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BOOK OF ABSTRACTS

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Participants and Abstracts

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Self-testing quantum systems of arbitrary local dimension

Imagine that we are given a quantum device whose internal working is unknown to us and our task is to verify whether this device operates on the promised quantum state and performs the promised quantum operations on it, without opening this device, and thus destroying it. A possible way to tackle this problem is self-testing [1], which is a device-independent certification method, allowing to make statements about quantum devices only from the statistical data these devices generate. In recent years there has been a wave of results presenting self-testing protocols for various composite quantum systems and measurements. In particular, in [2], exploiting the results of [3], self-testing method for any pure entangled bipartite state was proposed. This method is, however, based on violation of many two-outcome Bell inequalities such as the CHSH [4] or the tilted CHSH [5] ones, and it remains a highly nontrivial problem to propose certification scheme of d-dimensional quantum states based on violation of a single d-outcome Bell inequality that uses genuinely d-outcome measurements.

Here we propose a self-testing protocol for the maximally entangled state of arbitrary local dimension and the well-known CGLMP measurements [6], which does not rely in any way on self-testing results for qubit states and exploits the minimal number of measurements on both sites, that is, two. Our result exploits a genuinely d-outcome Bell inequality proposed recently in [7] as a generalization of the well-known CHSH Bell inequality to scenarios involving any number of measurements and outcomes. To this aim, we exploit the sum of squares decomposition of this Bell inequality and show that up to local isometries the state and measurements maximally violating this Bell inequality is the maximally entangled state of two qudits and the CGLMP measurements [6]. We also show that the outcomes of d-outcome measurements made by Alice and Bob are perfectly random and thus our results give rise to a device-independent scheme for randomness expansion from quantum correlations.

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Scalable Bell inequalities for graph states and robust self-testing (poster)

Bell inequalities constitute a key tool in quantum information theory: they not only allow one to reveal nonlocality in composite quantum systems, but, more importantly, they can be used to certify relevant properties thereof. We provide a very simple and intuitive construction of Bell inequalities that are maximally violated by the multiqubit graph states and can be used for their robust self-testing. The main advantage of our inequalities over previous constructions for these states lies in the fact that the number of correlations they contain scales only linearly with the number of observers, which presents a significant reduction of the experimental effort needed to violate them. We also discuss possible generalizations of our approach.

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Observations on maximally entangled mixed states in higher dimensional systems

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Quantum entanglement among coupled systems represents a powerful resource for information related purposes and suitable criteria to quantify it are of primary importance [1]. Concerning bipartite states, a relevant issue is given by the relation between entanglement and purity [2]. In particular, for fixed global purity, one may ask which state displays maximal entanglement. The concept of maximally entangled mixed states (MEMS) was introduced by Ishizaka and Hiroshima for two-qubits [3]. Optimal two-qubit states with respect to global spectrum were found by Verstraete et al. [4]. However, the characterization of MEMS in higher dimensions is still an open problem. In this work, starting from the two-qutrit case, we provide numerical evidence that MEMS states are found within the class of circulant states, introduced in [6], and identify suitable candidates. We also generalize the two-qutrit candidate states to arbitrary bipartite dimensions.

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Operational relevance of resource theory of quantum measurements

For any resource theory it is essential to identify tasks for which resource objects offer advantage over free objects. We show that this identification can always be accomplished for resource theories of quantum measurements in which free objects form a convex subset of measurements on a given Hilbert space. To this aim we prove that every resource measurement offers advantage for some quantum state discrimination task. Moreover, we give an operational interpretation of robustness, which quantifies the minimal amount of noise that must be added to a measurement to make it free. Specifically, we show that this geometric quantity is related to the maximal relative advantage that a resource measurement offers in a class of minimal-error state discrimination problems. Finally, we apply our results to two classes of free measurements: incoherent measurements (measurements that are diagonal in the fixed basis) and separable measurements (measurements whose effects are separable operators). For both of these scenarios we find, in the asymptotic setting in which the dimension or the number of particles increase to infinity, the maximal relative advantage that resource measurements offer for state discrimination tasks.

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Data-Driven Inference and Observationally Complete Devices

Quantum theory stipulates that any physical system admits a mathematical description in terms of the Hilbert-space formalism, but it does not give a general rule to construct such a description, which traditionally relies on empirical assumptions on the internal behaviour of the system and on how it has been assembled. However, if the system is given as a black box, such assumptions are untenable, and quantum theory alone is insufficient to provide a description.

In this work we fill this gap by introducing a machine-learning inference protocol, that we name "data-driven inference", based on a principle of statistical minimality, according to which the "right" mathematical description to be inferred should be the least committal one explaining the data produced by the black box. Our protocol naturally leads to the notion of "observationally complete devices", a concept that exhibits deep connections with other notions quantum tomography, in particular, symmetric informationally complete structures and, more generally, 2-designs.

