstract: We build resource theories on the level of operations, exploiting the concept of resource destroying maps. We discuss the two basic ingredients of these resource theories, the free operations and the free super-operations, which are sequential and parallel concatenations with free operations. This leads to defining properties of functionals that are well suited to quantify the resources of operations. We introduce these concepts at the example of coherence. In particular, we present two measures quantifying the ability of an operation to detect, i.e. to use, coherence, one of them with an operational interpretation, and provide
methods to evaluate them. In a recent experiment we have applied these methods to the characterization of a quantum detector that can be continuously interpolated from purely classical to fully quantum detector.

Jitendra Prakash, University of Waterloo, Canada

Non-closure of the set of quantum correlations

Abstract: Consider a bipartite system with two observers, Alice and Bob, who are performing measurements in their labs. There are two models of quantum mechanics which describe the joint lab of Alice and Bob --- the quantum model and the commuting quantum model. Tsirelson's original question asked whether these two models were essentially the same. We shall show that these two models are different for bipartite systems with five quantum experiments and binary outcomes for each experiment, by using the notion of correlation functions of graphs. (This is a joint work with Ken Dykema and Vern Paulsen.)

Ravishankar Ramanathan, University of Hong Kong, China

Optimal randomness amplification schemes from Hardy paradoxes

Abstract: Randomness amplification, the task of obtaining secure random bits from weak sources of randomness, is a fundamental cryptographic task. Device-independent protocols for this task secure against no-signaling adversaries have so far relied on specific proofs of non-locality termed pseudo-telepathy games, and have remained out of reach of experimental implementation. In this talk, we will relate the problem of finding experimentally friendly randomness amplification schemes to the vast field of Hardy paradoxes and, as a consequence, present a device-independent randomness amplification protocol secure against no-signaling adversaries in the simplest experimentally feasible Bell scenario of two parties with two binary inputs. Furthermore, we will show that just as proofs of the Kochen-Specker theorem give rise to pseudo-telepathy games, substructures within these proofs termed 01-gadgets give rise to Hardy paradoxes and we will use them to construct Hardy paradoxes with the non-zero probability taking any value in (0,l]. Finally, we will see how to design optimal randomness amplification schemes based on Hardy paradoxes from arbitrary entangled two-qubit states.

Alex Retzker, Hebrew University of Jerusalem, Israel

Overcoming resolution limits with quantum sensing

Abstract: In this talk I will present a formulation a general criterion for superresolution in quantum problems. Inspired by this, we develop new spectral resolution methods with quantum sensing. In particular, we show that quantum detectors can resolve two frequencies from incoherent segments of the signal, irrespective of their separation, in contrast to what is known about classical detection schemes. The main idea behind these methods is to overcome the vanishing distinguishability in resolution problems by making the projection noise vanish as well.

Giulia Rubino, University of Vienna, Austria

Experimental entanglement of temporal orders

Abstract: The study of causal relations, a cornerstone of physics, has recently been applied to the quantum realm, leading to the discovery that not all quantum processes have a definite causal structure. While such processes have previously been observed, these observations opened a 'loophole' whereby the observed process could be explained by an underlying theory with a definite causal structure. Here, we present the first experimental demonstration of entangled temporal orders, resulting in a process that is incompatible with a large class of generalized probabilistic theories which are local and have a definite temporal order. We experimentally invalidate this class by violating a Bell inequality. We thus conclude that nature is incompatible with the class of theories requiring a local definite temporal order.

Maciej Stankiewicz, University of Gdańsk, Poland

Semi-device independent quantum money

Abstract: The seminal idea of quantum money not forgeable due to laws of Quantum Mechanics proposed by Stephen Wiesner, has laid foundations for the Quantum Information Theory in early '70s. Recently, several other schemes for quantum currencies have been proposed, all however relying on the assumption that the mint does not cooperate with the counterfeiter. Drawing inspirations from the semi-device independent quantum key distribution protocol, we introduce the first scheme of quantum money with this assumption partially relaxed, along with the proof of its unforgeability. Significance of this protocol is supported by an impossibility result, which we prove, stating that there is no both fully device independent and secure money scheme. Finally, we formulate a quantum analogue of the Oresme-Copernicus-Gresham's law of economy.

Nicolas Treps, Kastler Brossel Laboratory, France

Tailored non-Gaussian multimode optical states

Abstract: Quantum technologies depend on information encoding into a physical system that can be coherently generated, manipulated and measured. Light provides a suitable platform, but the most easily generated quantum optical states- the Gaussian states- are simply described and cannot be used for nontrivial quantum computation.