This talk presents the developments achieved so far in this direction, including some explicit inference examples and experimental implementations comparing our data-driven inference with conventional tomography.

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Generic Contractive States and Quantum Monitoring of Free Masses and Oscillators (poster)

Co-authors: P. Bhasin, S. M. Roy

Monitoring photon quadratures and free masses are useful tools to detect small disturbances such as gravitational waves. Here we report a large class of states for photon quadratures and free masses potentially useful for this purpose: (1) "generic coherent states" (GCS) of photons, whose width is independent of time and uncertainty product is arbitrarily large (a generalization of the minimum uncertainty Schrödinger coherent states [1]) and (2) "squeezed generic contractive states" (SGCS) for photons and free masses (a generalization of the Yuen states [2]) whose width decreases with time, uncertainty product is arbitrarily large, and the covariance squared has an arbitrary value within the allowed range.

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The arXiv link to the article is: `https://arxiv.org/abs/1903.11845`

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Quantum trajectories and a priori evolution for two-level atom interacting with a single-photon wavepacket (poster)

We formulate a problem of description of a reduced evolution of a two-level system interacting with a single-photon wavepacket using quantum filtering theory. Thus we consider a set of stochastic master equations describing the evolution of the two-level system conditioned by results of continuous in time measurement of photons in the output field. The evolution of the system is not given in this case by one equation but by the set of four coupled equations, so the evolution is non-Markovian. We present the formulas for the quantum trajectories and describe their physical interpretation. Making use of the formulas for the conditional operators we write down the analytical solution to the set of master equations and present POVM associated with the considered observable.

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Genuinely entangled subspaces: constructions and properties

Unextendible product bases (UPBs) are interesting mathematical objects arising in composite Hilbert spaces that have found various applications in quantum information theory, for instance in a construction of bound entangled states or Bell inequalities without quantum violation. They are closely related to another important notion, completely entangled subspaces (CESs), which are those that do not contain any fully separable pure state. Among CESs one finds a class of subspaces in which all vectors are not only entangled but genuinely entangled. Here we explore the connection between UPBs and such genuinely entangled subspaces (GESs) and provide classes of nonorthogonal UPBs that lead to GESs for any number of parties and local dimensions. We then show how these subspaces can be immediately utilised for a simple general construction of genuinely entangled states in any such multipartite scenario. Futher, we present methods for computing the entanglement of the constructed GESs.

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Ensembles of random generators of Markovian quantum evolution: spectral properties and universality

Co-authors: W. Tarnowski, D. Chruściński, and K. Życzkowski

Where to look for footprints of dissipative chaos in open quantum systems? Intuitively, it is apparent that, similar to the case of Hamiltonian quantum chaos, we should search for these footprints in the spectra of generators of evolution — but now dissipative. Following this line further, we immediately arrive at the problem of defining an ensemble of random generators of Markovian completely-positive quantum evolution. I will introduce such an ensemble and then demonstrate scale-invariance and universality of the spectral properties. Finally, I will touch upon ensembles of density matrices corresponding to the asymptotic states of random Lindbladians.

My talk is based on our recent work `arXiv:1811.12282 [quant-ph]` *"Universal spectra of random Lindblad operators"*. To understand typical dynamics of an open quantum system in continuous time, we introduce an ensemble of random Lindblad operators, which generate Markov evolution in the space of density matrices of a fixed size. Universal spectral features of such operators, including the shape of the spectrum in the complex plane, are explained with a non-hermitian random matrix model.

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Mathematical Models of Markovian Dephasing

Co-authors: J. E. Gough, H. I. Nurdin and L. Viola

We develop a notion of dephasing under the action of a quantum Markov semigroup in terms of convergence of operators to a block-diagonal form determined by irreducible invariant subspaces. If the latter are all one-dimensional, we say the dephasing is maximal. We study characterization of a maximally dephasing evolution in terms of unitary dilations with only classical noise. In particular, we introduce an intrinsic quantity constructed from the generator which quantifies the degree of obstruction to having a classical diffusive noise model.

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Complete positivity and positivity of quantum dynamical maps under time deformations

We subject convolutionless and convolution master equations to time deformations and explore properties of the modified maps. It is revealed in Ref. [1] that even a uniform time deformation of timescale may result in a non-legitimate dynamical map (violating complete positivity). In Ref. [2], we have related this observation with the divisibility property of the original map and obtained the following main result: the original convolutionless master equation describes a completely positive divisible dynamics if and only if the deformed map is completely positive under any time deformation. As far as the convolution master equations are concerned, we have found a necessary condition for positive divisibility of a Hermitian commutative dynamical map in terms of timescale deformations.

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Product Formulae and Quantum Control (poster)

Product Formulae are used in physics to adress the problem of describing the evolution of a quantum system undergoing a dynamics generated by two non-commuting operators. The importance of such formulae dates back to Feynman's path integral approach and are useful nowadays in the context of quantum control. I will discuss the role of such formulae in establishing a bridge between different control techniques, and I will introduce a generalization of the classical Trotter product formula.

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Relativistic causality and no-signaling

Some time ago it has been pointed out [1] 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] and have highly nonstandard properties. 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].

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Schur-Weyl duality in one-dimensional Hubbard model

I will present the application of the Schur-Weyl duality in one-dimensional Hubbard model in the case of half-filled system of any number of atoms. I replaced the actions of the dual symmetric and unitary groups in the whole 4^N-dimensional Hilbert space by the actions of the dual groups in the spin and pseudo-spin spaces. The calculations significantly reduce the dimension of the eigenproblem of one-dimensional Hubbard model.

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Symmetry adapted basis in coupled spin systems (poster)

We propose an alternative approach for the construction of the symmetry adapted basis in coupled spin systems. Our method is based on Gelfand-Tsetlin patterns, graph theory and a technique called pattern calculus. Representation of spin system in such basis results in a change of degrees of freedom, uncovering the information hidden in non-local degrees of freedom. This information can be used, *inter alia*, to study the structure of entangled states, their classification, and may be useful for the construction of quantum algorithms.

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On some Computational Method for Explicit Form Decomposition of Master Equations

Unlike the analysis of closed quantum systems, the analysis of master equations for open quantum systems may become difficult. For this problem, the reduction of systems can help us study our systems in detail. In this presentation, we will show a computational procedure for the explicit forms of the reduced open quantum systems.

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Quantum frequency estimation with local decoherence of arbitrary type

Co-authors: J. F. Haase, A. Smirne, R. Demkowicz-Dobrzański, S. Huelga

One of the fundamental schemes in quantum metrology is the task of quantum frequency estimation. It considers N quantum probes (atoms) that are employed to most accurately sense an unknown parameter linearly affecting their internal Hamiltonian (e.g., laser detuning, strength of an external magnetic/electric field) or, in atomic spectroscopy, the energy-level spacing itself. As the parameter is then frequency-like, in order to deal with asymptotic statistics the total experimental time must be assumed to be long enough, so that sufficient protocol repetitions can always be assured. As a result, the "central limit theorem" can be applied, which in the classical setting imposes then the sensitivity (mean-squared error) to decrease as $1/N$ with the probe number — to follow the so-called Standard Quantum Limit (SQL). In stark contrast, if quantum entanglement between probes is allowed, a quadratic enhancement of sensitivity can be achieved with error decreasing as $1/N^2$ — following the ultimate Heisenberg Limit. Such conclusions, however, change dramatically if one explicitly accounts for the impact of local decoherence that independently disturbs each probe and gradually erases its information about the parameter along the duration of the experiment.

In this work, we present a general framework that allows one to determine ultimate bounds on attainable asymptotic sensitivity in frequency estimation protocols, given a generic master equation describing evolution of each individual probe. Importantly, our method applies to arbitrary local dissipative dynamics, while accounting for, e.g., complex geometry of the noise, its short-time inhomogeneous behaviour—the "Zeno regime" — or non-Markovian features. As a result, we can directly pinpoint decoherence subclasses for which asymptotic $1/N$-scaling of sensitivity is inevitable, with only a constant quantum enhancement being available. On the other hand, our method lets us formulate explicit requirements for noise models to allow for sensitivities asymptotically breaching the SQL-like behaviour.

Focussing on qubit evolutions, with help of our framework we unify proofs of ultimate asymptotic sensitivity for important noise-types previously considered, as well as provide novel derivations for ones only speculated before. In particular, by considering semigroup dynamics, we firstly demonstrate the $1/N$-scaling being always asymptotically inevitable with the only exception of perpendicular dephasing noise, for which we explicitly derive the exact asymptotic $1/N^{5/3}$ behaviour of sensitivity. Secondly, we prove that it is the "Zeno regime" that generally allows for $1/N^{3/2}$-scaling beyond SQL, which, however, can be further enhanced to $1/N^{7/4}$ when simultaneously benefiting from perfect perpendicular geometry. Finally, we demonstrate that non-Markovianity should not be generally associated with the super-classical asymptotic behaviour in frequency estimation. We achieve this by considering evolutions for which all the above observations consistently apply, even though the dynamics leads to indivisible (non-Markovian) probe evolutions at arbitrary time-scales.