We will explore here the conditional preparation of non-Gaussian states of light through appropriate non-Gaussian measurements on an ancillary system, and the control and characterization of these states. The objective is to benefit from the scalability and versatility of Gaussian states generation, along with the computational advantage offered by non-Gaussian states.

We will demonstrate experimentally such multimode states generated from ultrafast optical pulses (optical frequency combs) and parametric down conversion[1]. Mode dependent photon subtraction is implemented through sum-frequency generation[2], and characterization is performed through frequency resolved homodyne detection.

We will then study, both theoretically and experimentally, the influence of a non Gaussian ingredient on a Gaussian graph state. In particular, we will demonstrate propagation properties of non-gaussianity within the graph, and its implications on the nature of entanglement[3,4].

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Jakub Zakrzewski, Jagiellonian University in Kraków, Poland

Recent advances in many-body localization

Abstract: I will discuss our recent results on many-body localization covering the application of quantum chaotic measures (energy level gap, curvature, fidelity susceptability distributions) for ``standard'' MBL models as well as the possibility of observing MBL in long-range interacting systems. In the latter case cold atoms in a dispersive-mode cavity will be discussed - such a system may realize all-to-all interactions of controlable strength.

Mario Ziman, Slovak Academy of Sciences, Slovakia

Quantum learning of quantum gates

Abstract: The question of a quantum memory storage of quantum dynamics will be investigated. In particular, I will design an optimal protocol for N -> 1 probabilistic storage-and-retrieval of unitary channels on d-dimensional quantum systems. If we may access the unknown unitary gate only N-times, the optimal success probability of perfect retrieval of its single use is N/(N−1+d^2). The derived size of the memory system exponentially improves the known upper bound on the size of the program register needed for probabilistic programmable quantum processors. These results are closely related to probabilistic perfect alignment of reference frames and probabilistic port-based teleportation.

Marek Żukowski, University of Gdańsk/ICTQT, Poland

Entanglement conditions for quantum optical fields

Abstract: We show that any multi-qudit entanglement witness leads to a non-separability indicator for quantum optical fields, which involves intensity correlation and is useful for states of undefined photon numbers. We get, e.g., necessary and sufficient conditions for intensity or intensity-rates correlations to reveal polarization entanglement. We also derive separability conditions for experiments involving multiport interferometers, now feasible with integrated optics. We show advantages of using intensity rates rather than intensities, e.g. a mapping of standard Bell inequalities to ones for optical fields. All that may find applications also in studies of non-classicality of ``macroscopic" systems of undefined or uncontrollable number of ``particles".

Karol Życzkowski, Jagiellonian University in Kraków, Poland

Five isoentangled mutually unbiased bases and mixed-states t-designs

Abstract: An Euclidean design is a finite set of points in R^n with certain approximation properties. This concept generalizes the notion of a spherical t–design *κ*, which consists of points belonging to a sphereS_n−1 selected in such a way that the average values of the first *t* moments averaged over the set *κ* coincide with the moments obtained by integrating over the sphere. Taking the corresponding set of normalized pure quantum states |*ψj* one arrives at a projective *t*–design – a construction useful in quantum theory.

We introduce a related notion of a mixed state *t*–design, which consist of a finite number of density matrices of a fixed dimension *n*, such that the mean value of any polynomial function *f* of their spectra of order not exceeding *t* agrees with the integral of *f* over the entire set Ω_n of mixed quantum states of size *n* with respect to the flat, Hilbert-Schmidt measure. We establish necessary and sufficient conditions for a given set of density matrices to form a *t*-design and demonstrate that any projective *t*–design on a composed Hilbert space $H_n \otimes H_n$ yields by partial trace a mixed states *t*–design in the set Ω_n.

In particular, the standard symmetric informationally complete measurement in H_4 leads to a configuration of 8 density matrices forming a regular cube inside the Bloch ball Ω_2 which forms a 2–design. Another solution consisting of 6 points on the Bloch sphere and a point at the center of the ball with quadruple weight is obtained by reduction of 20 bipartite pure states which form the known set of 5 mutually unbiased bases in H_4. Furthermore, we construct a set of five isoentangled *MUBs* in H_4, consisting of states with the same degree of entanglement. Performing partial trace on any of both subsystems leads to 20 one–qubit mixed states which form a regular dodecahedron inside the Bloch ball – a 3–design.

Co-authors: J. Czartowski (Cracow), D. Goyeneche (Antofagasta) and M.Grassl (Erlangen).