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(Post)Quantum Bregman divergences, nonlinear resource theories, and renormalisation

I will present a quantum (and generalised probabilistic) generalisation of Bregman relative entropies. Among their key properties is the generalised pythagorean theorem, which establishes a geometric decomposition of a nonlinear signal into a sum of nonlinear data and nonlinear error (with respect to constrained relative entropy maximiser). With their help, I will introduce a rich family of nonlinear transformations of states with well-defined monotonicity properties, giving rise to a class of nonlinear resource theories. In essence, one can see these theories as a nonlinear convex-theoretic analogue of the positive/CP linear paradigm. Furthermore, each quantum Bregman divergence induces a pair of linear connections over strictly positive states, which turns into a dually flat geometry under some additional conditions. In finite dimensions, this gives rise to a setting of information-theoretic renormalisation of state spaces in the sense of Jaynes–Mitchell–Favretti. All results (except the last one) are obtained in the general infinite dimensional Banach space based setting.

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Fidelity susceptibility in Gaussian Random Ensembles

The fidelity susceptibility measures sensitivity of eigenstates to a change of an external parameter. It has been fruitfully used to pin down quantum phase transitions when applied to ground states (with extensions to thermal states). Here we propose to use the fidelity susceptibility as a useful dimensionless measure for complex quantum systems. We find analytically the fidelity susceptibility distributions for Gaussian orthogonal and unitary universality classes for arbitrary system size. The results are verified by a comparison with numerical data.

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The Friedrichs-Lee Hamiltonian and its singular coupling limit

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We show that the single-excitation interaction of a family of n two-level systems (TLS) with a structured boson field can be effectively modeled by a singular finite-rank perturbation (Friedrichs-Lee model) of a Hamiltonian with n eigenvalues; the resulting perturbation preserves the absolutely continuous spectrum but drastically modifies the singular spectrum. Some peculiar examples are presented and discussed.

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When is a Szilárd demon really quantum?

The classical Szilárd engine has been studied in the quantum context in various models. But when is such a quantum description really quantum in the sense that it cannot be described in terms of classical statistics? Here we investigate how to check whether the demon is really quantum, which leads to a quantum steering task.

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Three-diagonal blocks of two-magnon Hamiltonians with specified wavenumbers for Heisenberg rings (poster)

Co-authors: J. Milewski

We demonstrate the method of creating blocks of Hamiltonian matrices for Heisenberg rings with N nodes and $r = 2$ overturned spins, depending on total quasimomentum k. Initial problem of dimension $\binom{N}{2}$ reduces, approximately, N-tuply, depending on N and k numbers. We consider block Hamiltonians using a particularal basis, called wavelet basis. In such a basis, these blocks take three-diagonal form.

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Quantum mutual information based on quantum conditional probability

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In classical information theory, Shannon mutual information has three types of interpretation at the same time: (I) the common information (or correlation), (II) the information gain by observation, (III) the transmitted information via a channel. Such interpretation can be done on the basis of Bayes's formula of probabilities.

In quantum theory, however, the notion of conditional probability is not uniquely defined and hence given a quantum channel one can construct different quantum joint states such that its marginal states are compatible with the input and output states of the channel. Introducing a natural quantum analogue of conditional probability we analyze the relations between different notions of mutual information. They do correspond to different conditional probability and different compound states and allow to introduce an analogue of the quantum discord for the channel. Such argument also gives us a good understanding for the relations among three types of interpretation (I), (II) and (III) of quantum mutual information.

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Membership Problem in Quantum Computing

The Membership problem for a Lie algebra $\mathfrak{g}$ is deciding if an element of $\mathfrak{g}$ is generated by a finite set of elements of $\mathfrak{g}$. Instead of looking at the subalgebra of $\mathfrak{g}$ generated by the set, I give a solution to this problem by using the adjoint representation of $\mathfrak{g}$ and the notion of centralizer.

This is a work in progress and is done in collaboration with Dr. hab. Adam Sawicki: our ultimate aim is to solve the analogous problem for Lie groups in quantum computing.

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Some mathematical aspects of port-based teleportation (poster)

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The port-based teleportation (PBT) protocol introduced in 2008 by Ishizaka and Hiroshima is a variant of quantum teleportation scheme which transmits an unknown state to the receiver without requiring any corrections on his/her side. It is the opposite of the standard setting presented by Bennett et al. where a correction in the form of rotation has to be applied to the obtained state by the receiver. Regardless of the version of the PBT scheme, the absence of the necessary correction allows for many important applications, such as design of efficient protocols for instantaneous implementation of measurements and computation, communication complexity, some implications on the limitations on quantum channel discrimination, and quantum message compression.

In our work, we discuss a connection of all variants of PBT with the algebra of partially transposed permutation operators recently studied by us. In particular, we focus on the key innovation which is the theory of partially irreducible representations – a new tool for an efficient computation of products of operators which possess partial symmetries. These tools allow us to present the full analysis of the performance of PBT schemes, like entanglement fidelity or probability of the protocol success, in a purely group-theoretical manner. Additionally, we present the first result on PBT simulation by projective measurements. We prove a negative result showing that in the class containing optimal POVMs we cannot construct von Neumann measurements.

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Nonuniform losses and classical simulation in linear optics

Multi-photon experiments in large linear-optical networks are an attractive platform for demonstrating quantum computational supremacy via the paradigm of Boson Sampling. Unfortunately, large linear-optical networks typically suffer from photonic losses which can undermine the computational hardness of the process. Here we present a comprehensive study of the impact of non-uniform, i.e. path-dependent, losses on the computational complexity of linear-optical processes. Our main result is that, if we assume each beam-splitter in a network induces some loss probability, non-uniform network designs cannot circumvent efficient classical simulation of the corresponding optical processes. This solves an open problem from previous work that assumed losses occurred uniformly.

To obtain our main result we develop new technical tools that can be of independent interest for quantum optics and computer science community. First, we show that, for any network of lossy beam-splitters, it is possible to extract a layer of non-uniform losses that depends on the network geometry. Specifically we prove that, for every input mode of the network it is possible to "pull out" from the network s_i layers of losses, where s_i is the length of the shortest path connecting the i'th input to any output. The second technical result is an extension of a recent algorithm due to Clifford and Clifford for (weak) classical simulation of Boson Sampling. The original algorithm assumes that the input state is a collision-free state of n photons. We extend this algorithm to any n-photon input Fock states (i.e. to any input configuration of photons in the input modes). Moreover, we identify two types of input configurations that yield classically simulable instances of Boson Sampling: (A) when n input photons occupy a constant number of input modes; (B) when all but $O(\log n)$ photons are concentrated on a single input mode, while additional $O(\log n)$ modes contain one photon each.

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Distinguishability of quantum measurements

In this work we study the problem of discrimination of von Neumann measurements, which we associate with measure-and-prepare channels. There are two possible approaches to this problem. The first one is simple and does not utilise entanglement. We focus only on the discrimination of classical probability distributions, which are outputs of the channels. We find necessary and sufficient criterion for perfect discrimination in this case. A more advanced approach requires the usage of entanglement. We quantify the distance between two measurements in terms of the diamond norm. We provide an exact expression for the optimal probability of correct distinction and relate it to the discrimination of unitary channels. Finally, we consider unambiguous discrimination schemes.

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Stochastic unravellings of master equations: Markovian, non-Markovian — and in-between

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Monte Carlo methods with quantum jumps are widely used to unravel and solve open system master equations [1]. For Lindblad-Gorini-Kossakowski-Sudarshan master equation and semigroup dynamics, Monte Carlo wavefunction (MCWF) method was developed almost 30 years ago [2]. It was generalized to open system dynamics with memory effects with non-Markovian quantum jump (NMQJ) method in 2008 [3]. However, there exists an in-between region between the two — also when describing memory effects — when master equations contain negative decay rates but the corresponding dynamical maps are P-divisible. We have developed a framework unifying all the three regimes and also discuss what this implies for the existence — or non-existence — of the measurement scheme interpretations for the unravellings of open system master equations [4].

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Bound states in the continuum for an array of quantum emitters (poster)

We study the bound states in the continuum for a system of n two-level quantum emitters, coupled with a one-dimensional photon field, when a single excitation is shared among the different components of the system. The emitters are equally spaced at fixed positions. We first consider the approximation of distant emitters, and exhibit degenerate eigenspaces of bound states corresponding to resonant discrete values of the energy. We then consider the full form of the eigenvalue equation, in which the effects of the finite spacing and the field dispersion relation become relevant, yielding significant nonperturbative effects that can lift some degeneracies. We explicitly solve the cases $n = 3$ and $n = 4$ emitters.

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Necessary and sufficient condition of separability for D-symmetric diagonal states

For multipartite states, we consider a notion of D symmetry. For a system of N qubits, it coincides with the usual permutational symmetry. In the case of N qudits ($d \geq 3$), the D symmetry is stronger than the permutational one. For the space of all D-symmetric vectors in $(\mathbb{C}_d)^{\otimes N}$, we define a basis composed of vectors which are analogues of Dicke states. The aim of this paper is to discuss the problem of separability of D-symmetric states which are diagonal in this basis. We show that if N is even and $d \geq 2$ is arbitrary then a positive partial transposition property is a necessary and sufficient condition of separability for D-invariant diagonal states. In this way, we generalize results obtained by Yu [Phys. Rev. A **94**, 060101(R)(2016)] and Wolfe and Yelin [Phys. Rev. Lett. **112**, 140402 (2014)]. Our strategy is to use some classical mathematical results on the moment problem.

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Mathematics of efficient quantum compilers

A quantum compiler is a part of a quantum computer and its core consists of quantum gates. Any operation performed by a quantum computer is implemented using gates and an effective compiler uses as few gates as possible to perform the given unitary operation. In my talk I will discuss mathematical methods used in designing efficient quantum compilers and outline some open problems in this area.

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Is ESIC stronger than Realignment criterion?

Abstract: ESIC is a criterion for the separability of a bipartite system based on SIC-POVMs. We compare this criterion with the well-known realignment criterion (CCNR) by the associated entaglement witnesses (EWs). We found a new approach to compare the relative families of EWs claiming that ESIC is stronger than CCNR, in the sense that ESIC detects any entaglement state detected by CCNR. We have numerical outcomes which support our conjecture and an analitycal proof which works only in some special case.

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On the geometry of one-mode Gaussian channels

Co-authors: W. Strunz, K. Luoma

Using the Choi-Jamiołkowski isomorphism, we establish the duality between the two-mode Gaussian states and one-mode Gaussian channels. We show that there exists a correspondence between the entanglement breaking Gaussian channels and separable Gaussian states, as well as the incompatibility breaking Gaussian channels and steerable Gaussian states. We derive the volume element of the one-mode Gaussian channels, which helps us to find the relative volumes for the entanglement and incompatibility breaking channels.

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Tailoring properties of atomic systems using photonic environment: analysis beyond electric dipole approximation (poster)

Co-authors: M. Kosik, O. Burlayenko

An atomic system (e.g. an atom, molecule, quantum dot) coupled to a surrounding photonic bath acquires a correction in its transition energies and spontaneous emission lifetimes. A photonic bath shared by multiple atomic systems acts as an interaction carrier and gives rise to collective, Dicke-type emission.

We derive analytical expressions for the spontaneous emission rate, eigenfrequency shift and collective effects of an atomic system in a photonic bath which can be spatially and spectrally tailored, e.g. with photonic nanoparticles. Their unprecedented influence on the properties of the bath, expressed in terms of electromagnetic Green's tensor, requires in some conditions a description beyond the paradigmatic electric dipole approximation [1–3].

We base our analysis on the dyadic Green's tensor formalism following Refs. [4, 5] and generalize it beyond the electric dipole approximation. The electromagnetic Green's tensor accounts for the geometry and material properties of the nanoscopic surroundings of the atomic system. The latter is characterized by transitions with electric dipole, magnetic dipole, and electric quadrupole moments, which can simultaneously be nonzero. In this framework we solve Heisenberg equations for field and emitters' operators dynamics combined with the Markovian approximation, to arrive at the desired expressions for transition rates and interaction strengths.

To provide examples, we apply the formalism to simple geometries like a pair of nanospheres, and identify scenarios where a step beyond the electric dipole approximation is necessary for accurate description of emitters' dynamics.

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Symmetries of LME states and asymptotic SLOCC (poster)

In my poster, I will present some results of our undergoing work. I will define the notion of asymptotic SLOCC (Stochastic Local Operations and Classical Communication) equivalence of states which can be used to divide the space of quantum states into equivalence classes. This classification is coarser but related to one obtained by SLOCC operations. Using the notion of stable action I will characterize the structure of geometric invariant theory quotients for the stable actions and present a useful test of the non-triviality of asymptotic equivalence which is related to the symmetries of locally maximally entangled states. Then I will show how to apply our test to completely describe the dimensions of $2 \times m \times n$ systems for which the asymptotic equivalence of states is non-trivial. This is a joint work with Adam Sawicki. Currently we are working on enriching our results using the technique of algebraic pencils which is a joint work with Martin Hebenstreit and Barbara Kraus.

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Entanglement negativity as a universal non-Markovianity witness

In order to engineer an open quantum system and its evolution, it is essential to identify and control the memory effects. These are formally attributed to the non-Markovianity of dynamics that manifests itself by the evolution being indivisible in time, a property which can be witnessed by a non-monotonic behavior of contractive functions or correlation measures. We show that by monitoring directly the entanglement behavior of a system in a tripartite setting it is possible to witness all invertible non-Markovian dynamics, as well as all (also non-invertible) qubit evolutions. This is achieved by using negativity, a computable measure of entanglement, which in the usual bipartite setting is not a universal non-Markovianity witness. We emphasize further the importance of multipartite states by showing that non-Markovianity cannot be faithfully witnessed by any contractive function of single qubits. We support our statements by an explicit example of eternally non-Markovian qubit dynamics, for which negativity can witness non-Markovianity at arbitrary time scales. For more details see `arXiv:1903.08663 [quant-ph]`.

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Group theoretical structures in multiport quantum teleportation protocols and fundamental bounds on their performance

Co-authors: M. Horodecki, M. M. Wilde

Quantum teleportation is one of the earliest and most widely used primitives in the Quantum Information Science which performs an arbitrary quantum state transfer between two spatially separated systems. This involves pre-sharing entangled resource state and consists of three simple stages (joint measurement, classical communication, correction operation). Already except standard quantum teleportation protocol presented by Bennet et al. we distinguish Knill-Laflamme-Milburn schme based soley on linear optical tools and so called Port-based Teleportation scheme, where in the last step the unitray correction is absent. Lack of the correction in the last step extends permieter of possible applications to position-based cryptography, communication complexity or theory of the universal quantum processors.

In our work we show that mentioned above quantum teleportation protocols can be derived from one unified scheme based purely on group theoretical and algebraic tools. More formal — the output which is of the form of teleportation protocol depends on the type of a controlled unitary on the sender's side, where unitaries used for the construction are considered to be representations of a finite group. Additionally ,we derived using the convex split lemma, lower bound on the primal parameter describing the performance of our unified scheme — the entanglement fidelity. Obtained bound is of the fundamental nature, giving limitations on the performance to any teleportation procedure fitting the scheme and reproducing limits in known cases. As the second result, we propose novel unified teleportation schemes, following from the unification procedure for transmitting more than one unknown quantum state in one go, togheter with lower bound on their performance. We show how to extract from them, by choosing proper group symmetry of the system, new port-based like teleportation schemes. The proof is based on generalisation of the convex split lemma proven additionally by the authors. At the end we discuss potential power of new teleporation schemes with respect to known teleportation procedures used for teleportation more than one unknown quantum state. The problem of the interplay between amount of resources needed for teleportation and unitary correction is also discussed.

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Time-independent formalism for CP-divisible quantum dynamical maps governed by periodic Lindbladians in finite dimension (poster)

Co-authors: R. Alicki

We develop the so-called *time-independent formalism* describing evolution of finite dimensional open quantum system governed by Markovian master equation (MME) of the form $\dot{\rho}_t = L_t(\rho_t)$, where L_t is a *periodic*, time-local Lindbladian in standard (Kossakowski-Lindblad-Gorini-Sudarshan) form. Such approach is known for some time and applied successfully in case of unitary dynamics and Schrödinger equation, and originates from e.g. Shirley [1], Howland [2] and Sambe [3]. We introduce the *enlarged space of states* of open system as a Bochner space $\mathcal{L}^2(\mathbb{T}, \mathbb{C}^{d\times d})$ of periodic, square integrable matrix-valued functions. We show that under certain assumptions, one can then replace the time-dependent Cauchy problem imposed by the MME with a "static" eigenproblem of time-independent *generalized Lindbladian* $\mathcal{L}$, which is unbounded and densely defined. Next, we show that $\mathcal{L}$ may be understood as a generator of strongly continuous contraction semigroup $\tau \mapsto e^{\tau\mathcal{L}}$, $\tau \geqslant 0$ of completely positive and trace preserving maps on enlarged space of states; furthermore, one can effectively express solutions of time-dependent MME by means of this semigroup. Finally, we discuss some possible extensions of the formalism, including a large and important class of *quasiperiodic* Lindbladians, governing MMEs under assumption of being Lyapunov-Perron reducible.

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Faster ground state preparation and high-precision ground energy estimation with fewer qubits

Co-authors: Y. Ge, J. I. Cirac

I will present a general-purpose quantum algorithm for preparing ground states of quantum Hamiltonians from a given trial state. The algorithm is based on techniques recently developed in the context of solving the quantum linear systems problem [Childs, Kothari, Somma'15]. We show that, compared to algorithms based on phase estimation, the runtime of our algorithm is exponentially better as a function of the allowed error, and at least quadratically better as a function of the overlap with the trial state. Additionally, we show that our algorithm requires fewer ancilla qubits than existing algorithms, making it attractive for early applications of small quantum computers. Furthermore, it can be used to determine an unknown ground energy faster than with phase estimation, in the case a very high precision is required.

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Reachability in Infinite-Dimensional Unital Open Quantum Systems with Switchable GKS-Lindblad Generators

In quantum systems theory one of the fundamental problems boils down to: given an initial state, which final states can be reached by the dynamic system in question? Here we consider infinite-dimensional open quantum dynamical systems following a unital Kossakowski-Lindblad master equation extended by controls. More precisely, their time evolution shall be governed by an inevitable (potentially unbounded) Hamiltonian drift term, finitely many bounded control Hamiltonians allowing for (at least) piecewise constant control amplitudes plus a bang-bang switchable noise term in GKS form (generated by some compact V). Generalizing standard majorization results from finite to infinite dimensions, we show that such bilinear quantum control systems allow to approximately reach any target state majorized by the initial one as up to now only has been known in finite-dimensional analogues.

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On Entropy for Quantum Compound Systems

The quantum entropy was introduced by von Neumann around 1932, which describes the amount of information of the quantum state itself. It was extended by Ohya for C^*-systems before CNT entropy. The quantum relative entropy was first defined by Umegaki for σ-finite von Neumann algebras, which was extended by Araki and Uhlmann for general von Neumann algebras and $*$-algebras, respectively. By introducing a new notion, the so-called compound state, in 1983 Ohya succeeded to formulate the mutual entropy in a complete quantum mechanical system (i.e., the input state, the output state and the channel are all quantum mechanical) describing the amount of information correctly transmitted through the quantum channel. In this talk, we briefly review Ohya's S mixing entropy and quantum mutual entropy for general quantum systems. Basing on the concept of Ohya's compoud state generated by the Jamiołkowski iso- morphism, we discuss the entropy for quantum compound systems.

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No purification in all discrete theories and the power of complete extension (poster)

Co-authors: T. Das, K. Horodecki, P. Horodecki, Ł. Pankowski, M. Piani, R. Ramanathan

Quantum theory has an outstanding property, namely each state has its well defined purification — a state extremal in the set of states in larger Hilbert space. It is known that the classical theory and the theory of non-signaling boxes does not have purification for all of their states. These theories are examples of the so-called generalized probabilistic theories (GPTs). However in any non-signaling GPT each state has a number of extensions to a larger system. We single out the most relevant among them, called a complete extension, unique up to local reversible operations on the extending system. We prove that this special, finite dimensional extension bares an analogy to quantum purification in that (i) it allows for an access to all ensembles of the extended system (ii) from complete extension one can generate any other extension. It then follows, that an access to the complete extension represents the total power of the most general non-signaling adversary. A complete extension of a maximally mixed box in two-party binary input binary output scenario is up to relabeling the famous Popescu-Rohrlich box. The latter thus emerges naturally without reference to the Bell's non-locality. However the complete extension is not a purification (a vertex) in the generic case. Moreover, we show that all convex discrete theories does not provide purification for almost all of it states. In particular the theory of contextuality does not possess purification. The complete extensions are by nature high-dimensional systems. We were able however to provide explicit structure of complete extension for the noisy Popescu-Rohrlich-boxes and the 3-cycle contextual box.

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Kinetic equation for a heavy marked particle in an externa field (poster)

We study the so-called Smoluchowski's diffusion, which is a diffusion in an external field, and we obtain a general kinetic equation, valid within the framework of classical statistical mechanics. We start from Liouville theorem, which is a key theorem in classical statistical and Hamiltonian mechanics. Considering the gas composed of N particles, we pay particular attention to Brownian diffusion (one heavy marked particle among $N-1$ light particles), and we obtain an equation which generalizes the Smoluchowski's diffusion.

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Divisibility of qubit channels and dynamical maps

Co-authors: D. Davalos, C. Pineda

The concept of divisibility of dynamical maps is used to introduce an analogous concept for quantum channels by analyzing the simulability of channels by means of dynamical maps. In particular, this is addressed for Lindblad divisible, completely positive divisible and positive divisible dynamical maps. The corresponding L-divisible, CP-divisible and P-divisible subsets of channels are characterized (exploiting the results by Wolf et al.) and visualized for the case of qubit channels. We discuss the general inclusions among divisibility sets and show several equivalences for qubit channels. To this end we study the

conditions of L-divisibility for finite dimensional channels, especially the cases with negative eigenvalues, extending and completing the results. Furthermore we show that transitions between every two of the defined divisibility sets are allowed. We explore particular examples of dynamical maps to compare these concepts. Finally, we show that every divisible but not infinitesimal divisible qubit channel (in positive maps) is entanglement-breaking. This is a joint work with David Davalos and Carlos Pineda, `arXiv:1812.11437 [quant-ph]`, accepted in Quantum.

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Pauli channels accessible by a Lindblad semigroup

Co-authors: Z. Puchala, Ł. Rudnicki and F. Shahbeigi

We analyze the set of one-qubit Pauli operations and look for these channels which belong to a semigroup, $\Phi = \exp(\mathcal{L}t)$. We show that the set S_2 of such channels, embedded inside the regular tetrahedron spanned by identity and Pauli matrices, is bounded by three surfaces composed of product probability vectors and includes the identity map and the maximally depolarizing channel Φ_*. Consequently, every member of the Pauli semigroup is unitarily equivalent to a unistochastic map, describing a coupling with one-qubit environment initially in the maximally mixed state, determined by a unitary matrix of order four. We demonstrate that the nonconvex set S_2 is star-shaped with respect to the depolarising channel Φ_*. Some analogous results are also obtained for mixed unitary channels acting on N-dimensional systems.